Impacts of a Research Experiences for Teachers Program on Rural STEM Educators

Abstract

This study investigates the impacts of a Research Experiences for Teachers (RET) program on rural STEM educators and reports teachers' perspectives on how these experiences influence classroom practices. The program of focus occurred at a mid-sized university in the upper Midwest from 2016-2019. Over this period, eleven rural secondary STEM teachers participated in the 6-week long summer program and various workshops and professional development activities. The teachers in the program were "solitary" STEM teachers, meaning they were the only teacher of their subject in the school building. In this qualitative research study, a thematic analysis approach was used to code and analyze transcripts of teacher-participant interviews. Results from this study demonstrate that the "solitary" rural teachers who participated in an engineering-focused RET showed an increased understanding of design-based learning, workforce skills (i.e., 21st century skills), and the engineering design process. Other findings include participants developing a deeper appreciation of teaching a growth mindset, valuing professional networks and supports, and flattening the power structure in the classroom to empower students to have more freedom, responsibility, and control over their design choices.

Keywords: Rural Educators, STEM Education, Engineering Design, Research Experiences for Teachers, Professional Development, Qualitative Methods

Introduction

Quality professional development for K-12 teachers is an essential component of the United States (U.S.) education system. Providing access to opportunities for educators to strengthen their teaching practices is vital for improving student learning experiences (Darling-Hammond & Baratz-Snowden, 2005; Guskey, 2002; Wei et al., 2009). Given the current focus on Science, Technology, Engineering, and Mathematics (STEM) education, exposing teachers and students to the engineering design process (EDP) has become a national imperative for developing students' design thinking skills and overall future workforce skills, including 21st century skills (P21, 2019). However, access to quality professional development in engineering design is limited for rural educators (Showalter et al., 2019). Rural educators face unique challenges that require unique solutions to their professional development needs.

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 (Bowen & Shume, 2018, 2020; Darling-Hammond & Baratz-Snowden, 2005; Stewart, 2014; Webb, 2015). Professional development involving engineering or scientific research has proven to increase a teacher's awareness of the need to provide authentic classroom learning activities for students, as well as to develop the knowledge and skills needed to do so (Barrett et al., 2015; Barrett & Usselman, 2005, 2006; Basalari et al., 2017; Bowen et al., 2019; Farrell, 1992; Kantrov, 2014; Silverstein et al., 2002; Silverstein et al., 2009). Grant-funded programs such as the National Science Foundation's (NSF) Research Experiences for Teachers (RET) can provide a vital avenue for delivering professional development for rural educators (Bowen et al., 2018, 2019; DeJong et al., 2016). This project reports how an RET program in the upper midwest taught rural teachers about the EDP through an immersive research experience and examines how teachers described impacts on their classroom practices.

Background

Rural educators face a unique set of challenges that differ from those of their urban and suburban counterparts. Unlike most urban educators, many teachers in rural areas teach multiple subjects and grade levels, requiring additional time to prepare materials that cover a variety of course subjects and student skill levels (Barley & Brigham, 2008; Goodpaster et al., 2012). With little planning time for a diverse range of classes at varying grade levels, these teachers face many challenges when seeking to make transformational changes in their classrooms. Having multiple teaching responsibilities can also result in rural educators teaching subjects they are less qualified to teach, therefore increasing the burden on the educators to obtain additional teaching certifications (Goodpaster et al., 2012). Compounding the issue, rural educators often report less access to cooperative supports, such as opportunities for peer-observation and shared planning time, compared to urban and suburban educators (Lavalley, 2018; Wei et al., 2009).

Serving as a STEM educator in a rural school brings an additional layer of challenges. Rural communities often have STEM teacher shortages due to difficulties retaining highly qualified teachers in STEM areas (Dee & Goldhaber, 2017). By analyzing data compiled through the Schools and Staffing Survey from 1999, 2003, 2007, and 2011, Player (2015) reported that rural areas in the U.S. have higher STEM teacher vacancies than non-rural areas. With a large number of STEM vacancies, it can be difficult for rural STEM teachers to receive sufficient mentorship and support from their peers and supervisors (Lavalley, 2018). In a survey about factors affecting rural STEM educator retention, participating educators frequently reported insufficient mentorship as a factor negatively impacting teacher retention (Goodpaster et al., 2012). Participants in the same survey also reported a lack of access to university resources, such as research support and specialty programs. Rural schools also typically lack the funding required to provide quality professional development and properly equipped educational facilities (Williams, 2010). Moreover, a lack of internal resources and support from the school or district increases the difficulty for rural STEM teachers to develop and implement effective lessons (Du et al., 2019; Hart, 2018; Lavalley, 2018). Rural school structures may also be more resistant to change, making it difficult for STEM teachers to introduce innovative teaching approaches (Goodpaster et al., 2012).

When comparing teachers in rural and non-rural schools, Glover et al. (2016) found no significant difference in how many hours each group of teachers engaged in professional development. However, teachers in non-rural schools spend more days participating in professional development than teachers in rural schools. This suggests professional development experiences provided for rural teachers are more condensed, offered less frequently, and may be less in-depth than professional development provided to teachers in non-rural schools (Glover et al., 2016; Player, 2015). Rural districts may also be less likely to sponsor professional development opportunities for non-rural teachers due to the costs and availability, preventing rural teachers from receiving the professional development they need (Player, 2015).

The geographic isolation of many rural areas makes it difficult for teachers to find and obtain high-quality professional development opportunities (Showalter et al., 2019). In addition, distance from urban centers can result in less access to university-sponsored or third-party professional development opportunities (Player, 2015). However, rural teachers benefit significantly more from professional development than non-rural educators in regards to improving their teaching practices (Barrett et al., 2015; Glover et al., 2016). With a slew of challenges facing the rural STEM educator, increased access to high-quality professional development opportunities is paramount to helping educators develop the pedagogical content knowledge and confidence to better address these barriers and serve their students (Barrett et al., 2015; Bowen et al., 2018, 2019; Ficklin et al., 2020; Glover et al., 2016).

Although professional development is available for rural educators, there is a significant need for more engineering-specific opportunities (Ficklin et al., 2020). Engineering-focused professional development, such as RET programs, allows teachers to engage in authentic engineering research. These programs are designed to immerse participants in research experiences, resulting in teachers applying what they learned to improve their classroom instruction. For example, after participating in an engineering RET, high school science teachers in rural Michigan reported an increased understanding of collaborative instructional approaches, the EDP, and how to integrate engineering into their pedagogical practice (Yelamarthi et al., 2013). The participants also demonstrated a positive change in their attitudes towards engineering. A majority indicated they felt capable of teaching basic engineering concepts and would apply what they learned to redesign and implement new projects. Participation in engineering-focused RET programs also helps teachers understand the learning benefits of student engagement in the EDP (DeJong et al., 2016). In another engineering-focused RET program, K-12 STEM teachers developed higher levels of confidence for integrating engineering concepts into their science instruction (Pinnell et al., 2013). Using knowledge gained from their participation in an engineering-focused RET, teachers can enhance their instruction by integrating real-world engineering applications (Reynolds et al., 2013). If designed appropriately, engineering-focused RET programs can improve participants' confidence and readiness to incorporate the EDP into classroom activities.

Program Description

The three-year RET program of focus in this study engaged rural teachers in a six-week summer research-intensive program from 2016-2018. In 2019, the researchers used a no-cost extension to provide follow-up professional development workshops both on-campus and virtually. The program was conducted in the upper midwest and took place on the campus of a mid-sized university. Over the three-year grant period, five in-service teachers and five pre-service teachers participated each year. During the program, teachers worked in pairs, with one in-service teacher working with one pre-service teacher. Due to the heavy influence of the agriculture industry in the region, a notable strength of many rural communities, the program engaged teachers in research within an agricultural framework. The faculty and graduate student-led research projects in which the teachers participated combined the advancement of electrical hardware, software design, and development of biobased materials for investigations into sustainable materials and precision agriculture. Some examples of the research projects conducted during this RET program include the following: Electrical Properties of Bio-Composite Materials, Development of Thermoplastic Bio-Based Composites for 3D Printing, Measurement of Plant Growth Effect on Wireless Sensor Signals, Statistical Analysis of Moisture Sensor Performance, and Development of Bio-Based Resins from Vegetable Oils.

One of the strengths of this program's design was the constant interaction between the teacher participants and the project team, multiple exposures to model K-12 learning activities, and shared experiences with colleagues. The program also included follow-up activities and support for each cohort as they translated the experience into a shift in pedagogical practice the following academic year. It also included other support systems such as materials and equipment for project implementation and the development of a rural educator professional learning community. At the conclusion of the summer activities, teachers presented their research findings, provided recommendations for future research, and created a poster for a campus-wide research symposium. During the following academic year, the teachers developed, implemented, and reflected on design-based learning activities created for their content based on the EDP framework. They were also required to have their classroom-tested lesson approved by reviewers from the University of Colorado's TeachEngineering website as part of the project outcomes.

Research Question

This project reports how an NSF-funded RET program in the upper midwest provided rural teachers with knowledge about the EDP through an immersive research experience. The primary goal was to enhance STEM education for rural students by exposing rural teachers to the EDP within an agricultural framework. The research question guiding this study was: How do rural mathematics, science, and technology education teachers describe the impacts of an engineering-based RET experience on their professional learning and classroom practices?

Methods

This qualitative study sought to determine how rural teachers described what they gained from participation in an RET program. Thematic analysis was used for this study because of the interpretive nature of the research question and because the teachers' viewpoints were the focus of the study. Thematic analysis is an established qualitative methodology that aims to identify key themes that arise from the data through iterative cycles of reading and rereading data to find patterns of meaning (Braun & Clark, 2006; Flick, 2014). The researchers coded the data using NVivo 11 software and collated the codes into themes. Following Braun and Clark, a theme "captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set" (2006, p. 82). In this study, the researchers analyzed the data to identify patterns of meaning in teachers' perspectives on how they described the impacts of an engineering-based RET experience on their professional learning and classroom practices.

Study Participants

The participants in this study are described as "solitary STEM teachers." The researchers used this phrase to refer to teachers in rural communities who are the only teacher of a STEM subject in their school building. The researchers contacted the local Regional Education Associations to identify teachers that met this qualification in the upper midwest region of the United States. The researchers then contacted these teachers by email to determine their interest in participating in the RET program; consent to participate in the research study was obtained separately. During each year of the three-year grant period, five in-service teachers and five pre-service teachers participated in the RET program and agreed to participate in the study. During the program, teachers worked in teams of two, with one in-service teacher and one pre-service teacher paired together. However, for this current study, the researchers focused exclusively on the project outcomes of the in-service teachers. Table 1 describes the RET in-service teachers who participated in this study. Study participants will be referred to as "teachers" in the remainder of this article.

Table 1

Demographics for RET In-Service Teacher Participants (Pseudonymns)

Participants	Years	Gender	Grades	Subjects*
Amber	2016, 2018	Female	8-12	Bio
David	2016, 2017	Male	7-12	Bio, Chem
Austin	2016, 2017	Male	7-12	Math, Science
Kayla	2016	Female	9-12	Bio, Chem
Leigh**	2016	Female	7-12, 4-8	Bio, Chem, Science ELA, Science, SS
Jake	2017	Male	8-12	Science
Anna	2017	Female	7-12	Science
Ashley	2017, 2018	Female	9-12	Math, Science
Erin	2018	Female	7-12	Science
Jessica	2018	Female	6-8	Science, STEM, SS
Emily	2018	Female	K-12	Technology Education

* Bio = Biology, Chem = Chemistry, ELA = English Language Arts, SS = Social Studies, STEM = project-based learning
** Leigh taught in two different schools during the research project

During the RET program, a total of 11 teachers participated; seven participated for one year, and four participated for two years. Three participants were male, two of whom participated for two years, and eight participants were female, with two participating for two years. All the teachers taught either mathematics, science, or technology education, and in some cases taught more than one of those with some additional responsibilities for teaching English Language Arts and social studies. When a STEM subject (science, technology education, or mathematics) is listed in the table, that teacher is the only teacher that taught that subject in the school building for the indicated grade levels. In many cases, teachers used the general term of science since they taught many courses within the life science discipline and did not identify each course separately.

Data Collection

Data collected for this study consisted primarily of individual, in-person interviews. Each participant was interviewed during the summer while participating in the on-campus RET experience, and each interview lasted approximately 30-45 minutes. Additionally, participants who returned for a second summer in 2017 were interviewed together as a focus group. Also, participants from 2018 were interviewed a second time during the fall of 2018; a small number of those interviews occurred over the phone due to travel distances. Interviews were semi-structured, meaning there was a core set of questions posed to all participants. If participants offered comments about a particular area of interest, the interviewer probed to allow the participant to share their ideas on that topic more fully. All interviews were audio-recorded and transcribed verbatim for data analysis.

Data Analysis

The researchers conducted a thematic analysis of the interview transcripts, a process described by Braun and Clark (2006, p. 86) as “searching across a data set - be that a number of interviews or focus groups, or a range of texts - to find repeated patterns of meaning.” Specifically, we followed Braun and Clark’s (2006, p.87) recommendation for six phases involved in an iterative process of data analysis: “1) familiarizing yourself with your data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, 6) producing the report." Notably, these phases do not constitute a linear process but instead form a "more recursive process, where movement is back and forth as needed, throughout the phases" (Braun & Clark, 2006, p. 86). This thematic analysis yielded a set of related themes that adhere to Patton's (2015) criteria of internal homogeneity and external heterogeneity, meaning that each theme is internally coherent yet also distinct from the others.

Findings

Data analysis produced six major themes that captured key dimensions of what teachers gained through participation in this RET program. The themes were: (a) Networking and Professional Supports, (b) Design-based Learning, (c) 21st Century Learning, (d) Engineering Design Process, (e) Growth Mindset (Dweck, 2006), and (f) Flattened Power Structure in the K-12 classroom. These major themes are summarized below.

Networking and Professional Supports

One theme that clearly emerged through data analysis centered on the benefits gained from opportunities to network with other rural teachers and university personnel. In particular, teachers appreciated connecting with others, gaining access to novel curriculum supports, and learning about new opportunities for ongoing student and professional learning. During interviews, most teachers commented on the value of connecting with other rural teachers, all of whom had a unique teaching load at their school. For example, Amber stated,

> I felt kind of lonesome being the only science teacher in my school, and now I know a lot of other science teachers who actually have the same experience as me because they're also from rural schools. So I liked hearing their stories. They're very relatable…I think

> the biggest support I got through this program is meeting people, like the connections that I made.

Throughout the summer program, teachers shared knowledge with each other about relevant curricular supports such as STEM-related websites, software applications, and lesson plan ideas. Further, many teachers expressed enthusiasm and appreciation for the program's $2000 for each teacher to purchase classroom equipment and materials, committing their allocations to a wide range of items such as Ozobots (small programmable robots), puzzle cubes, and a spectrophotometer, among many others.

Moreover, many teachers pointed out that networking with K-12 colleagues and university personnel resulted in learning about STEM-related events and programs for students and additional professional development opportunities for STEM teachers. Notably, teachers collaborated closely within and across teams while working on summer RET research projects, creating research posters, and planning related lessons. Most teachers expressed confidence that the camaraderie and collegiality built during the summer would extend into the academic year, and some teachers reported maintaining connections with others beyond the summer months.

Design-Based Learning

Nearly all teachers credited their RET experience with inspiring commitment to prioritizing active learning experiences in their K-12 classrooms. In addition, most teachers commented on their new or renewed vision for implementing learning activities that engaged students in design-based learning. During his second year in the RET program, Austin reflected on how his teaching practices had changed because of his RET experience.

> It's that innovative and creative process that I wouldn't have experienced otherwise. So, in years past, I just lectured about it [content]. And they [students] sat at their desk, and

> they wrote down what I told them is important. And, this way [designed-based learning], they got to decide what was important and then communicate that to the rest of their class. The process of allowing them to be on their own, to trust their creativity, and trust their own innovations and whatever it is they decide to create…Trying to give them these activities that teach them the content but also teach them the communication skills, the technology skills, the perseverance, stuff like that.

A component of this RET program involved the teachers working collectively to create design-based K-12 lesson plans that were published on the University of Colorado's TeachEngineering website. Teachers reported on the process of implementing these lessons in their classrooms during the school year. For example, during her second year at this RET program, Ashley explained that she had instituted "Engineering Wednesdays," dedicating one afternoon per week in her classroom for students to participate in design-based learning, especially lessons from the TeachEngineering website. While some teachers indicated that their RET experience renewed their enthusiasm and affirmed their ongoing use of designed-based learning activities, others expressed excitement about their new commitment to adding project-based learning and engineering design challenges into their classroom curriculum.

21st Century Learning

Another theme that resonated broadly across the teachers' experiences was an increased commitment and eagerness to provide experiences for K-12 students to practice 21st century skills in the classroom. This RET program centered on authentic engineering research, and thus the teachers were consistently engaged in the 4C's: collaboration, communication, critical thinking, and creativity. In the interviews, teachers often noted that their RET experience had opened their eyes to the importance of making room for K-12 students to develop several dimensions of 21st century learning, especially the 4Cs. A representative quote came from Jake when he talked about the value of developing his K-12 students' critical thinking skills. He said:

> I've always thought that critical thinking is the most important takeaway [from being a student in my class], the most important thing, for my students. Whether they learn all the science they need to learn or not, if they walk away being able to think critically, they've learned a very valuable skill. This has gotten me to thinking [that] this program with the engineering can help them much more in their critical thinking skills if I leave them some wide open questions… They'll have to do a lot of brainstorming and a lot of critical thinking, and then they've got to design the experiment.

Additionally, many teachers explained how their experience working collaboratively in teams and communicating at weekly research meetings shaped their views about the importance of implementing small group work and communication tasks in K-12 classrooms. An important finding was that teachers expressed an increased understanding of the value of providing K-12 learning experiences that foster 21st century skills and a keen commitment to do so in their classrooms.

Engineering Design Process

The RET program permitted teachers to experience the EDP firsthand by engaging in emergent, iterative, collaborative problem-solving processes while participating in authentic engineering research projects. Many teachers pointed to the tremendous value of gaining a deeper and more authentic understanding of the EDP and ways of incorporating it into their K-12 classroom teaching. Leigh said, "Biggest takeaway [from participating in this RET program]? Probably that EDP. I learned a lot more about that through this program. So, that's the biggest takeaway. And how to use it in all my classes." Further, teachers' understanding of the EDP became more nuanced and sophisticated; they came to more fully understand that, in practice, EDP does not function as a linear cascade of discrete steps. In an interview during the school year after her RET experience, Jessica said:

> I've noticed that I pull in the EDP a lot more and have more identifying as we're going. Where before, we'd do an experiment and then talk about it after. Where now, we tend to pause a lot more throughout because I want them to identify, 'What stage are you at? What could you do differently?' And kind of see that evolving process. That it's not always in a circle. You are constantly changing back and forth or jumping from one to the other…So, that's changed quite a bit.

Like Jessica, many teachers indicated that the way they approached implementing the EDP with their K-12 students had changed because of their participation in the RET program. Teachers explained that they were more intentional about allowing time for their K-12 students to reflect and redesign their projects.

Growth Mindset (Dweck, 2006)

Another prevalent theme that emerged across the teachers' interviews was an increased understanding of the valuable roles of learning from mistakes and persisting when seeking creative solutions. A representative quote from Kayla stated:

> My biggest takeaway [from participating in this RET program] is really being able to be in the engineer's shoes…The problem solving and just experiencing that [as an RET participant] helps drastically to bring it into the classroom, too, for students to understand you are meant to struggle. It is okay. And I think that's going to be huge.

Many teachers offered anecdotes of particular instances where they conveyed or planned to convey to K-12 students the value of learning from mistakes. Some teachers, however, experienced a more profound change, a new approach allowing students to grapple more fully with obstacles rather than stepping in immediately to assist. Erin explained her transformed vision for instructional practices that allow students more opportunity to wrestle with challenges and that encourage them to persist in seeking out possible solutions. She said:

> I think I'm going to be more inclined to not give students the answers right away. Like kind of have them struggle a little bit…One project I've done in physical science is designing simple motors using a battery and a copper wire. In the past, I've kind of shown them exactly how to do it, but now going through this experience, I think I'd be more inclined to just give them the materials and say, "Okay, using what you know and what I've taught you, how would you make this motor?" And give them time to just use their critical thinking skills and problem-solving skills…I think it's important to give them that freedom to use their critical thinking skills.

Teachers expressed a new awareness about the importance of creating learning experiences for K-12 students that foster a growth mindset (Dweck, 2006) in terms of learning from mistakes and persisting in finding solutions.

Flattened Power Structure in the K-12 Classroom

A theme closely related to other themes yet worthy of specific attention was teachers' commitment to flattening the power structure within their K-12 classrooms to allow students more freedom, responsibility, and control over their design work and related learning experiences. Jessica said:

> So, it's kind of like having them [K-12 students] constantly see that it's okay to make a mistake, and then we figure out from there what we're going to do. So, it's been kind of of

> fun to see them go, ‘Oh, yeah, I don’t need her approval before I start.’ … or like, ‘Go and try this. It’s okay.’

Some teachers indicated they were already advocates of student choice and voice and that their RET experience further affirmed those beliefs. Other teachers, however, reported that their RET experience brought them new awareness and inspiration to provide opportunities for students to take ownership of their problem-solving processes. Most teachers also discussed how their RET experience presented obstacles and challenges that resulted in them struggling in design-based processes and relying on assistance from others. These teachers came to recognize the value of not positioning themselves in the K-12 classroom as an all-knowing expert and saw possibilities to draw on examples from their RET experience when working with their K-12 students. Emily related an episode from her RET experience where she became frustrated because the blades she designed to propel a toy car were repeatedly driving the car in circles. One of her RET teammates stepped up to help find a solution. Emily explained that when implementing this learning activity with her students, she planned to let them know she herself had struggled with this aspect of the design. She said, “So I think it makes it a little more real too for the students when they know that, ‘Hey, she doesn’t know everything either, and it’s okay.’” Teachers frequently pointed out ways that their RET experience compelled them to empower K-12 students with responsibility and choice and position themselves as learners alongside their K-12 learners.

Discussion

This study examined how rural teachers described the impacts of an engineering-based RET program on their professional learning and classroom practice. In looking across the six themes, two main types of impacts can be identified.

First, teachers reported that the RET program transformed their vision for teaching engineering design and related student competencies. Teachers explained how their participation in the RET program awakened a new sense of awareness and a strong sense of imperative to infuse authentic engineering design experiences into their classroom practice. In particular, teachers' reflections repeatedly returned to the importance of granting time and responsibility for students to grapple with iterative cycles of testing and retesting in design-based problem-solving contexts that require critical thinking and collaboration. This notable finding adds to the research that reports how engineering-based RET experiences compel teachers toward transformed classroom practices as a result of direct participation in authentic engineering research (Bowen et al., 2018, 2019; DeJong et al., 2016; Yelamarthi et al., 2013).

Second, not only did teachers report that the RET program impacted their vision for effective instruction related to engineering design, but also that the RET program equipped them with essential tools and resources for doing so (Du et al., 2019; Hart, 2018). As the only STEM teacher at their rural school, teachers participating in this study faced obstacles similar to other rural STEM educators, including isolation, responsibility for multiple courses at multiple grade levels, and limited access to equipment and materials (Bowen et al., 2018, 2019; Du et al., 2019; Wei et al., 2009; Williams, 2010). As teachers described their transformed visions for classroom practices related to engineering design, they highlighted the value and importance of establishing a network of rural peers who share a deep understanding and empathy for the challenges of rural teaching and who exchange teaching ideas, resources, and materials. Additionally, this RET program was designed to provide much-needed stipends along with additional funds to purchase necessary equipment and materials, enabling them to bring a variety of projects to fruition in the classroom. These findings highlight the importance of designing professional development experiences that target the particular needs of rural STEM teachers.

Conclusion

This study demonstrates that an engineering-based RET program can increase rural teachers' commitment to incorporating authentic engineering design experiences into their instructional practices, as well as improve their readiness to do so by providing resources and supports responsive to challenges experienced by rural STEM teachers, further supporting the work of Bowen et al (2018, 2019). Participating teachers demonstrated a richer and deeper understanding of instructional practices that target the development of engineering design skills and related competencies, including 21st century skills and growth mindset (DeJong et al., 2016; Dweck, 2006; Hart, 2018). Our ongoing research will continue to tease apart how authentic engineering research experiences impact rural teachers' ideas about classroom practice. Additional research is needed to determine the extent to which rural teachers' commitment and readiness to implement transformed visions for teaching engineering design translates into sustained changes in the classroom. Further investigation into the professional learning and lived experiences of rural STEM educators is an essential avenue for elucidating and addressing challenges particular to rural STEM education.

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