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Professional Development for Rural Stem Teachers on Data Science and Cybersecurity: A University and School Districts' Partnership

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Abstract

The research experience for teachers (RET) professional development was a six-week long summer-intensive National Science Foundation (NSF) funded project that took place at a large university in western Texas. It was designed to provide a research-rich learning environment in data science and cybersecurity for STEM teachers in the region, which is mainly rural. Due to geographical isolation, rural teachers lack resources to prepare their middle and high school students for STEM careers and often find it difficult to bring innovative science teaching into their classrooms. The team was comprised of nine teachers, five professors, and six graduate students. We utilized discourse analysis within the situated perspective to examine teacher reflections and artifacts to discover how they assimilated disciplinary knowledge of data science and its application to cybersecurity and how they transferred this knowledge into their middle and high school curriculum. We found the teachers acquired this knowledge by gradually developing a scientist persona. They also acquired sophisticated pedagogical knowledge to integrate complex concepts into their middle and high school STEM curriculum without sacrificing the state standards, while creating a community of learners. This led to reduced feelings of isolation often experienced by rural teachers. It is clear that partnerships between universities and rural school districts can transform the way STEM disciplines are delivered, creating a strong pipeline for rural students in the STEM workforce.

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Introduction and Background

The need for comprehensive and effective middle and high school in-service professional development is essential for science, technology, engineering, and mathematics (STEM) teachers because of the lack of highly qualified STEM teachers in schools, particularly in subject areas that rely heavily on specialized mathematics such as physics, chemistry, and the computer sciences (Goodpaster, Adedokun, & Weaver, 2012; Maher & Prescott, 2017; Peterson, Bornemann, Lydon, & West, 2015; Whannell & Tobias, 2015). Research has shown that rural schools struggle to attract and retain quality STEM teachers because there are fewer social, emotional, or monetary incentives for qualified STEM specialists to seek jobs or persist in rural contexts after they are hired (Goodpaster et al., 2012; Whannell & Tobias, 2015). This can lead to teachers of STEM disciplines in rural contexts being alternatively certified with little or no formal content or pedagogical training (Goodpaster et al., 2012; Maher & Prescott, 2017). In-service teachers may have little content mastery or pedagogical knowledge to effectively teach STEM. Thus, to effectively support in-service STEM teachers, professional development should focus on simultaneously developing teachers' disciplinary content and improving their pedagogical skills.

In this qualitative case study, we describe a six-week long summer intensive professional development program held at a large research university in western Texas. It was designed for middle and high school STEM teachers from the region within two hours driving distance to the university. The professional development integrated disciplinary content in the field of data science and cybersecurity, taught by Computer Science (CS) faculty, while simultaneously introducing pedagogical knowledge taught by the College of Education (CoE) faculty. Data science is an interdisciplinary field of computer science and statistics with the goal of extracting patterns and knowledge from large amounts of data and to transform that knowledge for practical use (Foroughi & Luksch, 2018). Cybersecurity is the protection of computer systems and networks from theft, damage, disruption and misdirection by criminals (De Zan, 2019). Thus, an example of utilizing data science in the application of cybersecurity would be to write a computer program that determines whether an email is considered to be spam from a large data set of emails.

There is a dire need to motivate middle and high school students to pursue careers in data science and cybersecurity because there is a severe shortage of qualified personnel in these fields (Muro, Liu, Whiton, & Kulkarni, 2017). According to recent statistics, data scientists are the third best job (based on earning potential, job satisfaction and number of openings) in the United States as stated by Glassdoor's annual list of the top 50 jobs (Glassdoor, n.d.) with over 6,500 job openings on Glassdoor from 2019 to 2020 (Woodie, 2020). In Australia, job postings for data scientists from Indeed.com rose 58% in 2018 and in April of 2019 postings rose 30% ahead of the same period the year before (Pickering, 2019). Cyber security estimates indicate that there will be about 3.5 million unfilled cybersecurity jobs globally by 2021 (Morgan, 2017). Yet, data science and cybersecurity is rarely, if ever, taught in middle and secondary STEM education in the United States. Thus, our goal for this professional development program was to reach teachers who work in rural contexts and to provide them with a rich learning experience in data science and its application to cybersecurity. Our intent for the professional development was for teachers to transfer their content knowledge and enthusiasm of data science and cybersecurity to their students and to encourage them to pursue careers in these fields. The purpose of this study was to investigate the impact of a professional development experience on teachers' understanding of disciplinary knowledge of data science and its application to cybersecurity and their ability to integrate the concepts to their middle and high school STEM curriculum. Specifically, the study was guided by the following two research questions: a) To what extent were teachers able to assimilate disciplinary knowledge of data science and its application to cybersecurity? b) How were they able to transfer this knowledge into their middle and high school curriculum?

Literature Review: Professional Development for STEM Rural Teachers

Recent research has identified challenges that impact the teaching and learning of STEM disciplines in rural contexts. Whannell and Tobias (2015) identified the transition between primary-to-secondary school as a period in student development "where interest in studying science appears to decline sharply" (p. 92). This lack of interest in pursuing STEM leads to a decline in students pursuing STEM careers, especially careers as STEM K-12 teachers (Peterson et al., 2015). The problems caused by the lack of qualified STEM teachers is compounded by the inability of many teacher preparation programs to teach specialized STEM disciplines (Whanell & Tobias, p. 94). Those who are qualified STEM teachers tend to work in urban or suburban contexts because many teachers hold the perception that they would be underpaid and overworked in rural contexts (Goodpaster et al, 2012); thus, schools in rural areas have greater difficulty filling open positions. As a consequence, rural students have lower interest in STEM, which directly impacts their academic achievement (Whannell & Tobias, 2015). This continues to perpetuate the cycle of a lack of qualified STEM teachers in rural contexts and negligible participation of rural students in the STEM workforce.

While some teachers who originate from rural communities purposefully choose to teach in those communities, many other teachers leave rural schools soon after their initial employment (Goodpaster et al., 2012). As a result of this teacher turnover, rural schools are staffed predominantly with young and inexperienced teachers who most likely do not possess graduate degrees (Goodpaster et al., 2012). These teachers may not well-equipped to meet the needs of the student population and lack sufficient preparation in the STEM disciplines (Desoff, 2010). Due to the low population of STEM teachers in rural areas, the kinds of professional development opportunities available to rural STEM teachers in the United States and Australia, whether in-school, within the district, or through regional professional development services, tend to involve pedagogical knowledge only (Goodpaster et al., 2012; Maher & Prescott, 2017). STEM teachers have limited access, due to geographical distance, to universities and resources that focus on developing their disciplinary content, resulting in little opportunity to collaborate with other STEM teachers and feelings of isolation (Goodpaster et al., 2012; McCluskey, Sim, & Johnson, 2011). Thus, the need for comprehensive and effective professional development, with a specific focus on disciplinary content, is, therefore, essential for teachers in rural contexts.

Theoretical Framework: The Situative Perspective

The framework in which we base our professional development comes from the situative perspective (Greeno, 2006; Greeno, Collins, & Resnick, 1996; Greeno & van de Sande, 2007; Kwakman, 2003; Putnam & Borko, 2000; Warford, 2011) in which cognition is situated in the everyday world of human activity. This theory notes that the context in which an activity takes place is an integral part of the activity and that teachers learn best when they participate in authentic activities (Kwakman, 2003; Putnam & Borko, 2000). Putnam and Borko (2000), define authentic activities as those similar to what actual practitioners do. These activities are intended to foster the kinds of thinking and problem-solving skills that are particular to specific out-of-school settings.

Previous research involving professional development for STEM teachers has utilized the situative perspective to increase teacher confidence in teaching STEM and to transfer disciplinary knowledge learned in professional development to their unique teaching contexts (Annetta et al., 2013; Baker & Keller, 2010; Burrows et al., 2016). These professional development programs engaged teachers in authentic inquiry-based projects of specific disciplinary STEM fields so that teachers learned the knowledge of these fields as well as scientific dispositions of joint problem-solving and generating new knowledge through extending, evaluating, and contrasting ideas (Greeno, 2006). For example, in Baker and Keller's (2010) professional development program, teachers partnered with university faculty from mathematics and science departments. Teachers learned how to be science researchers as they worked side-by-side with faculty on their research projects. In Annetta et al.'s (2013) professional development program STEM teachers became game designers as they were taught to develop their own science-based educational games for use in their classrooms. In Burrows et al.'s (2016) professional development program, STEM teachers became astronomy researchers as they developed research questions and used astronomy tools, such as a giant telescope with a 16-inch primary mirror, to make observations and answer their research questions. Engaging STEM teachers in authentic projects and disciplinary contexts increased enthusiasm for the disciplinary content to which they were exposed, increased teacher confidence to teach these disciplines, increased confidence in using forms of technology, decreased feeling of isolation because they developed networks of fellow

STEM educators, and increased motivation to implement more inquiry-based projects in the classroom (Annetta et al.2013).

In our professional development, we engaged STEM teachers in authentic activities similar to those that data scientists and cyber security experts conduct. Teachers utilized a common programming tool called "R" and engaged in activities with large data sets, such as data cleaning, data mining, and data clustering. Teachers were then tasked to engage in a collaborative inquiry-based project on a real-world problem, such as writing a program in R that determines which Facebook posts on COVID -19 were informative or filled with misinformation. Thus, teachers were enculturated into the specific dispositions and ways of thinking, communicating, and using texts relevant to the work of data and cybersecurity scientists. In our study, we investigated how this professional development aided middle and high school STEM teachers to acquire disciplinary knowledge of data science and its application to cybersecurity and how they transferred this knowledge into their curriculum.

Methods

As the context in which our professional development took place is an integral part of the learning by our STEM teachers, we chose explanatory case study as our methodology. In evaluation research, explanatory case studies "link program implementation with program effects" (Baxter & Jack, 2008, p. 547) and in our case we wanted to explain how our professional development led to the transfer of disciplinary knowledge.

Research for Teachers Professional Development Context

Our case study was bounded by our Research for Teachers (RET) professional development that took place at a university situated in western Texas. Teachers came from rural communities within a two-hour drive from the university. Teachers attended professional development for six hours a day, five days a week for six weeks, for a total of 180 professional development hours. For the first two hours of a typical professional development day, teachers received direct instruction on the content of data science and cybersecurity from CS faculty, followed by an hour for lunch. At least once a week, the faculty provided lunch which they shared with the teachers to promote a sense of community. Teachers also reciprocated by bringing snacks to share with everyone in the afternoon. After lunch, teachers engaged in a one-hour reflection with the CoE to synthesize what they had learned and visualize how they could transfer the knowledge learned to their middle and high school classroom context. Teachers wrote reflections in a digital blog, engaged in conversations with faculty, and then expanded on their blogs after the conversation. Finally, the last two hours were designated for application. Teachers would engage with CS graduate students to apply and reinforce the concepts learned during the morning session in a 'follow as I do' demonstrations on R programming.

After three weeks of direct instruction of content in the mornings the teachers were divided randomly into three teams and each team was partnered with a CS faculty member and graduate student. The teachers were asked to complete an inquiry project on a real-world problem of data science and cybersecurity. They developed a research question (such as "How can you detect a spam email from a regular email?") and used the content they had learned about data science and cybersecurity as tools to solve the real-world problem including phishing detections using URL attributes, sentiment analysis using social media and text-mining, and spam detection. In the last week of professional development, teachers gave an oral presentation of their research projects in a conference-like format to peers, graduate students, and faculty.

During the last two weeks of professional development, CoE faculty taught pedagogical knowledge to aid in designing a unit plan on a topic that integrated data science and cybersecurity concepts into their STEM curriculum. We asked teachers to create and present a model lesson (we referred to this as micro-teaching), so that they could work out any logistical problems before they taught their students at the middle and high school context. These activities were intended to transfer teachers' content knowledge, skills, and dispositions they had learned to their own practice. The unit plans and model lessons were uploaded to a digital depository supported by our grant stakeholders so that other STEM teachers can use them as guides for their own instruction in data science and cybersecurity.

Participants

Rural Middle and High School STEM Teachers

The teachers were selected through an application process which included the documentation of the applicants' leadership qualities and their STEM teaching background. Teachers taught subject areas in computer science, robotics, mathematics, physics, chemistry, and elementary science. We purposefully selected candidates who had the agency to integrate concepts of data science and cybersecurity into their existing curriculum and who would be willing to provide leadership to other teachers at their school to do the same. Participants from designated Title 1 rural schools (40% of students come from low-income families) were strongly encouraged to apply. A total of nine teachers, (7 females and 2 males) participated in the program. Teachers had a range of levels of disciplinary and pedagogical expertise. Some teachers had a bachelor's or master's degree in a STEM field and were alternatively certified and others had a bachelor's or master's degree in Education. Teachers also had a range of years of teaching experience (2-15 years).

Computer Science Faculty and Graduate Students

The computer science team comprised of three faculty members (2 females and 1 male) and three graduate students (2 males and 1 female). All the faculty members have rigorous research projects in computer science and have an intense interest in improving science in K-12 classrooms. Each taught a specific topic in data science/cybersecurity including a) Classification of cyber-attacks, b) Detection of phishing URLs and c) Sentiment analysis of social media messages. All instructors also stressed the relevance of concepts covered to the middle and high-school STEM curriculum. The graduate students would later reinforce the concepts by demonstrating the same concepts in a lab environment through hands-on activities. Since teachers were new to programming with R, the CS graduate students supported them to make sense or fix errors when running the code. They also collaborated with teachers in planning the trajectory of their inquiry projects and assisted in literature searches for material needed to guide implementation of the projects.

College of Education (CoE) Faculty and Graduate Students

The education team was comprised of two faculty members (2 female) and four graduate students (4 females). The role of this team was to aid the teacher participants in understanding the pedagogical knowledge needed to break down complex concepts for consumption by middle and high-school students. CoE faculty also assisted in updating teachers with innovative approaches to unit and lesson planning. Graduate students performed data collection and analysis, conducted naturalistic observations of the professional development as described below, and collected teacher artifacts.

Data Sources

The distinguishing characteristic of case study research is the use of multiple data sources to enhance data credibility (Baxter & Jack, 2008). Our data sources, described below, merged together to create a holistic understanding of how our professional development guided teachers in transferring data science and cybersecurity content to their teaching contexts.

Naturalistic Observations

Four graduate students from CoE conducted naturalistic observations each day the project was in session. The students kept track of what was happening in the classroom, including the time spent by the CS faculty and graduate students delivering the content. They documented the interactions between faculty and teachers, as well as across teachers. They also observed the manner in which the material was transferred to the research projects once the teachers moved into their respective groups. They monitored such aspects of teaching style such as didactic methods, active interactive learning, hands on demonstrations, collaborative team learning and questions raised by teachers for clarification.

Artifacts from Teachers

Artifacts included teachers' reflective journals and blogs, PowerPoint presentations of their inquiry research projects, teacher units, lesson plans, and a model lesson plan for micro-teaching. Teacher units and lesson plans were aligned to the Texas state standards, Texas Essential Skills Standards (TEKS).

Data Analysis

The situative perspective considers an analysis of activity to focus on "the processes of interaction of individuals with other people and with physical and technological systems." (Greeno et al., 1996, p. 17). We utilized discourse analysis to analyze the interactions teachers had with content experts (both CS and CoE faculty and graduate students), each other, and the disciplinary content and activities provided within the professional development context. Specifically, we used Greeno and van de Sande's (2007) aspects of discourse practice within the situative perspective. We analyzed graduate students' notes and teacher artifacts to identify changes within their interaction or participation within the professional development that determined teachers' conceptual growth. We considered teacher growth to involve ways of acquiring disciplinary knowledge of data science and cybersecurity and ways of transferring this knowledge into middle and high school classroom practice. We noted the presence of disciplinary words, concepts and the meanings ascribed as teachers reflected on the direct instruction, engaged in their collaborative inquiry-based projects, and its transfer into their units and lesson plans. The situative perspective also highlights that learning from individuals or groups "involves becoming attuned to constraints and affordances of materials and social systems with which they interact" (Greeno et al., 1996, p. 17). We note the constraints of our professional development context in terms of challenges that the teachers expressed when thinking about how they were going to transfer the complex disciplinary knowledge to their classroom practice. We looked for how teachers discussed breaking down the science concepts and processes for their students of varying levels and how they considered integrating state standards into their curriculum.

Findings

Data analyses revealed three themes or aspects regarding ways teachers acquired disciplinary knowledge and transferred this knowledge from this professional development to their middle and high school educational contexts. The three themes emerged as follows: a) ways of being a data and cybersecurity scientist, b) ways to apply and integrate concepts into STEM curriculum, and c) ways of collaborating as scientists. We conclude our findings by examining the challenges pertaining to transfer.

Ways of Being a Data and Cybersecurity Scientist

Teacher reflections demonstrated an increased use in discipline-specific ways of knowing, doing, thinking, reading, and writing. It is clear our teacher participants internalized the discipline-specific specialized language when they began to effortlessly mention terms associated with data science and cybersecurity such as "R programming", "KNN", "clustering", "data sets", "coding", "cleaning data," and so forth. They had recognized what counts as authentic texts and practices in the discipline of data science and cybersecurity. As the teachers expressed their need to understand the concepts in depth, they also recognized the cultures and demands of data science and cybersecurity and began to think about how to tailor this content into curriculum that would highlight the ethos and goals of data science and cybersecurity. One teacher shared in a reflective blog:

> *the most important is to start the learning of R software and its basic operations, such as how to define and create the dataset, and how to input the data from different files into the software. It is nice to start the learning of the new computer language. (June 11)*

The teachers' scientist persona was demonstrated in the way they taught the concepts in their classrooms as observed by one CS faculty:

> *The students put header names on the columns in the dataset, performed "iconv" (convert a character vector between encodings) on the tweets, and ran sentiment analysis on the converted tweets. They created a bar plot of the ten different emotional categories to see how the comments related to cyberbullying. (October, 7)*

The ease of using this specialized language was critical for deep learning in data science and cybersecurity.

Ways to Apply and Integrate Concepts into STEM Curriculum

Using the newly learned ways of knowing and thinking as data scientists, teachers envisioned how they would transfer what they had learned about data science to their specific content area classrooms in the following year. Teachers were quick to envision how they could use R programming as a tool within their already-established curriculums. They appreciated how useful the R programming tool would be in helping students conduct authentic performance-based activities or experiments in their specific content areas. One teacher shared:

> *I could see myself creating a lesson where students need to gather data and then use R programming to create charts and graphs. They can be asked to find different types of data by using some of the items, be asked to categorize the data by its appropriate attribute, and they can work on this with new cases. (June 10)*

Teachers hypothesized that students would see the real-life applications of data science. Other teachers saw how they could use the tools of data science, specifically R-Studio, as an opportunity to expand their students' knowledge in the content areas they taught. They identified how these tools opened new pathways that were not possible to them before as shared by a teacher in a reflective blog:

> *This [data scaling] is going to give the students even more tools to develop more confident results of their experiments. I'm thinking next year I can consolidate their data into a larger csv file. Maybe with these data skills, my students can perform some experiments that would normally be outside the reach of high school students, such as the Cavendish balance. (June 10)*

Clearly, teachers were excited about the newly acquired knowledge which would facilitate problem-solving skills for their students. Teachers often mentioned the need for their students to be able to solve problems in real life applications, a skill characteristic of STEM disciplines.

Ways of Collaborating as Scientists

The RET professional development opportunity gave rural teachers a rare opportunity to collaborate with each other on their inquiry projects. Rural teachers often face isolation in their workplace and therefore, appreciated the ability to work in groups to complete a research project. Collaborating was a chance to get to know each other better and a way of building a community of learners as shared by a teacher in a reflective blog:

> *The projects that we have been working on have been a great opportunity, not only to better understand the data science concepts, but also to get to know each other better and create that community of learners. Working in small groups most of the day has better facilitated the building of that community, I think. (July 11)*

Through this experience, teachers mentioned how they were able to identify the strengths that each of their team members brought, divide the work up accordingly based on their strengths, and support each other in their frustrations. These frustrations were discoveries to these teachers as they began to imagine how frustrated their students could be with the content that teachers present. For instance, one teacher shared in a reflective blog:

> *I need to be mindful of those kids that might go through the same problems that I am facing. I need to try to instill in them the drive to persevere even when it gets difficult or they do everything completely wrong and lose all of their data. (July 1)*

Reflecting on what they had experienced in a collaborative team environment, teachers increased empathy for their own students and viewed collaboration as a good pedagogical practice as shared by one teacher in a blog:

> *The elements to bring to our classroom would be reminding students that a learning community has many answers to a question you may have as an individual. This is to ensure that students will not shy away from asking questions to their group members. I will express the ideas and concepts to my students that I too had to work in a group and we collaborated well together in sharing our ideas throughout the project. (Jun 30).*

Teachers used these experiences to discuss elements of collaboration they wanted to implement in their own classrooms, such as asking questions if one does not understand, being resilient when the challenge becomes difficult, and having a shared space to brainstorm ideas.

Challenges Pertaining to Transfer

From our observational notes, teachers were at first visibly overwhelmed by the content because it was new and complex. They were often anxious and indicated that their middle and high school students would never master this content. The difficult and complex content helped them empathize with students, who often face challenges understanding some concepts in the classroom as shared by one teacher in a reflective blog, *"I now understand what my students go through"* (June 9). During the professional development, teachers were overwhelmed with the amount and complexity of concepts involved in data science and cybersecurity. They agreed that these concepts, as presented to them by the CS faculty, would be too difficult for their students. Teachers spent a substantial portion of their reflection time thinking of ways to utilize portions of the R programming tool or to break down the concepts even further for their students. The feeling of being overwhelmed by the thought of integrating the data science and cybersecurity concepts was shared by a participant who said:

> *Challenges I foresee include getting the students to understand all of the outside information like teaching them how to normalize data and fix skewness. I would need to find a way to chunk the material down into easier steps with material that might be more relevant to them. (June 10)*

There was a consensus from the teachers that they would have to break down the complex concepts into even further steps than what was done by the CS faculty's direct instruction:

> *I'm not sure how to teach neural networks to 6th grade students on a level in which I think they would build any comfort. At this level, students are only beginning to understand basic concepts of generating a graph, so I think that showing them that a neural network divides data into groups using a line is about as far as I could go with this concept. (June 17)*

Teachers were also worried about their own level of understanding the content and wondered if they could teach it to their students as shared by a teacher in a blog post:

> *I do worry about explaining these concepts in depth to my students because as the quote goes "You only really know material if you can explain it simply". So I do not know how deeply or well I will know this material at the end of the summer. (June 11)*

However, they identified some pedagogical strategies such as peer tutoring, collaboration, and hands-on modelling, would make the complex concepts more accessible to their students because "some will get way quicker than others" (June 11). Others talked about using strategies that had been modeled for them by the CS faculty: *"I would probably have to slow down and spend time going over each of the elements of this portion of R [programming]" (June 11).*

Discussion

Rural teachers are key to increasing the STEM workforce as they nurture their students towards a STEM pipeline. However, they can only attain this goal if they are provided with sound professional development programs that immerse them in an authentically research-rich environment where they are made aware of STEM career opportunities and the rigorous study needed for their students to compete for those positions (Peterson et al., 2015). Our study used the situative perspective as a framework to investigate the conceptual growth of STEM teachers through our professional development and how they transferred disciplinary dispositions, knowledge and practices to their middle and high school curriculum.

We observed the importance of teachers talking, writing, and interacting as data scientists and cybersecurity experts. Their reflections and discussions routinely included increased levels of language practices in the discipline. In the situative perspective, deep learning requires an apprenticeship in the discourse community (Greeno et al., 1996). For our teachers, this opportunity for apprenticeship was given to them by the CS faculty and graduate students. By immersing themselves in the "social and cultural practices, interactions, and cultural norms" (Moje, 2015, p. 255) of data scientists and cybersecurity experts, the teachers became proficient members of the community, which, in turn, they could share with their students.

Equally as valuable as learning the content, were the one-hour reflections with CoE faculty that prompted teachers to help synthesize the concepts they learned in the morning. In the situative perspective, transfer of learning is dependent on "how the learner is attuned to the constraints of the activity in that situation" (Greeno et al., 1996, p. 24). During the reflection sessions, teachers had to contend with their own classroom constraints such as varying conceptual abilities of students as well as the integration of mandatory subject area standards. Thus, teachers were pushed to think about how to scaffold the use of the R programming tool and break down the complex concepts into more manageable processes for adolescent learners. They had to purposefully select concepts learned during the morning session that could reasonably transfer to middle and high school classroom context. Teachers envisioned how they could use the tools and concepts to illuminate problem-solving skills during planned, authentic, performance-based activities or experiments in their specific subjects. Teachers saw how data science and cybersecurity was connected to many subjects and planned to introduce it in their STEM disciplines to stimulate student interest.

The final valuable aspect of the RET professional development was the collaboration among teachers as they were engaging in their inquiry projects. In the broader field of engineering, in which data science and cybersecurity found, work is "done in a community of people and, therefore, encompasses the hopes and values; the curiosity and imagination; the motivations, challenges, and rewards of working with others to address real world problems by innovating and improving technologies" (Giroux & Moje, 2017, p. 302). We wanted to replicate this sense of community with our teachers, as they had an opportunity to work on a real-life problem involving data science and cybersecurity. Our one-hour reflections enabled teachers to use their direct experience working in groups to think about elements of collaboration they could cultivate in their own students working on collaborative inquiry projects. Teachers reflected on how they were able to identify the strengths team members brought to the task, ask for help from one another, and build emotional supports when the problem became overwhelming and frustrating. We believe that this collaboration aspect was vital, as our teachers had expressed previous feelings of isolation and lack of engaging professional development in their rural contexts. These teachers continued this sense of community throughout the following school year by creating their own Facebook group. They shared how their unit plans and lessons worked and continued to seek new ideas and support from their new colleagues.

Limitations and Next Steps

This was a National Science Foundation (NSF) funded program that established a partnership between a large university in western Texas and local school districts in the area. The teachers who applied and were selected for the program underwent a rigorous process of screening, including an interview with the principal investigator (PI) and the university research team. We can therefore conclude that these teachers were highly motivated and their experiences may not be generalizable to the population of rural STEM teachers. Secondly, there were only nine teachers accepted in the program. Given the amount of support put in place for them, including stipends, their success in the program was highly probable.

Even with these limitations, our study has established that rural teachers, with a variety of levels of pedagogical and STEM content expertise, can excel when immersed in research-rich professional development. We found that the feelings of isolation for rural teachers can be lessened or reduced through professional development. Professional development afforded STEM teachers the collaboration, intellectually rich conversations (Goodpaster et al., 2012; Burrows et al., 2016), and mentoring they needed. We also found that the teachers in our study developed deep empathy for the struggles experienced by their middle and high school students. The concepts to which the teachers were exposed were particularly overwhelming, especially because much of it was new and many of them have never been in a computer course. However, their struggles reminded them of their classrooms and how some of their students struggle to comprehend new concepts. It was refreshing to hear teachers discussing pedagogical practices such as peer teaching, collaboration, and hands-on modelling, that they would implement in their own classroom to ensure all students could access the complex concepts.

Finally, teachers mastered discipline specific concepts even though they were at first difficult and overwhelming. We can attribute this success to the fact that expert scientists were responsible for imparting the discipline knowledge. All the three CS faculty members are experts in the field of data science and cyber-security in general in which they hold advanced degrees but more specifically, have years of experience in the topics they each taught. Our expert scientists modeled the disciplinary specialized knowledge and effective strategies needed to acquire the scientist persona. There is no doubt that partnerships between universities and rural school districts in delivering professional development for STEM teachers can support success. We recommend that future research investigate the sustainability of the practices the STEM teachers learned in this professional development and whether the students from these schools gravitated towards STEM careers. Future research could also involve more than nine teachers.

Rural schools are key to strengthening the STEM pipeline in an effort to increase STEM graduates for the workforce. Some of the rural STEM teachers hold alternative credentials expected for the discipline they teach. It is, therefore, possible that the teaching methods they utilize in the classroom are not congruent to the practices needed to mold students as scientists and imbue them with the desire to pursue STEM careers in general, and more specifically in the fields of data science and cyber-security. Findings in this study provide evidence that a sound, well designed RET professional development can reverse this trend. Exposing rural STEM teachers to STEM discipline-specialized knowledge paired with sound pedagogical approaches has significant implications for building the STEM pipeline in American rural schools.

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