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RESEARCH ARTICLE

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Communities of practice as a framework to explain teachers' experiences within the community of science

Shannon G. Davidson[1] | **Roxanne Hughes**[2]

[1] Florida State University, School of Teacher Education, 1114 West Call Street, Tallahassee, FL

[2] National High Magnetic Field Laboratory, Center for Integrating Research and Learning, 1800 E. Paul Dirac Drive, Tallahassee, FL

Correspondence
Roxanne Hughes, National High Magnetic Field Laboratory, Center for Integrating Research and Learning, 1800 E. Paul Dirac Drive, Tallahassee, FL.
Email: hughes@magnet.fsu.edu

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Abstract

In this study, we argue that current conceptual frameworks used to understand how novices make sense of science ignore K-12 teachers' understanding to a detriment. If teachers are supposed to translate the content, context, and culture of science to their students, then it is important for researchers and policymakers to understand how this happens. Communities of science practice (COSP) research identify the ways in which novices make sense of the practices of science within a space where they interact with, observe, and are affected by other members at varying levels of legitimacy. In brief, K-12 students are rarely exposed to the COSP; therefore, teachers must translate these cultural pieces to their students while simultaneously teaching the content and practices of sciences. We chose to focus on teachers who participated in a Research Experience for Teachers (RET) program. The RET program served as a brief exposure to a COSP for these teachers. The goal for our study was to develop a conceptual framework to study teachers' experiences as spectator novices within a RET program. Spectator novice was the term we used to define teachers' roles as novices moving toward legitimacy within the COSP but with a different goal—that of observing the culture and translating it to their students—from science undergraduate and graduate students who are attempting to become full legitimate participants within the community. Through interviews with teachers, we developed a conceptual framework that can guide future research on the unique experiences of teachers as *spectator novices* within the COSP.

KEYWORDS

communities of practice, Research Experiences for Teachers, science teacher professional development

1 | INTRODUCTION

Currently, the major framework for understanding the content, context, and culture of science, technology, engineering, and mathematics (STEM) is that of communities of science practice (COSP) (Lave & Wenger, 1991; Wenger, 1998). Research guided by the COSP framework has focused on the trajectories of novices as they enter STEM fields and gain experience and develop a stronger understanding of the norms, expectations, resources, processes, and the ways of knowing that are exemplified by legitimate experts within the community (Feldman, Divoll, & Rogan-Klyve, 2013; Traweek, 1988). Typically, these novices enter their chosen STEM field through a hierarchical process (e.g., as undergraduates in a STEM major) with the goal of eventually becoming a full legitimate (or at the very least a legitimate peripheral) participant. The research focused specifically on the COSP, has identified full participation as adding or building on new knowledge through research (Feldman et al., 2009; Traweek, 1988). Within this framework, movement toward full participation within the COSP begins with an undergraduate degree in a STEM field. If the individual remains on a legitimate path toward full participation within the COSP, this would typically be followed by graduate school or a STEM career (peripheral) and could eventually culminate in a position as a researcher (full participant) (It is important to note that the term legitimate comes from the work of Lave and Wenger (1991).). K-12 STEM teachers do not fit neatly into this traditional COSP trajectory in terms of approaching full and/or legitimate participation. Some teachers may have an undergraduate degree in a STEM field but others might have just taken one or two STEM-related courses. Consequently, STEM teachers' understanding of the COSP can vary based on their exposure to the community and most STEM teachers have limited exposure (Banilower et al., 2013; Capps, Crawford, & Constas, 2012; Hodson, 2014).

K-12 students are expected to come away from their STEM education with an understanding of science content, context, and culture; STEM teachers are tasked with providing all students opportunities to meaningfully develop these understandings in ways that are authentic to the work of scientists—the COSP (National Research Council [NRC], 2012; NGSS Lead States, 2013; Schweingruber, Duschl, & Shouse, 2007). However, what often happens is that students struggle to develop a true understanding of the cultural aspects of the COSP because they are not exposed to it. In brief, STEM subjects are often taught as discrete facts to be memorized or final form canonical knowledge. But what can we expect if teachers are also not given opportunities to experience or at least observe a COSP?

The STEM teachers have the responsibility of supporting students in this complex endeavor of understanding STEM content and culture as interwoven constructs through the design and implementation of meaningful lessons and experiences (Hodson, 1993; Hofstein & Lunetta, 2004; NRC, 2012). To productively expose and engage students in the COSP in the classroom, teachers themselves must have a grasp of what counts as the cultural aspects of the COSP—the collaborative norms, discursive practices, and habits of mind of science—and how scientists engage in these to do their work in research. However, few teachers are ever actually exposed to authentic STEM research or experiences that mirror the COSP, making it difficult for them to provide this understanding to their students (Banilower et al., 2013; Capps et al., 2012; Hodson, 2014).

In response to this lack of exposure, Research Experiences for Teachers (RET) programs have been instituted at universities and national research institutions as a professional development (PD) venue wherein teachers are immersed in the authentic participation of scientific research through collaboration and shoulder-to-shoulder work with research scientists and engineers over multiple, consecutive weeks (Dixon & Wilke, 2007; Hughes, Molyneaux, & Dixon, 2012; SRI International, 2007). Broadly, RET programs may vary in their focused STEM content areas and disciplines, their approach to bridging STEM research and classroom pedagogy for teachers, and the degree to which teachers have autonomy in choosing their own direction of research (Hughes et al. 2012; National Science Foundation [NSF], 2013; SRI International, 2007). Nevertheless, the goal of all RET programs is to support the active involvement of K-12 teachers in STEM research to bring a more complete understanding of these disciplines to their students as a result of their participation (NSF, 2013; SRI International, 2007). The programs of RET were modeled after similar programs for undergraduates. However, undergraduates' (novices) goals for their participation in apprenticeship programs (eventual legitimate participation as a scientist) are different from teachers' goals of participating in PD. Teachers in an RET program are not necessarily planning to become legitimate participants at all, rather they are participating at a level where they can learn enough information about the COSP to confidently translate it to their students. We are calling this unique position within the COSP, spectator novices. These teachers are participating at the novice level but with a different end goal of observing (and in some cases actively participating) and taking the information back to their students rather than to become legitimate participants. Consequently, the current COSP framework does not help researchers to understand teachers' motivations to pursue RET as PD or the role that RET participation has on teachers' understanding of the COSP.

1.1 | Current framework and its gaps

To understand what is missing, one must first understand the current COSP framework used to study novices' experiences in STEM. Communities of science practice have their underpinnings in Lave and Wenger's (1991) work with communities of practice (COP). Communities of practice are places wherein situated learning occurs. Specifically, novices enter a community and through an apprenticeship process, learn to participate in it. In apprenticeships, novices work with mentors to learn the skills required for a trade. In these COP settings, learning is integral to the social practice that occurs. Learning is contextual and social and involves the whole person in the sense that they have agency in the process and their level of learning is dependent on their prior experiences. Therefore, learning within a COP cannot occur in a decontextualized environment. Apprentices must identify with the community to want to be part of it. Reciprocally, the community must welcome them as legitimate, even if peripheral, participants in order for them to feel like they belong. The learning that occurs within a COP involves the understanding of abstractions—symbols, tools, conceptual ideas—and their uses, which have different meanings in specific groups or cultures; therefore, to understand learning requires some knowledge of the culture and identity work within the culture (Lave & Wenger, 1991).

According to Lave and Wenger, there are three key dimensions to COPs: mutual engagement, joint enterprise, and shared repertoire. Table 1 summarizes these dimensions as well. *Mutual engagement* refers to the social and cultural practices that are unique to each COP. These include group norms and expectations that drive interactions. Traweek (1988) and Feldman, Divoll, & Rogan-Klyve (2013) have built on the COP framework to study COSP—a type of COP that focuses on specific

TABLE 1 Dimensions of COP[a]

Mutual Engagement	Communities culture and practices as evidenced by patterns of interaction among members (group norms, expectations, and interactions)
Joint Enterprise	The common purpose that brings members together for a unifying goal and drives collective action
Shared Repertoire	Communal resources within the community, accessible to all who are part of the community of practice

[a]Lave and Wenger (1991) and Wenger (1998).

science-related disciplines which have their own language, norms, and practices that are shared and understood by legitimate members. These norms and practices include: the use of evidence and data to make arguments and justify conclusions. Within smaller communities such as lab groups, there may even be social norms about speaking in the group based on one's location in the hierarchy (e.g., undergraduate vs. graduate student vs. faculty).

The second dimension is *joint enterprise*. All COPs must have a common purpose determined by a unifying goal that brings members together and drives collective action. In the COSP, the common purpose is typically to create new knowledge through research, which brings scientists together and justifies their participation in research projects (Feldman et al., 2013; Traweek, 1988). As novices move along a trajectory within the COSP, they begin to add more to the joint enterprise of STEM research. Undergraduates may begin as technicians or data entry personnel, whereas graduate students become involved in the analysis of data and work with equipment. Postdocs and faculty have a larger role in shaping the direction of projects and publishing new research that will shape the direction of the scientific disciplines in which they work.

The final dimension of COPs is *shared repertoire*. This is typically the most observable outcome of the COP and includes a shared set of community resources including: procedures, techniques, tools, and symbols. COSP, like COPs, are social. In STEM fields, the joint enterprise is cutting edge research, and because of this, the shared repertoire is continuously changing as it is developed and maintained. Shared repertoire is developed over time and hence the language for communicating the meaning of the practice is couched within a shared history of those within the community (Feldman et al., 2013; Traweek, 1988). In this way, the community and its practices are open to interpretation and may be seen as ambiguous by those who are novices. Like novices, spectator novices (teachers with the goal of understanding enough of the COSP to translate it to their students, rather than to become full participants) are often not completely aware of the COSP shared repertoire and history of the community (Feldman et al., 2013).

There have been two ethnographic studies that have articulated the COSP framework and the trajectories of novices within STEM communities (Feldman et al., 2013; Traweek, 1988). Both of these studies focused on STEM majors and research scientists not K-12 STEM teachers. They are described here because they highlight the traditional pathways for novices within the current COSP framework. Traweek (1988) conducted extensive ethnographic research on the COSP within two physics laboratory facilities. Traweek described the process of physicists developing from novices to legitimate and full participants. She described the undergraduate stage as the training stage where students were first exposed to physics and the community of physics. This training occurred through the transmission of knowledge and culture, which was done through formal education and observations of the norms of behavior and interactions within each person's respective physics department. Consequently, novices worked with more senior level students and faculty and learned the group norms, expectations, and interactions (mutual engagement). Through their coursework and interactions they began to learn the common purpose of physics (e.g., an understanding of the universe) and how it differed from other disciplines (joint enterprise). The novices began to use language and resources (e.g., research projects, tools, and equipment) that exposed them to the shared repertoire of physics. As individuals remained in a physics major and moved toward a more active and legitimately recognized role within the COSP, they also began to internalize the norms of the community and identify with it.

Traweek explained that the undergraduate stage was just the first step in a 15-year apprenticeship that included graduate school and a postdoctoral associate program. It was during these latter stages that physicists learned how to conduct quality research, promote that research, and carry themselves in a way that allowed them to be recognized as successful physicists. As they remained in the COSP, they had more opportunities to participate in the mutual engagement, joint enterprise, and shared repertoire of the physics community. According to Wenger (1998), novices were able to identify with a COP when they better understand what participation looked like within the community versus non-participation. Even as newcomers, undergraduate physics majors were interacting socially with older peers, graduate students, postdocs, and faculty. Through these interactions, novices began to negotiate their roles within the context of the physics community (Wenger, 1998). We chose to stop the discussion of Traweek's concept of the physics COSP novices at the undergraduate phase as most K-12 teachers would have similar levels of experience within their chosen STEM subject matter or possibly less.

Feldman et al. (2013) helped us to better articulate the difference between spectator novices and typical novices within the COSP. Feldman et al. (2013) conducted an ethnographic COSP study of university level science research laboratories, wherein they observed that undergraduate and graduate level researchers take on different roles in research groups based on their given level of expertise, experience, and collaborative abilities within the COSP. The authors observed that those considered to be novice researchers engaged in their lab community by merely *observing* others or developing research questions and projects under the guidance of a mentor (Feldman et al., 2013). More experienced participants took the role of "proficient technicians," engaging in procedural efforts such as setting up and monitoring experiments, collecting data, and conducting some data analysis (p. 237). Those at the most experienced end of the continuum were considered knowledge producers; these participants were not only a part of the general COSP, but were also considered a subset of the epistemic COSP. It was after reading this study that we coined the term spectator novice to clearly differentiate K-12 teachers in an RET program from other novices or more expert members. We realized that if novice researchers were considered observers within the COSP, then teachers would be akin to this but with the additional caveat that they did not plan to stay within the COSP to learn more and potentially become more active in the COSP.

Both of these studies highlighted the goal of typical novices (undergraduates and graduate students) within the COSP. The studies indicated that typical novices were granted certain access and allowed limited opportunities to participate in the COSP. After many years of participation and practice, these novices were given more opportunities to participate and demonstrate their expertise, eventually moving toward legitimate participation and recognized membership within the community. Although RET programs place teachers within a COSP to conduct research and experience/participate in the cultural norms of the scientific community, teachers are not necessarily entering the space with the same goals as the typical COSP novice. Therefore, the current COSP framework does not provide an accurate guide for understanding how K-12 teachers as spectator novices understand the COSP and then translate it to their students. Most RET researchers have framed their studies within PD frameworks rather than COSP because of the differing goals of K-12 teachers within the COSP. However, framing RETs within PD is also problematic.

Research on PD in science education describes five core features that are essential for effectively influencing change in teacher knowledge, beliefs, or practice: focus on specific content; engage teachers in an active approach to learning; enable the collective participation of teachers involved; include sufficient duration; and have coherence with the expectations and policies placed on teachers (Desimone, 2009; Wilson, 2013). By and large, RET programs typically address these five core features of PD (Desimone, 2009), albeit in differing ways depending on the mentoring philosophy of the lead scientist, the structure of the research group, and teachers' own sense of expertise/understanding of the COSP (Blanchard, Southerland, & Granger, 2009; Capps et al., 2012; Hughes et al., 2012; Sadler, Burgin, McKinney & Ponjuan, 2010). For example, some mentors allow teachers to develop their own questions and research methods (Blanchard et al., 2009; Buck, 2003; Dresner & Worley, 2006) with support from the research group, whereas others engage participants in ongoing research projects chosen by the mentor (Faber, Hardin, Klein-Gardner, & Benson, 2014; Grove, Dixon, & Pop, 2009; McLaughlin & MacFadden, 2014). These decisions are often made by the mentor and based on their philosophy of mentoring and the constraints of their research group structure. Additionally, some but not all RET programs are structured to provide teachers with opportunities to explicitly connect and reflect on how their research can influence their pedagogy (Bahbah et al., 2012; Blanchard et al., 2009; Dresner & Worley, 2006; Faber et al., 2014; Hughes et al., 2012; McLaughlin & MacFadden, 2014; Miranda & Damico, 2015; Varelas, House & Wenzel, 2005). Teachers also enter RET programs with varying levels of understanding of the COSP as well as varying levels of confidence in their science content knowledge (Bahbah et al., 2012; Hughes et al., 2012; Pop, Dixon, & Grove, 2010). In some cases, the structure of the program and the mentor's choices in terms of research can influence teachers' understanding of COSP and science content in different ways (Hughes et al., 2012). One common goal for teachers in RET programs is that they enter their respective program with the purpose of taking their new understanding back to their students. We as researchers know little about how teachers interpret the COSP during and after their experience within an RET, as previous studies have focused on outcomes such as confidence or self-efficacy in science teaching, but the goal of RET is not necessarily to change their teaching but to expose them to a COSP.

2 | METHODS

Consequently, our goal in this study was to create a conceptual framework that helps researchers understand teachers' experiences within the COSP as spectator novices. The guiding questions for this study were as follows:

1. How do teachers experience the COSP through their participation within an RET?
2. How does their experience within the COSP affect their understanding of each of the concepts differentiated within COSP (mutual engagement, joint enterprise, and shared repertoire)?
3. What differences do spectator novices experience that could add to a more complete COSP framework for RET research?

2.1 | The lab RET program

This study focused on participants in a six week paid summer RET program. The program occurs every summer and began in 1999. It is held annually at a national interdisciplinary laboratory (the Lab) with more than 600 scientific faculty and staff from STEM fields that include: engineering, physics, biochemistry, chemistry, and materials research. The Lab is made up of smaller lab groups composed of research scientists, technicians, postdocs, and graduate students. Participating teachers must apply for the program in the preceding spring. The application includes a description of interest and a letter of support from each teacher's principal. The teachers are selected so that the program has a mixture of teachers from each grade level: elementary, middle, and high school. Teachers are paired together and assigned a scientist mentor based on their STEM fields of interest.

The structure of the program is designed so that teachers work with their scientist mentor during the morning and early afternoons five days a week (Monday through Friday). Different scientists may participate each year and each mentor scientist determines the research projects designated for their teachers. Teachers are given explicit roles and responsibilities within their mentor scientist's lab and are active participants in the ongoing research of that lab; they do not act as passive observers. The afternoons are scheduled as opportunities for the teachers to participate in the pedagogical components

TABLE 2 Typical schedule for afternoon RET sessions

Monday	Lab crawl and research update	Two paired teachers take the cohort on a tour of their mentor scientist's lab and present their on-going research
Tuesday	Open for continued research	Work with mentor scientists may sometimes require extended hours in the lab
Wednesday	Mini-workshop or hands-on activity	The cohort participates in a hands-on science activity or lesson facilitated by RET support staff
Thursday	Expert talk or focus group	A guest expert speaks to the cohort about aspects of science or scientific work; twice in the RET, programmatic teacher focus groups are held
Friday	Lesson share	Two teachers each present a lesson they feel is one of their best science lessons to share with peers and receive peer feedback

of the program, sharing their thoughts and experiences about the research work with their cohort peers. A description of these afternoon activities is summarized in Table 2. The final week of the six week RET is dedicated to poster preparation for the culminating research presentation poster session on the last day of the RET.

2.2 | Participants

To understand teachers' experiences in and translation of the COSP based on their RET participation, we wanted to interview teachers who had had time to reflect on their experience and practice skills learned during the RET within their classrooms. Consequently, we limited our participants to teachers who had participated in the program one year or more before the time of the study. Of the 45 past (2000–2015) participants with updated contact information, 12 agreed to participate in telephone interviews during the summer of 2016. Table 3 lists the pseudonym names for the teachers as well as other relevant demographics. All of the teachers were still teaching or working with students in formal classrooms at the time of their interviews. One of our teachers, Sally, participated in the program more than 15 years ago. We chose to keep Sally's interview despite the length of time between her participation and the interview for two reasons: she participated in the program twice which provides a unique perspective that only three other participants could give and because we believe that her lengthy experience in the classroom would give her ample opportunities to reflect on and practice her COSP understanding in her teaching which would offer valuable data to better develop a stronger COSP framework for spectator novices. The other participants had participated—at the most—10 years prior to the 2016 interview and—at the least—1 year, giving them sufficient time to reflect on and practice skills learned during the RET.

2.3 | Data collection

The primary data source for this study consisted of individual semi-structured interviews which focused on participants' RET experience and asked them to reflect on their engagement with scientific research, and what they currently perceive to be the most salient features and aspects of the RET program that are still applicable or practical to them in their current teaching. All questions were framed within the context of participants' RET experience and their current professional experiences. The interviews were conducted over the telephone by the first author during the summer of 2016. The

TABLE 3 Study participants

Name	RET Year 1	RET Year 2	Years teaching	Title I at time of program	Current school title I	What grade level do you currently teach?
Sally[a]	2001	2003	16–20	No	No	Elementary
Michaela	2006		6–10	Yes	Yes	Elementary
Samuel	2007		25+	No	No	High
Carrie	2007	2008	6–10	Yes	Yes	Elementary
Sidney[a]	2008		11–15	Yes	Yes	Elementary
Julie	2009		1–5	Yes	No	Middle
Eve	2010	2013	11–15	No	No	Middle
Gail	2012		25+	Yes	Yes	High
Lorie[a]	2013		11–15	No	Yes	Elementary then Middle
Jessica	2014		25+	Yes	Yes	Middle
Calvin	2014	2015	25+	Yes	Yes	Elementary
Tina	2015		25+	Yes	Yes	High

[a]The teacher currently teaches at a different school than the school they taught in while participating in RET.

interviews consisted of roughly 15–20 questions and lasted between 25 and 40 min for each participant. The interviews were audio-recorded and then transcribed. A copy of the interview protocol is available as a Supporting Information material (Methods S1).

The interview questions were created to gather each teacher's description of their experiences within the program. We did not explicitly attempt to define the COSP for participants nor did we ask them to define COSP. Rather we allowed them to use their own language to identify the aspects of the COSP culture that they observed. To give teachers an opportunity to describe the RET, we had them compare the RET to other PD that they had participated in. By discussing contrasts, we believed that this would give them the opportunity to describe in more detail the structure and impact of the RET program. This interview protocol also allowed us to gather more information on the teachers' motivations to attend the program, their reflections on their understanding of STEM before and after, and their perceived impacts of the program outside of the COSP codes. This latter feedback allowed us to answer research Question 3 and provided us with data to build our updated conceptual framework for understanding spectator novices' experiences within the COSP.

2.4 | Analysis

Initially, Lave and Wenger's (1991) COP framework and Traweek's (1988) and Feldman et al. (2013) COSP framework were the basis for our codes (Table 1). As we discussed these concepts, we realized that all three aspects of COSP—Mutual Engagement, Joint Enterprise and Shared Repertoire—fell under the concept of culture. We discussed terms that would allow us to differentiate culture from the three COSP concepts. Culture became the parent node to the Mutual Engagement, Joint Enterprise, and Shared Repertoire pieces. To refine these concepts, we discussed how Traweek's (1988) and

Feldman et al. (2013) pieces added to the COSP framework. As a result, we coded references to individuals (the *who*) as references to culture. These references to individuals could include the scientist mentor and/or members of the lab group. Mutual Engagement in our coding scheme included comments that related to *how* scientists do research. Specifically, we looked for terms and descriptions of investigation and the process of how scientific research is done. Joint Enterprise was coded as any reference to *why* scientists do research. Here, we were looking for language related to the reason why scientists pursue their research agenda and conversations around the motivation for conducting research. Shared Repertoire included references to *what* tools and resources were being used.

After discussing these codes, we decided to code three interviews separately then met to discuss differences in our codes and inter-rater reliability. As we coded the three interviews, we also jotted down memos identifying other codes related to teachers' unique experiences as spectator novices within the COSP that could be added to our codebook. We met to discuss the codes for our three interviews; initially, we had 88% inter-rater reliability. This percentage was developed by matching all of codes within the Nvivo software. We chose to code entire sections of comments rather than pieces within so that we would have context for our thematic analysis. Therefore, the data were not reduced before the inter-rater reliability comparison. We discussed interview portions where our respective coding segments did not overlap to understand each other's rationale. This allowed us to improve the codebook. For example, after reading the three interviews we were able to be more specific about the types of reference to Joint Enterprise as articulated by the teachers. These fell into two categories: "micropicture" and "macropicture." The micro includes references to the specific tasks that teachers participated in without reference to the macro or larger goal of research (e.g., to expand or create new knowledge). Macro references included an understanding that the individual RET research project was part of a broader research agenda. Macro also included an understanding that research is done not just for the sake of curiosity but to expand knowledge and solve problems previously not understood. Our final codebook is summarized in Table 4. We then coded the remaining interviews separately and achieved a 96.8% inter-rater reliability. For the purposes of this article, our findings will focus specifically on COSP codes and additional spectator novice experiences as our research questions were focused on teachers' understanding of this concept.

We were able to include three of Creswell's (2013) eight recommended validation procedures. Each of the authors has worked as a researcher (participant observer) during the RET program since 2007. Two of our participants were RET members before this year; however, the researchers have maintained contact with all of the RET teachers annually through follow-up communication and social media. Therefore, the researchers were known by the participants, which built trust between the researchers and the participants. Participants were sent copies of their transcribed interviews for member checking. We met with external auditors (colleagues) to review our findings and the results to determine if our findings were accurate. We utilized thick description with our quotes to give the external auditors and now the reader an opportunity to determine the accuracy for themselves.

3 | RESULTS

3.1 | Research Questions 1 and 2: COSP experienced through RET

Our analysis indicated that one of the most cited and discussed concepts of the COSP for participating RET teachers was the Mutual Engagement piece. All of the teachers explicitly discussed Mutual Engagement, the practices of science, as one of the key pieces that they brought back to their students based on their RET participation. Joint Enterprise was mentioned in reference to the micropicture—the project that they worked on in the RET—by half of our participants, whereas the broader goal of

TABLE 4 Data analysis codebook

1. Preprogram and early program reflections
   a. Goal for being part of the program
   b. Initial feelings as a novice
   c. Nontraditional path—that led them to science (e.g., Calvin came to science teaching from physical education, Gail had emergency certification)
   d. Lifelong learner—reference to always loving to learn or being a lifelong learner
   e. Comparison between RET and other RETs or PD
   f. Teacher's misconceptions about the COSP
   g. Difference—reference to difference between scientists and teachers
2. COSP description
   a. Culture (the who)
      i. Mutual Engagement (the how)
      ii. Joint Enterprise (the why)
      iii. Shared Repertoire (the what)
3. Effects of program
   a. Being seen as expert upon return
   b. Confidence
   c. Wanting to experience more RET-like PD
   d. More empathy for students after participation
   e. Giving students more time on projects
   f. Addressing students' misconceptions of science
   g. Making the science relevant to everyday life
   h. Mentoring from other RETs
   i. Networking (relationships developed during and maintained after RET)
   j. Translation of RET (COSP) to their students
      i. Culture
         1. Mutual engagement
         2. Joint enterprise
         3. Shared repertoire
4. Community of science teaching practice (working with colleagues, collaborating, how their experiences in their schools were identified in the community of practice codes
   a. Culture
      i. Mutual Engagement (collaboration)
      ii. Joint Enterprise (common goal of educating students)
      iii. Shared Repertoire (resources, including constraints)

scientific research was referenced only by three of the teachers. Shared Repertoire was the least described portion of the COSP framework and was typically only a passing reference. For example, four teachers (Calvin, Gail, Jessica, and Tina) referenced the articles they were encouraged to read and the role of specific tools (e.g., MRIs and microscopes) for analysis. Half of the teachers also saw their final poster presentation as well as science notebooks as tools that they used to translate the COSP to their students. In the next section, we will highlight how teachers experienced each of the concepts of COSP using their own words.

3.1.1 | Mutual engagement: Struggle and frustration

Most of the teachers categorized Mutual Engagement as processes of science that include: repeated experimentation, struggling to understand new information, learning from mistakes, and following through on a line of inquiry toward the production of new knowledge. Many teachers discussed these processes using references such as "It's all trial and error" (Calvin) and highlighting the concept of "getting things wrong" (Carrie). One of the teachers (Gail) was part of a publication based on her RET project. Hence, she was able to experience the process of communicating new knowledge as an aspect of the COSP:

> Some of the data we got was actually in the article. So that was really exciting. I think we were the only ones that actually published an article from the RET—this is the only time that I've been part of an article of all the RETs I've done. So that was really exciting. I liked watching that process too! He [scientist mentor] would e-mail us each piece of the process until it became an actual article so that was very informational for me to actually see how those science articles are published and to see how they're put together and written. We kind of went from the beginning to the end to see the whole process.

Here Gail described the process of science as not just the research but the communication of that research. Gail was an example of one of our participants who had a full COSP experience within RET and could articulate that experience. She was one of only three teachers (Gail, Jessica, and Tina) who described all three aspects of the COSP (Mutual Engagement, Joint Enterprise, and Shared Repertoire) in her interview.

Many of the teachers described the initial feelings of inadequacy upon entering their RET experience in their descriptions of Mutual Engagement. Jessica articulated the struggles that novices have when entering the COSP and how this struggle helped her to understand the process of mutual engagement better:

> Spending the time reading about the research and talking with people who are passionate about their field of science was also key. And they [scientists in her lab group] were willing to share and explain things. There was one word and I can't remember it, but it was in the papers I had read and I could not understand it and I looked it up on the internet and I could not find it and then I just asked, "what is this?" And they said "oh, it's this process" and I was like "oh." But it was funny in that I could not find out what this word meant on my own. So actually being around people was helpful. I had that struggle and it wasn't until I struggled with it that things began to make sense. So I think part of true learning is embracing the struggle. And that's what I enjoyed, being with others who were like "I have no idea what I'm doing but" and not only just the struggle but also coming to a place that we [teachers] weren't used to.

Jessica, like Gail, had a COSP experience in the RET and the language to describe it. In the above interview segment, Jessica referenced the tools used including language along with the "struggle" she experienced. One additional COSP aspect that Jessica mentioned was her own sense of comfort with the other novices and peripheral participants as she was able to admit that she did not know what a certain word was. This concept of struggle was part of the teachers' experiences as they entered the COSP in their lab groups. Many did not know all of the words being used nor were they familiar with the tools that scientists were using. These teachers had to take initiative to ask scientists in their group about concepts they did not understand.

Michaela described an experience of not understanding the science in a conversation with her research team, but rather than asking for clarification in the moment she talked about commiserating with colleagues which led to a sense of shared novice experience:

> I remember this day, where my mentor—he was so excited about what was going on. And he would give us so much information and we were loving it. We saw his

> enthusiasm and there was like four of us [teacher and lab group members] and we were engaged with him. But then he said something and we were like, "Oh crap." He went down this road and we didn't know what he was talking about, but we were all paying attention and listening to him the whole time. We were right there with him, and we just couldn't process the information as fast, and I remember just feeling like "whoa, just stop! This is too much information. It's good, but it's too much at once." And the others were like, "Oh my God, I know!" I mean, you get so used to it, but then you need a break. No matter how enthusiastic you are or how much involvement you have, you still need that process time to really get it.

Here, Michaela was referencing others in the lab group not just her teacher partner. This was an important distinction in that she felt like others in the lab also struggled to understand what the expert (lead scientist) was saying. Michaela, like Jessica, highlighted how teachers saw themselves in similar positions to early career scientist novices like graduate students.

In contrast, Tina described her misunderstanding as a novice but only from the context of her personal experience—there was no shared sense of being a novice with other novice scientists.

> One day Brian [her mentor] said, "well let's just cut a hole in it [a metal wire sample] and look at a cross section." And I'm looking around for a pair of scissors or whatever and he's just laughing at me and he's going "no. we're gonna do it with a beam of electrons in this machine." and I'm like, "excuse me?" that was my ah-ha moment. I was looking for a razor blade to cut this thing! I mean, I just didn't realize—technology blows my mind.

Tina, like Michaela, referenced her personal experience of not understanding concepts as a novice. The comparison between these two stories indicated that some teachers had a shared experience as novices with early career scientists (graduate students) in their labs, whereas only others had this experience with their fellow teacher partner. This demonstrated that the shared experience of novices was interpreted differently depending on the structure of the lab group—for example, Tina and her teacher partner worked only with their mentor not an entire lab group, whereas Michaela worked with her teaching partner and interacted with the entire lab group.

The common theme across all of the teachers' discussions of Mutual Engagement was struggle. Even Tina's and Michaela's comments come back to that fundamental concept of struggling to immediately understand concepts. Jessica best summarized her observation of the struggle within the COSP as represented by her lab group:

> So there was this frustration of having no idea if this is going to work and it's not working the way we think it should. We're trying this and in some of the discussions, we'd be like, "okay, I understand how this material works, but applying it it's not working the way I think it should and we have no idea why." So you know, I liked that there was this "we don't know" and "let's try and see." It's more like, let's see what this material does. Let's take this material and put it under high pressure and high heat and let's look under the microscope and see what types of oxidation took place.

Jessica highlighted the frustration that can come with the struggle of research with her reference to "we don't know" and "let's try and see." This was similar to Calvin's reference to trial and error. What was very telling for us was the use of the word "we." Notice that Jessica, Michaela, Tina, and Gail all included themselves in their descriptions, evidence that they all saw themselves as part of the COSP.

We chose to ask teachers how they translated their RET experience to their students to give them more opportunity to articulate their own perception of the COSP. The resulting interviews supported our initial sense that teachers' saw mutual engagement as struggle and perseverance. Calvin explained how he changed the way he prefaced labs with his students after participating in RET:

> What I learned [in RET] was that you will never get the "correct" answer for the outcome you're looking for the first time you do the experiment. It will never go perfect the first time. That helped me to tell my students, "Hey, everything is not gonna be peaches and cream the first time you do it." What I come up with, you may not come up with. I want them to understand it's a process. Let's discover. Let's take our time doing this. Let's go through the scientific process.

Calvin invoked terms like discovery and hinted at the concept of struggle and frustration through his metaphor of "not everything is gonna be peaches and cream," a metaphor for smooth and easy. Similarly, Julie described the messiness of science and how she explained this concept to her students:

> Like if we're [students] doing an activity where they have to do a little bit of experimentation and it's not going the way they thought it would, or they think it's tedious or they think their data is kind of difficult to understand, and it's hard to locate the evidence within that—like that's all part of doing science. It's not this cookie cutter thing. It can get messy and it can just lead to a whole bunch of other questions and it might not go the way you planned.

Here, again we saw evidence of teachers translating the struggle of doing of science (the how) to their students. Julie also hinted at the shared experience of frustration and struggle that RET participants could have with their students after participating in the program in that she used the term "we" to include herself with the students. Carrie highlighted this shared experience as well:

> There [are] some [experiments] that I do now that I don't test before trying it in the classroom because if it fails, it fails. We can move on and figure it out together. And before [the RET] I would have never done that. I would have made sure that it would go absolutely perfect before I went in and taught it so that it worked. But I think after being there and realizing that science doesn't always work the way we expect, the kids need to see that too.

Carrie's final sentence referencing how "the kids need to see *that* too" was the reference to Mutual Engagement. By participating in their own struggle in the RET, the teachers recognized the importance of struggle in the process of science. This was an incredibly powerful effect of the program on their teaching. The teachers in our study indicated that they became comfortable with not knowing the answer. Jessica described this new sense of comfort as:

> What I came away with [from the RET] was how true science embraces that they don't know it all. True scientists have a mindset that encourages others not to be set but to be curious. It encourages that learning, that curiosity.

Jessica described this sense of curiosity even in the face of not understanding. She hinted at this concept of struggling through a description of the frustration of not knowing. Michaela referenced this in terms that many students might understand:

> Being wrong is okay. I tell my kids, "It's okay if you're wrong. When we finish, I'd like for you to be right, but that's how we learn. You can make mistakes. You can be wrong.

> We just need to learn from it and figure out where to go from there." That's the part that takes the most time. They're not gonna come up with it the way you want them to, but they're gonna eventually come up with something, some learning is going to be had.

Michaela's comment highlighted the struggle of bringing the COSP to the classroom: the tension between allowing students to explore questions, be curious and potentially "get it wrong." The constraints of the classroom with its time limits and testing sometimes made it difficult for teachers to allow students to truly participate in the Mutual Engagement process of science.

3.1.2 | Joint enterprise: Micro versus macropicture

Joint Enterprise was mentioned less by our participants than Mutual Engagement. More of the teachers spoke of the Joint Enterprise piece in a micropicture (referenced by six) rather than a macropicture perspective (referenced by three). The term micropicture came up for us when we saw descriptions of specific tasks rather than the overall goal of creating or expanding new knowledge. For example, Eve described her RET experience very specifically with no link to broader goals:

> We were trained by the undergrads and graduate students on how to complete our tasks—we spend a lot of time with them in the sample making room. We made our samples, polished our samples, then took pictures of the samples under the microscope—but then someone else analyzed them.

Eve believed that the choices that her mentor made in terms of what he chose to communicate to her and her RET partner made it difficult for her to understand the macropicture:

> We didn't feel what we were doing had a purpose because our mentor never really told us the big goal, or like, what end result was expected. We didn't know if we were even going in the right direction. But by the end, we found out we were studying the crystal structure of copper and needed to understand crystal structure in general to be able to understand the copper formations! So, I mean, I get it—but I think we really wanted to know up front what we were supposed to get or see from those first crystals—but our mentor I guess knew what he was doing.

Eve learned that her mentor chose this tactic so that the teachers could learn about these concepts rather than simply being told the answers, but for Eve it led to a source of frustration and little understanding of how her small piece fit into the bigger research.

Similarly, Tina focused on the tasks that she and her teacher partner conducted without linking it to the why:

> My mentor was really good and he threw me into the mix and said "this is what you do, if you need help, let me know." You know? And I cut it and I polished it. We had to make sure everything was right and document it, take pictures, make the report, use the scanning electron microscope. You know, we analyzed it from top to bottom. It was really cool.

In both of these conversations, the teachers referenced the tasks they conducted in their lab. They saw the science being done by them in their labs as a series of task they were told to complete by their mentor without articulating why the research would be necessary for a broader purpose.

The micro became more apparent when we compared it to those teachers who described the broader macropicture. For example, Gail's RET research involved analyzing meteorite samples and she was able to not only translate this research to global scientific events happening at the time but she also made it relevant to her students:

> I was able to take some of those research skills that I learned [in RET] and transfer that to my students to teach them how to do research. And it just so happens that that particular year is when Curiosity was scheduled to land on Mars and I was actually a part of the group that was able to see it actually land. It was really an exciting moment. And I had learned so much about Mars and its composition so I was kind of able to follow a lot of the things that they were trying to get from Mars. And it turns out that they're the same! That our composition and assessment were right on point with the elements on Mars. So that was kind of exciting to see that that actually happens and to have that experience with it.

Gail was able to see how her work with meteorite samples could be applied to Martian rock and the benefits of research to broader issues in our universe. Jessica described the broader macropicture in a more general way when she talked about her mentor and his team's research:

> He lived it. He didn't really have a hypothesis. It was more like "let's just try and see if this will work." Materials science research is more of like…you read about what the material does and then you do tests to see if it does what you think. And they [the research team] were also in the process of coating a ceramic wire and they were having all sorts of trouble with the machine and the coating of it and trying all sorts of things. So there was this frustration of having no idea if this is gonna work and it's not working the way we think it should. So you know, I liked that there was this "we don't know" and let's try and see.

Jessica talked about the broader concept of "why" in her description, which was simply, the team did not know whether or how a material would work in certain conditions and hence they wanted to test it to see. Rather than seeing the research as simply tied to a person or group or RET project, she recognized that this was the broader purpose of materials science research. But even more interesting was she went from describing the team as a separate concept from herself through terms like "him" and "they" to within the same comment turning to inclusive terms like "we." She actually saw herself as a legitimate part of this group engaging in joint enterprise and mutual engagement. This inclusion was very different from Eve's comment: "*We* made our samples, polished our samples, then took pictures of the samples under the microscope—*but then someone else analyzed them*." Here, Eve differentiated between what she did in the micropicture and what "someone else" did but still within that micropicture. Oftentimes, a teachers' understanding of the broader macropicture of joint enterprise was based on their experience within the RET and their interactions with scientists who discussed it with them.

3.1.3 | Shared repertoire: Poster and notebooks

Shared repertoire was the least referenced COSP concept described by our participants. In some of the teachers' interviews they indicated specific tools that they utilized from their RET experience: their poster and science notebooks. Each teacher completed the RET program with a poster session. The poster highlighted their research project for the summer. The majority of our participating teachers hung this poster in their classroom. These teachers would reference the poster to their students as evidence of the struggle they endured as part of the COSP during their RET program. Calvin explained:

> And you know, the poster has helped me. The kids are like, "What is that?" and I can say "This is my poster. This is my research." They'll ask—"Explain how you did this!" and I'll go through the steps you know—"This is my poster, this is what I've had to do"—it was almost like my science fair project.

Calvin described how his poster was evidence of his research for his own students and served as a tool to help his students see him as a "scientist" that could provide advice on their own "research projects." Lorie viewed the poster more as evidence of her ability to persevere through the struggle of research:

> When I did complete that, I did feel like, "Wow, I made it through this!" and I did feel like I had that growth just in the understanding. I felt like by the end I did understand much more than coming into it.

Lorie viewed her experience as something she had to "get through" and she was proud of the fact that she had persevered. Here, she saw perseverance as understanding her research topic better at the end compared to the beginning. She indicated that this was something she felt helped her relate to her students when they encountered a new topic.

Besides the poster, some teachers referenced science notebooks that they had utilized during their RET and had chosen to introduce and utilize with their students. Sidney described his use of notebooks as:

> I want my students to feel like they are in a lab environment and so that's how we run it. We use science notebooks and discussion daily. And you know, I can tell them [in person and through my poster] what I did through RET helped me understand science and the world better. The students also know that I am the real thing. I didn't just read about lab work, I actually did it. My mentor scientist really helped me understand how to do the work and I am there to help them understand how to do science and what's important.

Here, Sidney described how he chose to translate his RET experience to his students by bringing tools, like science notebooks, into his classroom. But he also tied this decision to his experience by explaining how his mentor and his research helped him to better understand the importance of science and how he saw this as his role as a teacher for his students.

3.1.4 | COSP as mutual engagement, joint enterprise, and shared repertoire

Three of our participants (Tina, Gail, and Jessica) were able to articulate all three aspects of COSP, whereas the others focused mainly on mutual engagement or mutual engagement/joint enterprise. Tina and Gail had participated in multiple RETs before the Lab RET program, and hence they had a broader sense of the experience and how to describe it. For the Lab RET, Jessica, Tina, and Gail all worked on a project that had a start and finish, which Tina even referenced as something unique and different for her:

> [This summer] I'm down here in the optics lab in Arizona, their research is ongoing and it's just really cool, but a lot of that stuff is just long-term. So I might've jumped in and just worked for a moment in the middle of an 11-year research [project]. So you don't get in at the beginning and you don't get to see it finished, but you get a taste. Now, down at the Lab, I actually started at the beginning and then when we got to the end and we wrote a report and handed it in. So I started at the beginning and I finished it and I've never had that experience before. So I got to get through all the way and it was fabulous.

Similarly, Gail referenced her article as evidence of her legitimate participation in the "scientific method":

> The scientific method is used in the real world—it's not just something we teach out of a textbook. That was kind of shocking to see [in the RET] as well that, that's exactly what they did—the scientists. And to see the process from the beginning to the end was something I've never experienced before or since and to see it actually come out in the article like a finished product, that's what you want to happen. We created new information, new knowledge. It was very surprising to me. Some of the data we got was actually in the article. So that was really exciting.

Both of these comments demonstrated how impactful it was for these women, including those who had participated in RETs before, to work on a project from start to finish.

Over half of our participants were not able to fully articulate the COSP, and based on our data collection choice and the goals of the research project we were unable to determine why this was the case. We have provided examples of what it meant to not have the language to fully articulate the COSP below. Michaela talked about doing science in reference to her RET experience as follows:

> You're actually doing science, looking at research, talking about it, and you're actually feeling like what real world people would do. You're not being talked to, you're discovering on your own. It's kind of like what you really want your students to do, to discover on their own.

Michaela's statements were general without specifics. She did not provide details as to what "discovery" or "doing science" meant specifically as it related to RET. Similarly, Samuel, even when pushed for more details referenced the process of science as:

> [The RET] was important [for me] to see that scientists actually use the scientific method. It's not just something we teach our students but it's real. It's made me feel even more like I know what I'm doing because I've done it for real.

This concept of doing science "for real" did not explain what doing science meant for him. Similarly, Carrie talked about this real world aspect of science as well:

> The hands-on aspect of [RET]—you can't compare to that [other professional development or PD], because everything [in RET] was hands-on and we were doing like, actual real science. You can't compare to that. It was definitely the best thing I've done. And I've recommended it to lots of people. Like getting out there and actually seeing what science looks like in the real world, helps you put it into perspective for the kids, what they could do if they chose a career in science.

Here, Carrie talked about doing science in the real world but in her interview she never moved beyond the discussion of hands-on. Sally described how the RET allowed her to be seen as a "real scientist" by her students because they saw her at a "science level" but she never defined what that looked like. Michaela provided a longer version of some of the teachers' inability to articulate what "doing real science" meant.

> I remember [before RET] always thinking and saying, you know, "in the science world. . .dot dot dot," but I was never IN the science world myself so now [after RET], looking at how I frame it to my students I can say, you know, "I worked with real

> scientists and dot dot dot dot dot." You know, you can say it that way. "This is what they [scientists] did." So before, I had the concept of what they did, but actually doing it, it was a whole different thing. Because having that experience with working with scientists and now it's like I was a real scientist in a lab. Now when [I] have to do real world stuff and make those connections, you actually know what those connections are now. So having that experience to draw from has changed the way I teach. I make them record more of what they're doing and keep a notebook.

To quote the popular 90's television show *Seinfeld*, Michaela "yada, yada-ed" through the description of what the process of science was for her. However, she was able to translate aspects, like science notebooks to her students. Julie, similarly, could not articulate the process as experienced in RET but could translate aspects to her students:

> I don't know if I recognize anything consciously other than it makes me understand science better and helps me relay that to my students better. Like if we're doing an activity where they have to do a little bit of experimentation and it's not going the way they thought it would, or they think it's tedious or they think their data is kind of difficult to understand, and it's hard to locate the evidence—like that's all part of doing science. It's not this cookie cutter thing. It can get messy and it can just lead to a whole bunch of other questions and it might not go the way you planned. I think that part is what I learned about it and hopefully comes across in my lessons.

Here, Julie began to describe the process (e.g., experimentation, tedious, difficult, evidence within…) but then stopped herself and limited the language to "doing science" in contradiction to cookie cutter. It was interesting to note for all of our teachers that the ability to fully articulate COSP did not seem to affect teachers' abilities to translate aspects to their students.

Based on our analysis related to the first two research questions, we found that teachers' understanding of the COSP was impacted by the mentor's communication and mentoring style, similar to the findings of Hughes et al. (2012). Teachers appeared to understand the full picture of the COSP when their mentors gave them the opportunity to work on a project from start to finish. Also, the structure of the research group impacted teachers' sense of identification with other team members as novices within the COSP and their confidence to ask questions and interact with the group. The more opportunities teachers had to participate in broader group discussions the more opportunities they had to observe and in some cases participate in the conversations which improved their sense of shared identity with the other COSP members.

3.2 | Research Question 3: Spectator novices

Our final research question guided our investigation into whether teachers expressed their COSP experience differently from novices in current COSP frameworks. It was our hypothesis that teachers would experience a spectator novice role in that they would remain outsiders within the COSP because they enter knowing that they are not staying, rather they are peeking in to the complex world of the COSP for a minimum of six weeks and then leaving to return to their STEM teacher identities and classrooms. This sense of outsider status was evident through the teachers' references to expertise. Expertise was described in two different ways: when teachers compared themselves to research group members and when teachers compared themselves to other teachers. The first finding was expected in that many teachers lack the same level of STEM education as graduate students and other more senior level members of the group. The teachers would reference scientists that they worked with as experts.

For example, Eve made a comment during her interview, "We didn't get to analyze the data though, we just collected it and then it was given to important people to analyze." Here, she differentiated between herself and her teaching partner (the "we") and the "important people" (the scientists) who would analyze the data. In this statement, she demonstrated that she did not have the expertise to analyze and assigned value to those who do as important. In a slight contradiction to Eve, Michaela discussed how she was different from the scientists but in a way that still made her feel valued:

> Even though my job there [the RET] was mainly just to do background research for the scientists who work there, I still found value in doing that. You don't always have to be the star player. You can be some contributing member of the team.

Here, Michaela assigned value to her work compared to the scientists, "just" doing "background research for the scientists" indicated that she saw this as lesser than the scientists work. But she seemed to see value in this peripheral work. Consequently, teachers in our study could see themselves as legitimate participants but they remained outside of the core group based on how whether the experts valued their teaching identity and contributions.

What was surprising to us was how the teachers assigned the levels of expertise to teaching levels (veteran vs. novice and elementary vs. secondary) as well as among scientists at the Lab. For the latter, Tina described her mentor as: "one of the materials scientists—well, he wasn't a scientist or a professor, he was just an employee that ran samples and did studies on magnet materials. Brian is under professors that tell him what to do." Tina had this perception because her mentor described himself in this way. He mentioned his boss—the professors referenced by Tina—and described his job as a technician rather than a faculty member. He saw a hierarchy among the staff at the Lab with research faculty having a higher role in the hierarchy than staff and he passed this idea along to Tina.

In terms of expertise among teachers, some of our elementary school teachers often saw a differentiation in the levels of expertise between elementary versus secondary school teachers. In some cases, this was based on the opportunities for elementary school teachers as Sidney indicates:

> I saw [RET] as just an amazing opportunity to be in a stimulating environment. I'd never done anything like that before and to surround myself with the best and brightest scientists and other teachers—that's really amazing. I really appreciated the fact that it was designed for ordinary elementary, middle, and high school science teachers. Elementary teachers don't always get that kind of opportunity to do that sort of thing.

Sidney recognized that elementary school teachers often do not have opportunities to experience the COSP. Sally described her fear that veteran teachers had more expertise and how the RET helped her to develop her own sense of expertise. After participating in the RET, she saw value in both novice and veteran feedback:

> I used to feel so intimidated by the veteran teachers and more experienced teachers my first few years. [My first year of RET] I remember working with a chemistry teacher from a high school and the first conversation I had with him, I felt like he was speaking a different language. And by the end [of RET], I felt like, we're all speaking the same language, we're just doing it at different levels and everybody has something to contribute and bring to the table.

An unintended consequence of the RET program for Sally was that she worked with a high school teacher who she initially saw as an expert at a level that she couldn't reach, but through her interactions with the teacher throughout the program she came to realize her own level of expertise. We had initially only focused on teachers' sense of trepidation with the level of expertise of the scientist they worked with. This concept introduced by Sally and Sidney was interesting.

Both Sidney and Sally developed confidence through their participation in the program. Sidney explained:

> Going through the RET program allows me to have confidence in knowing that my classroom science lab procedures are you know, legitimate. It makes me feel like I have authority about science and I can say to my students "This is how it is done. I know [because] I worked at the Lab." They see me as a scientist and they know that when we do science they can do it too.

Here, Sidney highlighted how his experience in the RET with some exposure to the COSP gave him a sense of being "legitimate." He felt like a legitimate peripheral participant within COSP enough to call himself a scientist. Sally also talked about the confidence she developed through participation in RET:

> When I [told my students and colleagues] what I did at the Lab, a lot of people were kind of like "Wow, that's impressive!" and I'd only been teaching for five years at that point. So I think it made me feel like I had a little more credibility as a teacher and confidence.

Sally saw the RET as a program that gave her credibility and allowed her to be recognized as an expert. So, in a way she became a legitimate peripheral participant in the COSP.

The spectator novice term remained relevant throughout our study. Although some teachers saw themselves as part of the research group (e.g., using we to reference their membership in the group), all of the teachers indicated an outsider status (spectator) that prevented them from fully identifying with the other novices in the group. The teachers' sense of expertise impacted their level of participation and sense of belonging within the COSP. These teachers knew that their goal was not to become full participants and saw their identities as that of K-12 science teachers, not scientists.

4 | LIMITATIONS OF THIS STUDY

Before discussing the results and implications of this study, it is important that we identify the limitations to our study and our reasons for our choices. Our choice of methodology was helpful to gain an initial understanding of how teachers as spectator novices experience the COSP within an RET program. However, self-reported reflective interviews limit our ability to witness the trajectories within the COSP as they are happening. Even when we tried to ask teachers to provide more detail in their descriptions in the interview we were limited in how many ways we could frame the question. As a result, the inability for teachers to express all three aspects of COSP could be related to our interview questions rather than their own inability to articulate this.

Our study focused on one RET program, and hence we cannot speak to the influence that all RET programs have on teachers' understanding of COSP. However, our decision to focus on participants in one RET program and to use reflective interviews made sense for the goals of our study. We wanted to explore whether current COSP frameworks were adequate for studying teachers'—as spectator novices'—experiences in COSP. Focusing on one program with a consistent structure each year gave us confidence that the programmatic structure (e.g., pedagogical afternoon sessions) influenced teachers' understanding of COSP less than their experiences with their research groups and/or mentor scientists. By focusing on teachers' reflections of these COSP experiences in an RET program that the authors were familiar with, we could validate the experiences of the teachers with other participating teachers and each other. The choice of reflective interviews gave each teacher time to think about their experience and how it had influenced their teaching, which was the point of our research questions.

5 | DISCUSSION

Our study indicates that teachers have a different experience in the COSP than scientist novices. Hence, our term "spectator novice" is warranted as a term for teachers within RET programs and other similar COSP experiences. Teachers in an RET program have a shorter time of exposure (e.g., six weeks) to scientists and research groups than undergraduate and/or graduate STEM majors who spend multiple semesters and/or years in various lab groups within their discipline or at least are able to interact with varying members of their COSP discipline over four years or more. Hence, teachers in an RET program have different experiences from the traditional apprenticeship program and require an improved conceptual framework for understanding their unique experiences as spectator novices. There are some similarities between novices' experiences and spectator novices' experiences of the COSP which we will describe first. Figure 1 shows a picture of our updated conceptual framework. The COSP portion is on the bottom and has boxes for each of the components of the COSP: Joint Enterprise, Mutual Engagement, and Shared Repertoire (Feldman et al., 2013; Lave & Wenger, 1991). Our results indicated that teachers felt a sense of belonging within the COSP, sometimes even including themselves in references to the lab group (e.g., we vs. they).

Many of the participating teachers experienced a shared sense of camaraderie with scientists in their group, indicating that they did indeed feel like a legitimate peripheral participant within the COSP (Lave & Wenger, 1991). However, these teachers' levels of belonging depended on multiple factors including: the structure of the research group, the level of mentoring they received, and their own sense of expertise and value within the team. We are advocating these pieces—found in the upper

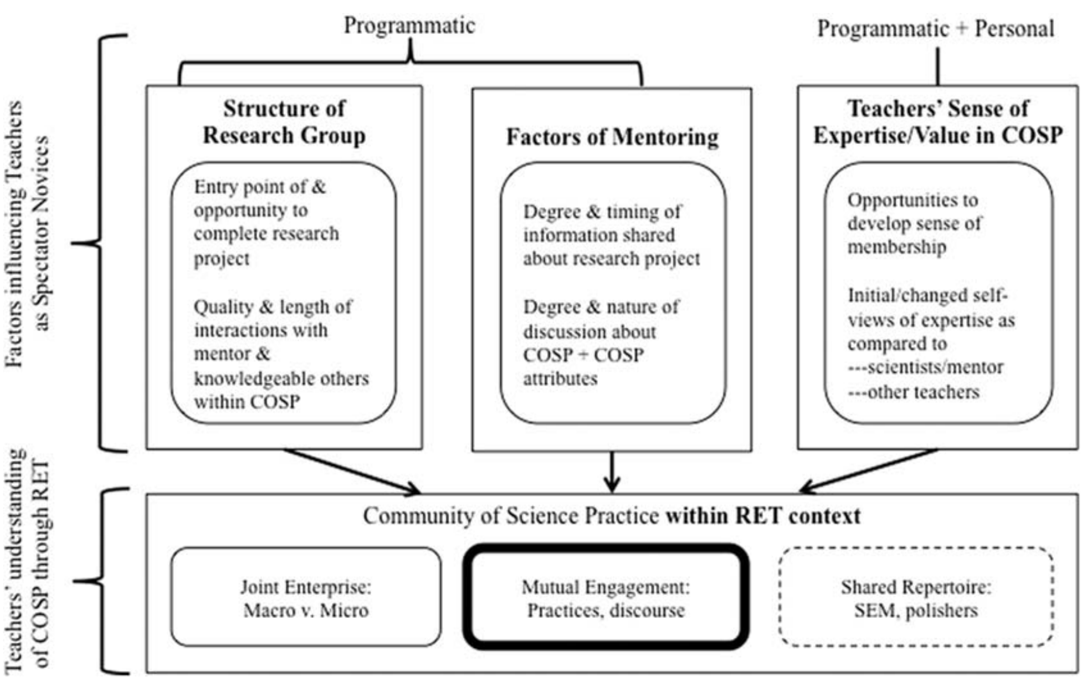

FIGURE 1 Conceptualization of factors influencing teachers' understanding of COSP as spectator novices during RET participation and examples of subsequent findings from this study

boxes of Figure 1—as an important addition to research on RET programs and teachers' understanding of COSP.

Figure 1 shows a conceptualization of the interplay between these three factors and gives descriptions of programmatic and personal considerations that may influence teachers' experiences as spectator novices within the COSP. Programmatic factors (structure of the research group and factors of mentoring) include those which can be controlled or planned for by RET program directors and mentor scientists. Factors which are both programmatic and personal are those which RET directors and mentors can try to influence through purposeful means, but are still dependent on the teachers' own personal perceptions of their expertise as compared to others and their sense of belonging within the COSP. In our study, we found that the ways in which these programmatic and personal factors are approached within the RET context impacted the ways that teachers came to understand the COSP within the RET, and in turn, how they translated this understanding to their students in the classroom.

Our study indicates that the RET experience led to differing levels of each of the three concepts that comprise the COSP (Mutual Engagement, Joint Enterprise, and Shared Repertoire). All of our teachers had some level of understanding of Mutual Engagement (indicated by the bold outline in Figure 1) but more limited understanding of Joint Enterprise (solid line) and even less of an understanding of Shared Repertoire (dashed line). This is not surprising as they are working in apprenticeship with their research team and hence the fact that they better understood the practices rather than the goals and shared resources makes sense. Traweek's (1988) study of physics COSP indicated that undergraduates and graduate students who spent time among the research groups at the facility had a more in-depth understanding of the Joint Enterprise and Shared Repertoire pieces of the COSP. Hence, a conceptual framework for STEM undergraduate and graduate students would have a thicker line around these two boxes than our current framework has for spectator novices. It would appear that teachers improved their understanding of STEM and the COSP as evidenced by our study and others, particularly the concept of Mutual Engagement within the COSP (Bahbah et al., 2012; Blanchard et al., 2009; Dresner & Worley, 2006; Faber et al., 2014; Hughes et al., 2012; McLaughlin & MacFadden, 2014; Miranda & Damico, 2015; Varelas et al., 2005).

Although Traweek (1988) observed novices gaining an understanding of all three aspects of the COSP in her study, only three of our teachers experienced all three of these aspects. Part of the explanation for this deeper level of understanding could be that two of these teachers had participated in RET programs before and hence they had had repeated exposure and varied experiences with the COSP. However, one of these teachers only had the Lab's RET experience and still could articulate the entire COSP. In addition, all of our participants could describe the Mutual Engagement piece. The level to which participants could describe Mutual Engagement or the other two aspects depended on three aspects of the RET and influenced spectator novices understanding of COSP.

First, the *structure of the research group* that the teacher participated in, affected their overall understanding of COSP. We define structure of the research group as the level of opportunity teachers have to work on a project from start to finish and how much access and interaction they have with their mentor and the research team. Tina, Gail, and Jessica were all able to work on a project from start to finish. Tina and Gail had participated in multiple RETs and indicated that working on a project from start to finish allowed them to gain a better understanding of COSP. The previous research on RETs has indicated that the structure of the research group impacts teachers' understanding of STEM content (Blanchard et al., 2009; Capps et al., 2012; Hughes et al., 2012; Sadler et al., 2010). However, these studies have not connected this concept of structure to teachers' varying levels of understanding of the COSP.

Second, the *level of mentoring* teachers received was influential in their understanding of COSP. Eve discussed the frustration she experienced not knowing why she and her partner were doing certain pieces of their project. This raises the question for mentors as to whether they should explicitly discuss the broader macropicture of Joint Enterprise with teachers or should they allow teachers to experience a certain level of cognitive struggle with concepts to make them stick. The previous studies have hinted at the role that mentor's choices (e.g., having teachers develop their own research questions or participate in ongoing research projects) can have on teachers' understanding of STEM (Blanchard et al., 2009; Buck, 2003; Dresner & Worley, 2006; Faber et al., 2014; Grove et al., 2009; McLaughlin & MacFadden, 2014). These studies all measured different outcomes (e.g., confidence in science teaching, science content knowledge) rather than specifically focusing on teachers' understanding of the COSP, making it difficult to assess the role of mentoring on specific outcomes.

One of the newest additions to the conceptual framework is our third one—the *sense of expertise* that teachers bring into an RET program. Our study is one of the first to indicate the impact that a teachers' sense of expertise can have on their level of participation and sense of belonging within the COSP. Past studies have focused on teachers' sense of apprehension at the beginning of an RET program or even their improved confidence in their teaching over the course of the program (Dresner & Worley, 2006; Grove et al., 2009; Hughes et al., 2012). But we found that this sense of expertise affected how teachers interacted with their research group, which in turn affected the questions they asked and level of understanding they developed about the COSP. We observed that it was this construct that took some of our participants from mere spectators, simply observing, to novices who felt a sense of belonging in the group. Researchers should assess this and observe how teachers assign expertise both among scientists and teachers. The COSP framework as it applies to science novices includes the influence of experts within the culture (Feldman et al., 2013; Traweek, 1988) but for teachers it would appear that there is an additional layer of science teaching experts (either veteran teachers or secondary school teachers) along with the varying levels of scientists who serve as experts.

6 | CONCLUSIONS: IMPLICATIONS AND FUTURE RESEARCH

Developing a conceptual framework to guide the studies of spectator novices within COSP programs is incredibly important to research within science education and teacher education, as well as to program directors and designers of science teacher PD programs and RET programs. Our conceptual framework creates a lens through which other researchers can study teachers' experiences in RET programs, and potentially other PD programs. Science education researchers can now structure RET programs in ways that can highlight the aspects of the COSP (Joint Enterprise, Mutual Engagement, and Shared Repertoire) while also attending to the new programmatic and personal constructs which we propose hold influence over teachers' experiences of the COSP (Structure of the Research Group, Factors of Mentoring, and Teachers' Sense of Expertise). These additions will allow researchers to better account for teachers' experiences within the COSP, how these experiences impact their own understanding of COSP, and their translation of this concept to their students. It is important that science education researchers understand how teachers' translate the COSP as this is a crucial expectation of current science education reform initiatives such as the *Next Generation Science Standards* (NGSS Lead States, 2013). With our framework, researchers can begin to shed light on the black box situation of how teachers' experience and translate COSP. With a stronger understanding of how teachers' experience the COSP, RET (and other PD) program directors and teacher educators can structure COSP experiences to meet the needs of teachers. These practitioners can structure RET programs so that teachers can gain an optimum level of the COSP understanding even with limited time within the COSP.

One important concept to consider is the importance of teachers' perception of expertise, particularly for elementary school teachers. The concept of varying levels of expertise was acutely salient for elementary school teachers who saw themselves as possessing lesser expertise than their secondary school colleagues. This is important to study because it could be preventing elementary school teachers from participating in opportunities that could situate them within the COSP. Similarly for those elementary teachers who do participate in RET, it could be affecting their level of participation and sense of belonging. Elementary school teachers often have less experience with STEM content and the COSP and yet, they are often the facilitators of students' first science experience. It is important for this group to have experience with the COSP in ways that allow them to feel confident to translate these experiences to their students.

Our conceptual framework is just a start to a better understanding teachers' experiences within the COSP. Future studies can build on this framework by observing and documenting teachers' experiences as they are participating in RET programs. These studies can use the conceptual framework as a guide and through observations, focus groups, and interviews determine when each programmatic and personal factor has a role in teachers' understanding of COSP. In addition, future research should follow RET teachers into their classrooms to study how these teachers then translate the COSP to their students. Finally, to solidify the conceptual framework for spectator novices, it is important for future researchers to compare spectator novices' experiences to those of science novices, and hence observing differences between the descriptions of members from both categories. Future research could include interviews with various members of the research group within an RET to see how teachers' descriptions differ from undergraduate/graduate students, faculty, and other staff.

In conclusion, this spectator novice conceptual framework will inform future research on teachers' experiences within COSP programs. This framework will also guide program directors to include programmatic aspects, or at least evaluate the impact of these, that will improve teachers' understanding of COSP. This improved understanding of COSP has the potential to improve teachers' translation of COSP to their students, which is a crucial part of science education.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ORCID

Shannon G. Davidson http://orcid.org/0000-0003-3583-4147
Roxanne Hughes http://orcid.org/0000-0002-6383-1341

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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