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Abstract

This study explored 8 high school science teachers' experiences in an 8-week immersive research laboratory professional development program. The aim was to understand their motivation for participating and what factors influenced changes in beliefs about science instructions. Mentor scientists and their lab members hosted teachers for the duration of the program allowing teacher participants to become active members of research. Results showed that participants used three major lenses to understand their research experience: *self as educator, self as learner, self as researcher*. The use of overlapping lenses provided participants with the impetus to change beliefs about science and research practices in their classrooms. Ample time and collaboration in professional development is critical to changes in beliefs about science instruction.

Introduction

Science education reform in the last several decades has called for more inquiry-based instruction that more closely mirrors the nature of science and scientific research (Capps & Crawford, 2013). This push to improve science education, however, has left many teachers feeling under-prepared to meet the demands of reform. Various forms of professional development have served to address this continued issue. Professional development broadly refers to continued support for teachers through various education mediums. Teachers often rely on their own beliefs to guide their teaching practices; however, rigorous professional development programs that offer the opportunity for science teachers to have research experiences may shape or reshape their beliefs about science education and inquiry-based learning (Southerland, Granger, Hughes, Enderle, Ke, Roseler, Saka, & Tekkumru-Kisa, 2016).

Call for reform

The US government and the professional agencies tasked with reforming science education suggest instructional changes for presenting science in the school curriculum, how science should be taught in schools, and how students' science learning outcomes should be assessed (i.e., NAS, 2006; NRC, 2011; NRC, 2012). These reforms emphasize teacher practices that use innovative, inquiry-based teaching strategies that promote students' conceptual understanding, application of higher-order thinking skills, knowledge construction, and the use of self-regulatory learning strategies. This includes conducting experiments, interpreting data, making arguments, and evaluating information (Lotter, Smiley, Thompson, & Dickenson, 2016). The US and other countries like the UK, Ireland, the Netherlands, and Canada have undertaken a curriculum shift to increase science, mathematics, and technology education at all grade levels, and to train teachers in adopting these more inquiry-based, constructivist teaching approaches (Sharp, Hopkin, & Lewthwaite, 2011; Van Driel, Beijaard, & Verloop, 2001).

A Shift to Active Learning - A Theoretical Stance

In contrast to traditional teaching practices, where students are passive recipients of instruction, science reform recommendations emphasize a rethinking of teacher's roles to that of facilitators of student learning, allowing students to do the bulk of the intellectual work (Poon, Lee, Tan, & Lim, 2012; Richardson & Liang, 2008; Patchen & Crawford, 2011; Maskiewic and Winters, 2012). These reforms encourage constructivist teaching strategies and a shift in student learning, from acquisition of facts, to higher-order thinking skills that enable students to self-regulate their learning, acquire more complex knowledge and skills, and ultimately become able to *do* science (Michalsky, 2012; Southerland et al., 2016). In a constructivist, student-centered teaching approach, students are actively involved in learning and share ownership of the learning process with teachers. Research shows that an important tool in shifting instruction to this kind of approach is placing a greater emphasis on developing students' and teachers' higher-order scientific thinking (Schraw, Crippen, & Hartley, 2006). Cognitive components (i.e., domain knowledge, strategies, and metacognition) and motivational components (i.e., instructional beliefs, teaching efficacy beliefs) are crucial elements in understanding how teachers develop professionally and adapt their instruction to a more reformed-based approach (Michalsky, 2012; Schraw et al., 2006).

Teachers' Beliefs and Practices

Unfortunately, research shows that US teachers' classroom practices often do not align with the above recommendations for inquiry-based, student-centered teaching practices, which may be because few teachers have experienced learning science through inquiry themselves (NRC, 2011, 2012; Lotter et al., 2016). As such, studies have found that teachers have significant difficulties presenting science content using inquiry-based or experimental approaches in their teaching (Anderson, 2002; Kamarski & Michalsky, 2009; Randi, 2004; Randi & Corno, 2000, Thomson & Gregory, 2013; Thomson & Nietfeld, 2016; Smith & Southerland, 2007; Waters-Adams, 2006).

Research investigating teachers' beliefs argues that changing teacher classroom practices depends in part on changing teachers' instructional beliefs (Pajares, 1992; Maskiewic and Winters, 2012), but studies within the US and UK (i.e., Smith & Southerland, 2007; Sharp et al., 2009, 2011) shows that many teachers' beliefs about science teaching are simply not in line with reform recommendations and inquiry-based teaching. Teachers' instructional decisions, their curriculum orientations, and the ways they enact or fail to enact reform in their science teaching are greatly influenced by their beliefs about science teaching (Southerland et al., 2016). Thus, understanding teachers' belief systems and how they impact classroom practices will help determine the types of experiences that are important for their teacher preparation and PD programs as they progress through their careers.

Professional Development

Professional development programs, in addition to shaping teachers' knowledge of skills and content, can help address beliefs about inquiry-based, active, and student-centered science teaching. The national standards recommend teacher education and professional development programs expand beyond domain and pedagogical knowledge, to emphasize the acquisition and application of higher-order thinking skills (e.g., analysis, application, evaluation), which will support adopting more research-based practices during instruction. Still, in a study of US teachers' reformed practices, Smith and Southerland (2007) found that teachers have a difficult time understanding and implementing reform-based changes in their classroom teaching, even after completing workshop training on reform practices. Thus, teachers often choose to rely on their personal beliefs about effective science teaching and choose to apply those in the classroom, despite having the tools for implementing reform offered to them (Mansour, 2009). Strategically structuring PD experiences to shape teachers' beliefs about their science teaching can support such shifts to more reform minded instruction (Southerland et al., 2016).

Influential Factors of Successful PD

Certain factors related to professional development programs impact whether teachers successfully change teachers' beliefs and practices related to inquiry-based science teaching, implement inquiry-based teaching practices, and ultimately impact students' science research literacy (Lumpe, Czerniak, Haney, & Beltyukova, 2012). Therefore, programs must incorporate certain factors, including adequate duration, collaboration, and immersive research experiences (Borko, 2004). Though there is not one definitive length for PD programs, there is agreement that programs must spend an extended number of hours and days in order to be effective, and improvements to inquiry-based instruction are often seen after 80 hours of participation in PD (van Driel, Meirink, van Veen, and Zwart, 2012; Lotter, Thompson, Dickenson, Smiley, Blue, & Rea, 2018).

Teachers tend to benefit from programs that encourage collaboration and co-learning, allowing them to utilize each other's expertise and shared experiences (van Driel, Meirink, van Veen, and Zwart, 2012; Herrington, Bancroft, Edwards, & Schairer, 2016). PD programs that create communities of practice allow teachers to construct knowledge, collaborate, and problem solve together, thereby making them active learners (Lotter et al., 2016). Teacher education programs in England and Wales introduced a system of professional development in teachers' respective communities of practice, where teachers were provided with training in specialized professional communities with the capacity to help teachers improve their content knowledge, and positively influence their instructional beliefs and attitudes around science teaching (Sharp et al., 2011).

Creating positive attitudes towards science teaching and instructional beliefs can impact the quality of teachers' science teaching in the long run (Waters-Adams, 2006). The literature shows that teachers' participation in immersive research experiences is critical for developing the fluency necessary to teach high-quality inquiry-based science, yet few teachers have had such experiences (Southerland et al., 2016). One strategy for incorporating these components for effective PD is the use of "summer institutes," where teachers work alongside academic, government, or industry scientists in authentic laboratory settings for an extended period of time, usually six to ten weeks during the summer (Southerland et al., 2016). Research Experiences for Teachers (RET) have been shown to impact changes in beliefs and practices related to inquiry-based science, even among teachers with varying years of teaching experience (Herrington et al., 2016).

Lack of PD Opportunities for Some Teachers

Research shows that many teachers in the US lack opportunities for science professional development, especially programs specifically tailored to meet teachers' instructional needs for their grade level or student demographics (i.e., Thomson, Huggins, & Williams, 2019; Peters-Burton & Frazier, 2012). Teachers from high-poverty schools, in which a majority of students identify as minority students, or economically disadvantaged face particular challenges in finding programs that present a good fit for their needs (Jacob, 2007).

This Study

The current study is part of a larger, five-year project (Thomson, Roberts, & Hubbard, 2020), funded by the National Institutes of Environmental Health Sciences (NIEHS). The overarching goal is to help teachers and students from high-poverty schools improve their science research literacy and improve science teaching. Every year, for five years, teachers from public schools with a large number of economically disadvantaged students are selected to participate in an immersive science research program. Teacher participants join the program for eight weeks during the summer break between academic years, and are immersed in and become fully participative in their host research labs. This program is designed to be constructive and collaborative amongst participants, mentor scientists, and researchers. Participants are encouraged to collaborate with one another (Richman, Haines, & Fello, 2019) as well as with university faculty (Southerland et al., 2016).

Within this particular cohort, the purpose of this study was to provide an extensive and immersive learning experience for science teachers without prescribed outcomes and to understand what aspects of the professional development experience shaped their understanding of science teaching. The following research questions guide this study:

1. How do teachers engaged in an immersive science research program describe their experiences, as related to their motivations for attendance, expectations, program relevance, and program challenges?
2. What factors influenced changes in teachers' beliefs about science instruction and the way they implemented instruction in the classroom after the program attendance?

Method

Participants

Participants ($N=8$) were seven certified science teachers and one pre-service science teacher. With the exception of one pre-service teacher, all participants taught high-school science at public schools with relatively high populations of disadvantaged students. Table 1 shows the demographic data of each participant.

Table 1. Participants' Demographics

Participant Pseudonym	Race/ Ethnicity	Gender	Age	Yrs Exp.	Subjects Taught
Erik	AA	M	50+	16	Biology, Physical Science, Forensics, Earth Science, Geology
Nora	Swed. Amer.	F	41-50	4	Forensics, Earth Science, Aquatics
Fran	W	F	41-50	15	Middle school science, Earth and Environmental Science
Rich	W	M	19-30	4	Biology, Earth Science
Cali	W	F	19-30	0	N/A (preservice teachers)
Joel	AA	M	19-30	2	Earth, Environmental, Physical Science
Macy	W	F	19-30	4	Earth Science, Biology
Mia	W	F	50+	20	Biology, Chemistry, Environmental Science

Recruitment

Teachers were recruited through emails from the research assistant associated with the project, school administration, and through word of mouth from previous program participants. Teachers interested in the program completed an online application consisting of short questions about background information, interest in science research, and school district information. Preference was given to applicants who met the following criteria: science teachers that taught at schools with higher populations of students utilizing free and reduced lunch services, science teachers that expressed interest in conducting laboratory-based research, and teachers that had less than 10 years of science teaching experience. As noted, some participants fell outside of these criteria, but based on the application pool, those teachers that best fit criteria were chosen.

Data Collection

In-person focus groups were conducted twice during the PD Program. The first was conducted by the research assistant after the first two weeks of the program. The second focus group was conducted by the principal investigator, during the last week of the program. Individual interviews were conducted via phone, 4-6 months after completion of the program, depending on the participants' schedule. These interviews were conducted by the research assistant and a graduate student associated with the project. Two participants, Joel and Mia, did not complete the second focus group or the individual interviews. Mia left the program at the halfway point to take a new teaching position. Joel was absent the day the second focus group was conducted and did not participate in individual interviews.

Data Analysis

All focus groups and individual interviews were transcribed verbatim by the research assistant. Data were coded by the research assistant and an additional graduate student associated with the program. In phase one of coding the focus group and interview transcripts, both coders used inductive coding, following the guidance of Merriam and Tisdell (2015). Simultaneous, in vivo, and descriptive coding was used to assign meaning to pieces of text (Creswell and Poth, 2016). Each coder used open coding to generate an initial list of codes, yielding 103 codes and subcodes. Phase two of analysis used axial coding to work towards agreement on all codes, combining codes that represented similar data, resulting in 53 codes. Next, in a continuous and iterative process of axial coding, the coding scheme was developed to categorize all codes into major themes. Three major themes, represented as lenses, emerged from the coding process. Codes that did not directly answer the research questions, or provide additional understanding to the overall study were not used in the results, <<but can be found in the coding scheme in appendix A.

In an effort to explain the process that occurs in the program, elements of grounded theory were used in the data analysis as “participants in this study would all have experienced the process” (Creswell and Poth, 2016, p. 82). Grounded theory, as used in this study, “might help explain practice or provide a framework for future research” (Creswell and Poth, 2016, p. 82). The results of this analysis are presented through lenses that emerged in analysis, which provided insight into the “interactions or process through interrelating categories of information based on data collected from individuals” (Creswell and Poth, 2016, p. 83).

Results

The purpose of this research was to understand teachers' motivations, expectations, and challenges when engaged in an immersive science research program, and what factors influenced changes to their beliefs about science instruction. Three major themes we describe as lenses through which participants engaged in the program emerged: self as educator, self as learner, and self as researcher. The lenses can also be thought of as perspectives or identities. Analysis also revealed that it was through these lenses that participants were able to see what changes could be made to better connect their students to science. Experiences in the program evoked these three lenses through various challenges, successes, disappointments, and realizations.

Connecting Students to Science

Because participants saw *connecting students to science* as their goal as well as the process through which they experienced the program, it will be highlighted additionally through each lens. In the beginning of the program, Mia comments on her motivation to start the program, explaining, “...that was the reason why I came here, to understand the techniques, the tendencies, the trends and to get a better way to translate that for [my students].” A common belief among participants was confidence that their students possess the ability to become scientists and to conduct scientific research if they know which pathways to take. Rich explained his beliefs, saying, “I think they can. They just need to know what steps they need to take in order to do that”. Other participants remarked on the program's ability to reveal specific steps participants can take to become involved in science and science research. In essence, the theme of *connecting students to science* was evident across participants' reflections of their professional goal for participating in the program as well as their own learning process.

Understanding How Lenses Interact

Though teachers clearly described experiences that represented themselves as educators, learners, and researchers, these were not discrete lenses that occurred independently, but were inherently connected to one another. Each lens and its substantive codes will be detailed individually. As figure 1 shows, there were areas where lenses overlapped, with codes that highlighted the bridge that participants used to connect the multiple lenses, these are subthemes. The overlap of lenses will be detailed as transitions between each of the three major themes with sub themes italicized. As an example, participants were often looking through the lenses of educator and researcher when understanding the *disconnects* between laboratory-based science research and classroom science. Grounded theory shows movement through phases, or a process (Creswell and Poth, 2016). In general, participants began the program thinking more like an educator, then moved to thinking like a learner, and eventually expressed thinking like a researcher. Though each participant did not move through this process in exactly the same ways, the nature of the program suggests that participants will generally move in that direction while using multiple lenses to see and understand a problem and solution. Because the laboratory-based science research seemed so different from their classroom science, participants reported being initially unsure of how the program would fit their needs as a classroom teacher. Though the program did not meet some of the expectations of the participants, the *fit of the program* was a catalyst allowing participants' to connect to the lenses of *self as educator*, *self as learner*, and *self as researcher.*

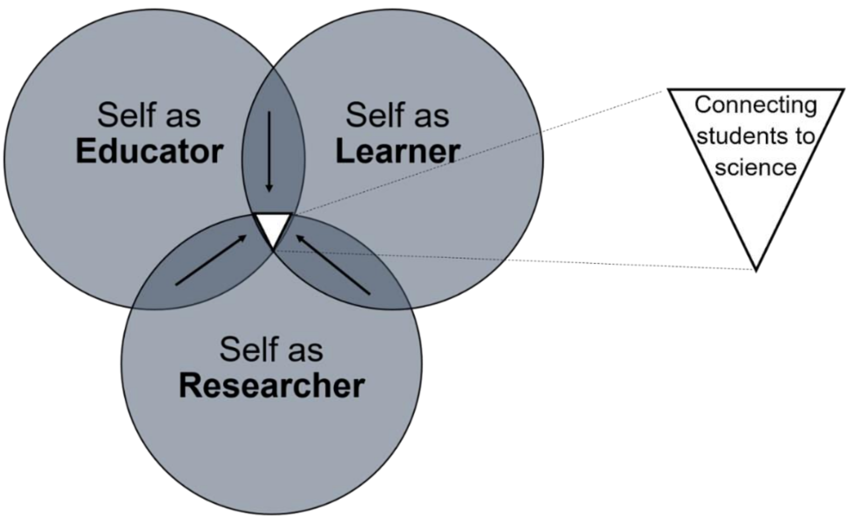

Figure 1. Overlapping Lenses

As seen from Figure 1, each lens overlaps with other lenses to provide a deeper understanding or a clearer look at how to connect students to science.

Self as Educator

Participants applied to the program as pre-service or active classroom teachers, and returned to their classrooms after the program to continue teaching science. Data revealed that participants most often thought of themselves as teachers and educators, making *self as educator* the most prevalent lens through which participants initially engaged in the program. *Self as educator* was most often demonstrated through participants' views and conversations around what could be taken directly from the program and used in their classrooms. The idea of having something to take back to the classroom became a major code under the umbrella of *self as educator* called, *takeaways*. Participants expressed excitement about taking educational resources back to their students and classrooms. Additionally, *takeaways* provided insight into how participants were constantly looking for ways to connect their students to science through resources and opportunities. Resources included new information, new skills, new supplies, online tools, and the potential to bring their students back to visit the university and labs in the future.

During focus groups, participants referred to one another as resources, explaining how they worked collaboratively to make sense of and maximize their experiences. This experience, *collaboration of cohort*, specifically captured the community of teachers and their experience of working together to solve problems. In particular, Cali mentioned how important it was for her as a preservice teacher to experience this type of collaboration with teachers that have already been in their classrooms for a few years, saying,

> "As a preservice teacher, I know that the more experiences I have with other teachers, with scientists in the classroom, anything, any perspectives I can gain are going to make me better prepared when I walk into my classroom on the first day."

Joel also expressed his appreciation for learning from one another, saying,

> "... some of the conversations that we have and what we can take away from them, I feel are a lot more beneficial … like a conversation you would have with your mentor teacher or another teacher before school or after school...now we're actually helping each other... think problems through, think situations through, or just open our eyes to new opportunities."

Under *self as educator,* participants often referred to the program as giving them *credibility as a science teacher*. Macy mentioned this view in the second focus group saying, "I think it gives me street cred, not only in...the science field, but more so in the education field of … just having that exposure. I think it's total street cred." Later, during her individual interview, she reaffirmed this experience by reflecting on her students' perception of her, saying,

> "they can see me as a viable and reliable science teacher... I've done the science and so I think that they feel that confidence in me and they feel... that I know what I'm talking about and so they're going to listen and learn as well."

Overlap of Educator and Learner

It was common for participants to think about and refer to their students' perspectives throughout the summer program. There were several distinct times when participants were looking through both the lens of *self as* *educators* and *self as learner*. When pressed to learn new things, participants reflected on how their students might feel while learning. Cali spoke about some of her challenges in learning concepts she'd never heard of, but that this experience connected her to her students' feelings. She explains,

> "...on the other hand it's been nice because….what does it feel like to be a student in the classroom? …. it's giving me a perspective … to understand how some of my students might feel when there are these questions…And so it's been an exercise in humility and understanding, asking questions and feeling what it feels like to not know the basics."

Participant's experiences in the labs and identifying with their students' perspectives allowed them to use the lens of a learner.

Self as Learner

The aim of this and other immersive PD experiences for teachers is to elicit the experience of being the learner with the overarching goal of translating the experience to students (Blanchard, Southerland, & Granger, 2009). Participants were immediately immersed into the day-to-day activities of their host labs. Just like students in a classroom, for many participants this was their first time learning certain concepts and techniques related to environmental health sciences. As participants began facing adversity and struggles, the differences between their expertise in the classroom and their novelty in the lab revealed the gap between what they knew and what they needed to learn to be successful in the lab. Differences in knowledge among the participants, as well as between participants and their labmates were captured as *knowledge differences.*

Information overload highlighted the feeling of being overwhelmed when learning these new and unfamiliar concepts, techniques, and scientific disciplines. Cali noted that as a chemistry teacher, a lot of the biology-specific vocabulary felt new to her. *Asking more questions* highlighted how participants took ownership in addressing and remediating differences in knowledge. Erik says,

> "I had to really press myself. And what I really found out, I had to go out of my comfort zone to ask the really smart people, "Hey, can you help me out? Because I don't know what I'm doing."

Despite any struggles encountered in the lab, participants' interest in learning the subject matter fueled their persistence in the program. The code *excitement/interest/enjoyment* captured the genuine enthusiasm that participants had for the subject matter and experience. Cali says, "it's so much fun. And everyday I'm excited to come again. What are we gonna learn about today?" and Macy remarked, "a program like this really stimulates me and excites me." This code captures the genuine interest and passion that the participants expressed for this kind of immersive, constructive learning experience.

Overlap of Learner and Researcher

Participants were in a constant state of learning, but this was almost always overlapping with another lens. A key feature of this program is immersing teachers in current research and experiments in environmental health science labs. As such, participants were forced to learn through iteration and find eventual success through initial mistakes.

Not only did this allow participants to take on a learner's perspective, it also highlighted the inherent nature of scientific research. What were initially perceived as failures by participants (e.g., the need to repeat a technique multiple times before it was perfected), were not only genuine learning experiences, but also genuine research experiences. Trial and error, repetition, and adjustments are all critical pieces of the research process. Many participants reflected on the feeling of failing at certain procedures, or having to learn from their mistakes in order to ultimately be successful. This was captured in the code, *learning from mistakes.* Erik expressed that learning a new technique in his lab required persistence and patience because, "that technique was difficult and it wasn't just the first time, it wasn't just the fourth time. It was a number of times before we really understood." Other participants also recounted the need to repeat running a gel, pipetting a liquid, working with fish embryos, and identifying differences in working with RNA or DNA. Still, the teachers ultimately recognized the ability to respond to initial failures, and stay committed to learning. Mia made a summative statement about this experience, "you make a mistake, you learn from it".

The repetition of learning through trial and error is inherent to the scientific research process. As such, *learning from mistakes* became a subcode within the larger code, *process of science and research*. Both of these occur when the *self as learner* and *self as researcher* lens overlap as seen in Figure 1. *Process of science and research* captured discussion of the general nature of science, the research process, and commentary on specific techniques. Rich remarked on the ubiquity of scientific inquiry when he said, "so as long as you keep asking questions… you're a scientist technically and you're looking for solutions to those questions." Mia commented on the ubiquity of scientific outputs, "for many, science seems something very abstract and dry...when it's actually it pertains and it touches every aspect of our life, from vitamins to the gadgets, to the, I don't know, spaceships, everything is science." Erik talked about the time that goes into thinking about a research question, before ever conducting an experiment in the lab, explaining,

> "...it really opened up my eyes to how they approach a particular problem. How they sit down and discuss it, look at all the research and data before they even attempt to assign an elaborate procedure in what needs to be done".

The time participants spent learning content and working through mistakes to succeed in their labs allowed them to transition from speaking about themselves only as learners, to speaking about themselves as researchers.

Self as Researcher

Over the course of the eight-week program, teachers became genuine members of their lab communities, working for 30-40 hours per week. They made legitimate contributions to both the research and social dynamics. This gave participants the opportunity to see themselves as contributing lab members, and highlighted the third lens, *self as researcher*. Participants acknowledged that this program filled a need and provided an outlet for engaging in scientific discussions with each other, their like-minded peers. Rich jokingly expressed his excitement, saying,

> "I look forward to having these biological conversations and just science conversations with you guys in general, because I'm not going to go home and have a conversation about transcription factors with my wife who never took science classes. You know what I mean?"

The knowledge differences that participants initially felt when entering their labs were often addressed and mitigated through effective *science communication*, allowing participants to really assimilate into the labs. Erik explains his experience in science communication with mentors and their graduate students saying they would, “break it down, to make it so that wherever level we were, it kind of made it all the same again.” Taking the time to explain, talk about, and understand new concepts and techniques helped create a feeling of equality between participants and their lab mates, thereby engendering feelings of confidence as practicing researchers. Participants began referring to themselves as “professionals” and remarked on the research they were able to conduct on their own. Participants spoke about this confidence in the lab and how it might translate into conversations with their students.

The role of *mentorship*, both by a lab’s principal investigator and its graduate students, played a critical role in effective science communication and supporting the participants’ experience as researchers. Participants remarked on how their lab mates worked to ensure that participants were successful when completing various techniques in the lab. The mentorship of faculty members and graduate students was often based in science communication (e.g., discussing specific techniques, using diagrams to describe new concepts), but this desire to help each other be successful researchers also pointed to a sense of community within labs and the program.

The code *science community* captured participants’ expressed feelings of being connected with a community related to science and viewing the lab as a model community. Teachers’ immersion in the labs allowed them to develop relationships with faculty members and graduate students as fellow researchers. Participants talked about the sometimes-unexpected sense of connection and camaraderie within their labs. In the beginning of the program, Erik talked about the importance of these supportive relationships in each lab, saying,

> “It's something that I wish we could ... take this program, with the way we are treated as professionals, and spread it across the teaching profession in the state. We would see a tremendous impact. I think we've been in the greatly appreciated, with whatever skill that we came here with, we have been appreciated, and walk with others even if their skill sets are different than ours”.

Participants noted throughout the program, the collaborative and communal nature of lab experiences led to co-learning and idea sharing as researchers. Faculty and graduate students made an effort to understand how different lab concepts could be applied in teachers’ classrooms. Mia explained, “They recognize the importance of bringing this to the classroom. And I think that that's huge. So I really appreciate it.” Rich, Joel, and Mia remarked that the mentors were likely learning from the teachers, just as they learn from their students. The science community extended beyond each teacher’s lab, to other program participants and their labmates. There was a sense of bonding among participants based on their shared experiences as researchers during the program. Mia explained this experience as,

> “It's so enriching because … you realize you're not the only nerd….People that have the same passion like you, it makes you feel better professionally and it's like the future has a silver lining, no matter how big it looks sometimes. But being with people of the same kind mental...frame and passions, I think that that matters a lot as well. At least for me”.

Ultimately, the collaborative and constructive nature of the research, community, and co-learning that the program facilitated highlighted how the program was greater than the sum of its parts.

Overlap of Researcher and Educator

As the program concluded, participants were once again thinking of themselves as *self as educator*, but now accompanied with the lens of *self as researcher*. Through both of these perspectives, participants began to think and speak about reform to their teaching beliefs and teaching practices. Cali explained how the experience of being immersed in the research process allowed her to learn by actually doing the research. She explained that this process will ultimately impact activities for her students and better connect her students to science, saying,

> "Really having students model what it was like to develop their own questions and their own scientific investigations to analyze these questions and even having them create research poster type presentations and practice. Going through that process, I feel now that I've actually been through that in a laboratory setting, I would be more able to implement that as a student activity".

As participants began to make connections between their own research experiences and their classrooms, they realized the disconnect between academic science and what is taught in their classrooms is larger than they previously realized. It was through both lenses, *self as researcher* and *self as educator* that participants were able to see where real change could happen. Using both lenses, participants identified the *disconnects between labs and schools*, addressed *barriers to science teaching*, and recognized *applications to the real world and teaching* that inspired overall *changes to teaching*. *Changes to teaching* captures specific changes that participants made in their classrooms upon completing the program. Rich often brought up questions around the relevance of what is taught in schools compared to what actually happens in research labs. Recollecting about his first two weeks in the program, he was reminded how important it is to teach his students the application behind the concepts, explaining, "teaching these kids science in high school... they need to know why or else they can't make connections to real world examples." Recognizing the application behind the concepts allowed participants to more clearly see the *barriers to science teaching*. Participants pointed to large class sizes and lack of time, funding, and support as major barriers to high-quality science teaching. At the end of the program, Rich made a summative statement, "... that's what's awesome about this program is, the reason is, is to bridge that gap between the teachers and the doctorates, or the PhD students, or the people that are doing the research on the stuff that we're teaching." Erik reflected on a similar experience of bridging the gap between research and classroom science, saying,

> "...my teaching model has changed dramatically, as opposed to just doing maybe a lesson plan and just going over the review material and getting students involved with some of the basic fundamental vocabulary, we now start with a research topic. We'll research it, look at it before we do an experiment...and then we'll look at all the parameters, lay out what could be done with it. It's a hands on, problem solving approach, like a project based learning approach. I've learned to apply from the program...and you know the students are engaged more…. Topics [have] come alive because of the experience that I had in changing the model. Students are no longer sitting in their desk taking notes. They're up, they're moving, they're communicating with group communication and they're sharing their experiences".

Erik goes on to explain that when his students are engaging with the scientific method through inquiry, they no longer see failure when their lab results are unexpected. Erik's experience of adapting his own teaching approach to more closely align with the practices of a research lab was common among other participants. Their own experience with inquiry-based learning informed their beliefs about their students ability to engage with science content in a similar way. As participants finished their time in the program and began planning for their return to their classrooms, they reported feeling more confident in themselves and their abilities to not only conduct research, but also to better teach science. Even though Cali did not have her own classroom yet, she commented on her confidence, explaining,

> “... I definitely feel much more confident in my ability to call myself a scientist after having spent this [summer] in this program, which I think will increase my confidence in my own future classroom as I work with my students, especially with inquiry-based lab activities... so I'm looking forward to seeing what that will look like”.

When asked in the second focus group, “do you think you could be a scientist?” participants responded that they had the abilities to be a scientist, but ultimately want to remain teachers. Macy said this of her ability to be a scientists,

> “I could see myself being a scientist or researcher, but I don't think I will ever switch gears and move into that sector… I'm very passionate about education…. but I definitely think I am capable of doing it. I just don't foresee wanting to ever make the switch”.

Joel had a similar take on his abilities to become a scientist saying, “I would love to go ahead and go and be a scientist….make more money obviously, but to be honest, I feel like I'd be letting down kids if I left. I felt like it's my calling….”. Additionally, Cali explained her view of herself in both roles, “I see myself as a scientist through my role as a teacher, but I don't think that I will ever be a scientist in the context that I was this summer”.

Connecting Students to Science

These three lenses complemented one another, allowing participants to see the pathways for students, the barriers to remove, and changes to be made more clearly than with any one individual lens. These concurrent lenses are unique to teacher participants, as no other members of the network were learning from or operating from these same three lenses. As seen in Figure 1, these lenses all overlapped, were highlighted by certain experiences, and challenged by others, but all ultimately helped teachers build the skills and capacity to better connect their students to science.

Discussion

Program Impacts

Quality science education is a priority in both the US and globally. Professional development offers the opportunity for science teachers to gain content knowledge and experiences that may shape their beliefs about quality science education. The PD experience outlined in this study provides an opportunity for immersive science research, which shifts participants' beliefs about themselves, their students, and science teaching. The findings in this study show that when teachers are in a research laboratory for eight weeks, conduct meaningful research, and collaborate with scientists and peers, their beliefs about science and science teaching are impacted. What was so influential about this experience? Teacher participants were not given specific curriculum or lesson plans to take back to their classrooms and they did not receive any intervention about science education reform. They experienced a genuine, iterative research process. Time, collaboration, and context of the program were requisite features for participants to foster three crucial lenses from which they viewed the program. These three lenses, self as educator, self as learner, and self as researcher, allowed participants to acknowledge and bridge the gap between what happens in science research laboratories and what happens in their classrooms.

Time

Consistent with the literature (Borko, 2004; Lotter et al., 2018), time was an important factor of this professional development program that influenced participants' changes in beliefs. The duration of the program provided participants with extended periods of time in their labs, working closely alongside their principal investigator mentors, and each lab's graduate students. Self as a researcher was an important lens for teachers to change their beliefs. Sufficient time with this process was necessary for them to develop that perspective. Because *self as researcher* was a lens experienced more regularly towards the end of the program, it took the duration of the program for participants to really come full circle back to viewing *self as educator* with new beliefs. Time also served as a crucial element in the development of collaborative relationships with peers and mentors, which were an important outcome of this study.

Collaboration

The constructivist nature of the program did not prescribe any explicit end goals or outcomes, other than the experience of science inquiry through working in a research laboratory. Participants constructed the nature of their experience in the program with each other, their labmates, and themselves. Even though almost all participants initially questioned if the program was a good "fit" for them, they all reported similar ideas of growth and new perspectives, positive impacts on teaching, and new understandings and beliefs about the nature of science and science inquiry (Capps & Crawford, 2013). Participants' experiences in this program are consistent with Lotter et al. (2016) in that teachers were "active participants in their learning" and it is "viewed as context dependent and socially constructed through dialogue and collaboration with others (p. 2714). Consistent with literature, the constructive nature of this program allowed participants to collaborate with other educators through dialogue, reflection, and sharing experiences (Herrington et al., 2016; Lotter et al., 2016). As in other studies, the network that participants built was extremely valuable and aided in the overall experience of the program (Pop, Dixon, & Grove, 2010).

Context

The context of the program allowed participants to engage in inquiry-based learning for themselves. Consistent with Lotter et al. (2016), participants developed confidence in scientific research, and because they learned through inquiry and higher order thinking during the program, they are better able to facilitate classroom learning in similar ways. Engaging in this learning process allowed participants to form new beliefs and connections to science education. If we simply provided a list of these resources to a group of teachers, they would not necessarily make any changes to their teaching or beliefs (Smith & Southerland, 2007). Participants were able to experience something brand new to them; they now have access to different lenses that allow them to more clearly see how a learner will experience science curriculum. The context of the program also provided a dynamic platform for participants to develop their sense of identity around science (Avraamidou, 2019; Thomson & Nietfeld, 2016).

Conclusion

Learning from and working with professionals in different fields develops an influential network. This program elicits exponential learning opportunities for all involved including, teachers, researchers, and scientists. Attrition of two participants from the program prevents the data analysis and results to show the full picture of all participants' experiences throughout the program and data collection process. Though both of these perspectives were left out of some of the data analysis, their voices are still represented in data from the first focus group. Future research interests include understanding the experience from the perspectives of the mentor scientists and the graduate students that host high school science teachers for immersive summer research experiences. Future research interests also include understanding students' benefits from having a science teacher that has participated in immersive summer research experiences.

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Appendix A. Coding Scheme with Major Themes and Codes

Themes	Codes/Subcodes	Description
1.Self as educator	1.1 Takeaways 1.1.1 Resources 1.2. Collaboration with cohort 1.3. Credibility as a science teacher	Teachers discuss "taking" and "bringing" things, information, ideas, applications "back" to their classroom, having access to new information/exposure to equipment as a resource for themselves and their students, includes suggestions from other teachers on how to apply experience to classroom, commenting on working with and communicating specifically with teachers in the cohort, feeling that having this experience in a research lab makes them more credible as science teachers
2.Overlap of Educator and Learner		Connecting with students' needs through understanding students' perspectives
3. Self as Learner	3.1 Knowledge differences 3.1.1 Information overload 3.1.2 Asking more questions 3.2 Excitement/ enjoyment/ interest	The differences in knowledge between mentors and teachers that sometimes creates tension, general excitement for participating in the lab/research experience, teachers showing interest in science and/or research experience, teachers trying to elicit interest to science in their students, captures enjoyment of experience and excitement of experience, showing interest in science and/or research experience
4. Overlap of Learner and Researcher	4.1 Process of science and research 4.1.1 Learning from mistakes	discussions about the nature of how things work and how things are in science, mentions of errors, failures, mistakes and the perception that these experiences are negative
5. Self as Researcher	5.1 Science communication 5.2 Mentorship 5.3 Science Community	Teachers talking in scientific terms, talking about science to others, talking with scientists, Guidance of lab members to teachers, mentors being helpful in growth process
6. Overlap of Research and Educator	6.1 Disconnects between labs and schools 6.2 Barriers 6.3 Confidence 6.4 Applications to real world 6.5 Changes to teaching	Teachers discuss barriers to teaching good science, including large class sizes, lack of supplies, lack of support from peers or administration. Feeling a sense of confidence around lab work, research, science communication, etc. knowing more about the way science works, applying what teachers are learning in lab experience to their classrooms and lives, discuss the changes made to teaching

Themes	Codes/Subcodes	Description
	6.6 "I could be a scientists but I want to be a teacher"	practices since the program, teachers express the belief that they have the ability to become a scientist but the drive and desire to be a teacher
7. Connecting Students to Science		Mention of steps or path for students to take to get to science, removing barriers for students to learn, providing better learning experiences for students to learn science
8. Fit of program		Teachers discuss if they are a best fit for the program or not, teachers make suggestions to better the program, teachers feel that the program is better fit for someone teaching biology, teachers struggle to see application from program to their classroom, teachers experiences don't meet expectations but it's not necessarily a negative experience

Appendix B. Example Interview Protocol

"Hello (participant pseudonym). Thank you for agreeing to participate in this interview which will last approx 20-30 min. Today is (insert date) and I, (researchers name) will conduct this interview. If you are ready, we'll start with our first question…"

1. Please tell me a little bit about yourself, about your teaching experience (Probe: i.e., subject taught, grade level etc).
2. How long have you been in teaching? If you no longer teach, do you work in an educational related area? Please give specific details.
3. You are one of the PD participants this past summer. How did you find out about this program?
4. What motivated you to participate (engage) in the EHS program?
5. Can you talk a little bit about what kind of expectations you had going into the EHS summer program? Were these expectations met?
6. Describe a little bit your science teaching efficacy:
    a) *before* and *after* your PD program.
    b) at the present time: How confident are you now about your science teaching related to the EHS topic?
7. What do you consider to be the most valuable about your participation in the EHS program?

Appendix C. Example Focus Group Interview Protocol

1. You are in the (insert week) of your summer PD program. Talk a little bit about your experiences so far (Probe: a. What sort of experiences you had so far, b. Give some examples.)
2. Can you talk a little bit about your motivation to attend the PD program in EHS this summer?
3. How relevant is the work you've done so far in the lab for you as a science teacher? Do you think you can use this experience and knowledge in your classroom teaching? (Probe: How, give me some examples)
4. What do you find valuable about the PD program? And what do you consider being challenging?
5. Describe your science teaching efficacy at this time. How confident are you about your science teaching related to the EHS topics?
6. Do you see yourself working as a scientist one day? Do you think you can be a scientist/ or have a career in science, generally, or in EHS, particularly? (Probe: Why is that?)
7. Do you see your students working as a scientist one day? Do you think they can become scientists / or have a career in science, generally, or in EHS, particularly?(Probe: Why is that?)