SCIENCE RESEARCH LITERACY THROUGH IMMERSIVE PROFESSIONAL DEVELOPMENT IN BIOMEDICAL RESEARCH

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ABSTRACT

High school science teachers require increased skills in science research literacy, so that their students develop research competencies in the classroom (Evans, Warning, & Christodoulou, 2017; Udompong, Traiwichitkhun, & Wongwanich, 2014). For teachers to promote a scientific atmosphere, literature points to training that fosters authentic spaces in the school setting. Working in collaboration with scientists offers teachers ways to scaffold laboratory experiences that address the needs of their students and models scientific communication and behaviors (www.nextgenscience.org/faqs).

This research includes creating and sustaining long term collaborations between scientists and teachers while also identifying professional development that enables both laboratory research and science education. Applying science research literacy skills will empower teacher to meet the challenges set by national standards, through which science laboratory experiments in secondary education classrooms necessitate teachers to embrace new methods of lesson delivery and identify organic points, in the required curriculum, for the incorporation of authentic scientific inquiry (Ufnar & Shepherd, 2018). Observing and interacting, with the participants throughout the various levels of immersive I anticipate creating enhanced programming, science teacher PD's, and workshops that will enable science teachers, both face-to-face and via virtual-hybrid programs, to impart the sense of being in a lab to their students while bringing authentic research activities to life during classroom inquiry. This promotes culturally relevant experiences within the context of the scientific one.

Ideal subjects for this study will be in-service science teachers in possession of a minimum Bachelor's degree. Subject matter and experience in research science is not a

disqualifier. However, interest in life science, biological science, health science, environmental science, or biochemistry will be required. Through ethnographic research, the cultural forms, values, and practices that are essential to the cultural reproduction of science research literacy will be documented. I will engage in this research as an ethnographer and having the role of active observer, analyzing cultural behaviors (Brandt & Carlone, 2012; Camarata, et al., 2017) and the development of science research literacy of science teachers following engagement with professional research scientists during immersive professional development programs. Ethnographic research will allow me to uncover the practices as I experience the process along with the participants and while my research will be conducted through an ethnographic lens, writing will be included as to acknowledge the work as a case study bounded by the shared experience and context of the participants. Moreover, following the proposed research, teachers could enact a swift change in science classroom culture, by embracing a more scientific one (Erickson, 1984).

DEDICATION

To all the amazing science teachers and teacher scientists who bring authentic research into their classrooms and share in their student's discovery. May you all continue to ask new questions and help drive biomedical research forward in your communities.

To the scientists that recognize the value of science teacher voices and ideas. May our collaborations grow as both fields tackle diseases like cancer, diabetes, and mental health- at the bench and in the classroom.

And most of all to the student scientists that work with these instruments of change. See yourself in them. Ask the questions that mean something to you. Forge ahead and change the faces of biomedical research.

ACKNOWLEDGMENTS

We made it! This dissertation is the result of seven and a half years as a doctoral student, with the work starting well before that. The road was fraught with loss, illness, and a pandemic! Some say sink or swim, well I say FLY! To my dissertation chair, academic advisor, and sherpa Dr. Carol Brandt, I thank you for celebrating personal research, your never-ending positivity, and your talent for recognizing how to get the best words from me through discourse. An ethnographer to the core. To Dr. Meixai Ding I thank you for pushing me to be a better writer and your enthusiasm for this qualitative study. To Dr. James “Jim” Byrnes, my first doctoral program professor, I thank you for the early support of a program that grew into a dissertation. To a new colleague Dr. Megan Mekinda, I thank you for jumping in and all your insightful comments. #Onward #ToWillBeFINE To Dr. John Hall, I thank you for believing that if someone could make a go at change, it would be me.

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To all the science teachers, teacher scientists, and scientists, I have the privilege of working alongside. Watching this force for change take root and grow has been a dream come true. You have gone from my colleagues to my friends and family. Thank you <u>all</u> so much for joining me on this journey and special shout outs to Alana, Chris, and Ebony. Your encouragement made the long hours of writing less daunting, and I look forward to our continued work together.

To my writing partner and soundboard, Kelsie. Thank you for holding me accountable for goals and for the late nights and early mornings spent together across the miles. We will celebrate in 2024! I have your back until the end! #WeGotThis

Hoot-Hoot-Hoot

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CHAPTER 1

INTRODUCTION

Background

High school science teachers require increased skills in science research literacy, so that their students develop research competencies in the classroom (Evans, Warning, & Christodoulou, 2017; Udompong, Traiwichitkhun, & Wongwanich, 2014). One aspect of (science) research literacy, authentic inquiry, redirects learners in their thinking and interactions with science (Bybee, 2002). This emphasis drives science teachers to undertake the task of scaffolding their lessons to promote students learning critical thinking skills and how they apply to real-world science experiences, all in alignment with local, state, and Next Generation Science Standards (NGSS Lead States, 2011). Updated standards lay out a roadmap for social reproduction of scientist training and community of practice in a bid to prepare today's science students for future Science, Technology, Engineering, and Mathematics (STEM) careers (NGSS Lead States, 2011). Concern for preparedness of science teachers in science research literacy, defined here as the ability to scientifically apply content knowledge to address real world questions beyond the scope of the original inquiry (Sanetti & Collier-Meek, 2019), is on the list of challenges they face as they develop classroom-based laboratory experiences (Brooks, Dolan, & Tax, 2011; Chiappetta, 2008; Peffer, Beckler, Schunn, Renken, & Revak, 2015). These authors argue that for students to be competitive in the STEM market, their science teachers will need to be versed in science research literacy (Ufnar & Shepherd, 2018).

This dissertation research operationalizes science research literacy in a three-pronged approach. First, its definition will include. 1) the cultural habits of scientists, 2) the ways to appropriately share scientific content, 3) the ability to generate new research questions versus repeating currently known work, and 4) the enrichment of scientific experience and knowledge by those collaborating with scientists (Brody, Dalen, Annett, Scherer, & Turner, 2012; Evans, et al., 2017). Second, teachers are observed in collaborative, immersive professional development sessions and in their classroom to identify which behaviors were transferred to the classroom context. Finally, through writings, interviews, and artifact analyses I describe how these professional developments impact science teachers and indirectly, their students through the utilization of science research literacy in school.

Applying science research literacy skills empower teachers to meet the challenges set by national standards, which s necessitate teachers to embrace new methods of lesson delivery and identify organic points for the incorporation of authentic scientific inquiry (Ufnar & Shepherd, 2018). Authentic science, as social context, includes the behaviors and practices of scientists outside of the classroom and how these practices can be used to drive student learning (Braund & Reiss, 2006; Holbrook & Rannikmae, 2017). For this research, I define authentic scientific inquiry as not only the hands-on aspect and utilization of authentic scientific practices, but also the “minds-on” component and the development of pairing pedagogy with skills in the classroom (Abd-El-Khalick et al., 2004; Supovitz & Turner, 2000). The addition of these new teaching strategies prompts the transition from the use of cookbook-style laboratory manuals in which all students arrive at the same answer towards inquiry-based scientific learning protocols. These strategies offer students the opportunity to shift from basic technical skills to the question development and data analysis processes of pre-professional scientists. Teachers that have the tools to promote more advanced scientific thinking and engage their students in the application of this type of literacy, move their classes away from rote memorization of content material and begin to address scientific questions as scientific researchers (Polacek & Keeling, 2005). This need for a scaffolded transition from basic skills to critical thinking in science classrooms and laboratories drives the purpose of this study. In this dissertation I examine the supports teachers require to increase science research literacy and authentic inquiry in their classroom.

Supported by the following review and my preliminary work in informal science education settings, I am learning the importance of not just sharing the content knowledge with science teachers, but also the habits of scientists. To meet rigorous science standards, science teachers can look to scientists for modeling examples that can aid them in bringing authentic scientific practices into their classrooms (Koomen, Blair, Young-Isebrand, & Oberhauser, 2014). As a result, this research also includes creating and sustaining long term collaborations between scientists and teachers while also identifying professional development that enables both laboratory research and science education.

Coming to my research question

As Maxwell (2005) suggests, I composed an "identity memo" to highlight why I am in a unique position to undertake this ethnographic research. For over 30 years I have bounced between two "distinct" career choices. science teacher and laboratory researcher. I did not feel quite at home in the laboratory lacking the "big questions" that drives research, and similarly, I worried about the quality of science teaching that I saw in the schools being taught to my own sons. However, I found a way to bring those two worlds together in 2013 when I was asked to design a teaching-research laboratory.

From personal experience as a learner with dyslexia, I wanted a space that was both a place to review protocols and write, as well as a place that is tactile and engaging. Using a flipped classroom approach (Bergmann & Sams, 2012), I quickly realized that rather than just teaching 16 high school students, we could train teachers to do science properly and help them bring it to their classroom to enhance their science teaching. We could reach 100s of students per year through such a program, and thus the Laboratory Training Institute-PLUS (LTI+) was born.

Apart from an ethnographic study completed in 2017 for a graduate course, no systematic data has been collected on the LTI/LTI+. I wanted to learn if it makes a difference when teachers not only experience, but also teach in a research environment. What ownership over the material do the teachers have and does the science culture change in their home-classroom? As a result, I have developed this study from an initial project in my first semester as a Ph.D. student. In the last few years as a doctoral student, I see ways that this program might offer a model for others who want to connect the science laboratory to enact real change in science teaching in school classrooms.

Science research literacy hallmarks

Science Communication

As with many soft job skills, post-secondary science students are not directly taught how to speak about science to the general public. Most of their public speaking takes place during seminars, conference poster sessions, and lab meetings. While important for the lab research pipeline, this creates a chasm when speaking to laypeople

(Brownell, Price, & Steinman, 2013). In times like these, where public health is at the forefront of daily news sources it is important for science to be disseminated in a fashion which imbues the listener with a sense of understanding. Knowing that this is a concern at the post-secondary level, by equipping high school teachers with the skills and vocabulary that are accurate, this can be addressed before college.

Science Culture

Science teachers face the growing task of presenting and engaging in authentic science within the classroom setting, they may find the need to employ some of the cultural norms enacted in research laboratories. The authentic inquiry pipeline is an important step in cultivating “teacher scientists" that adapt habits of research scientists. We are learning the importance of not just sharing the content knowledge, but the habits of scientists, of seeing the “scientific inquiry taken from how professional scientists practice science and bring [it] into the classroom” (Koomen, Blair, Young-Isebrand & Oberhauser, 2014, p. 4). To stoke the fire of scientific inquiry in the next generation of (cancer) researchers the Laboratory Training Institute or LTI+ (pseudonym) will continue to develop a system of teacher scientist immersive training which will allow for science teachers and their students “opportunities to engage in scientific research” (Farber, Hardin, Klein-Gardner & Benson, 2014, p. 786). Leading to the transitionary point by which the science teacher can take more of principle investigative role and developing a two-way, science collaboration can impact the next generation of scientist-educators entering STEM fields.

Commitment to science and education

This study fits into my professional mission because as the collaborative, science-education director of the LTI/LTI+, I work directly with faculty-scientist collaborators to blend the world of research with classroom teacher and student learning. By developing data-driven training programs for science teachers, I focus on documenting evidence to later support their students' learning, their critical thinking skills, and how they apply to real-world science experiences, all in alignment with current science and NGSS standards.

Investigative questions

Supported by the following review and my preliminary work in the informal science education space, I am learning the importance of not just sharing the content knowledge with science teachers, but also the habits of scientists to see an increase in (science) research literacy. The questions I will explore are.

1. How is science research literacy conveyed via immersive professional development?
2. How will teachers use their science research literacy skills to enhance their teaching of science?

CHAPTER 2

LITERATURE REVIEW

Theoretical Framework

I rely upon a socio-cultural theoretical framework rooted in information flow and activity-based learning (Archer, Dawson, Dewitt, Seakins, & Wong, 2015; Claussen & Osborne, 2012; Grenfell, 2014). I am interested in the forms of "capital" (Bourdieu & Passeron, 1990) that teachers bring to their experiences with the LTI/LTI+ and their approach to science research literacy. "Bourdieu was aware of the role that 'culture' played as a determinant factor in the way people responded to their surroundings; in other words, their cultural background partly shaped what they thought and how they acted" (Grenfell, 2014, p. 19). Further, Claussen and Osborne (2013) noted that "science education…becomes important as it is the means of ensuring the cultural reproduction of science…and forms the foundation of a pre-professional training and is conceptualized as a 'pipeline' supplying the next generation of scientists who will be producers of scientific knowledge" (p. 61). Through this ethnographic research, the cultural forms, values, and practices essential to the cultural reproduction of science research literacy are documented. I engage in this research as an ethnographer and having the role of active observer, and analyzing cultural behaviors (Brandt & Carlone, 2012; Camarata, et al., 2017) and the development of science research literacy of science teachers following engagement with professional research scientists during immersive professional development programs. Ethnographic research allows me to uncover the practices as I experience the process along with the participants and while my research is conducted through an ethnographic lens, writing is included as to acknowledge the work as a case study bounded by the shared experience and context of the participants. Moreover, my goal is that following this study research, teachers might enact a swift change in science classroom culture by embracing a more scientific one (Erickson, 1984).

In this research, I argue that people shape their cultural worlds while also being shaped by their practices and contexts. There are both temporal (historical) and contextual (spatial) features of this theoretical perspective (Holland & Lave, 2009). Archer et al. (2015) describes the "science capital" as the knowledge, attitudes, values, and experience a person might have about science. Like Bourdieu's notion of other forms of capital (1977), science capital has exchange value in educational systems that is privileged and is unevenly distributed within a "field" or a particular cultural context.

Definitions

Professional development

Professional development (PD) as outlined by Supovitz and Turner (2000) is a series of immersive experiences in which participants engage in collaborative learning through authentic scientific inquiry. As science teachers participate in PD with peers and scientists, they have opportunities to not only read about techniques but engage in discourse about the meaning of the scientific work while observing the behaviors of scientists in authentic research spaces. LTI+ facilitates immersive PD sessions through which participants engage with scientists in authentic research spaces, have the freedom to address novel scientific research questions, and can carry these experiences and behaviors into authentic research spaces in a leadership role and then into their formal education settings.

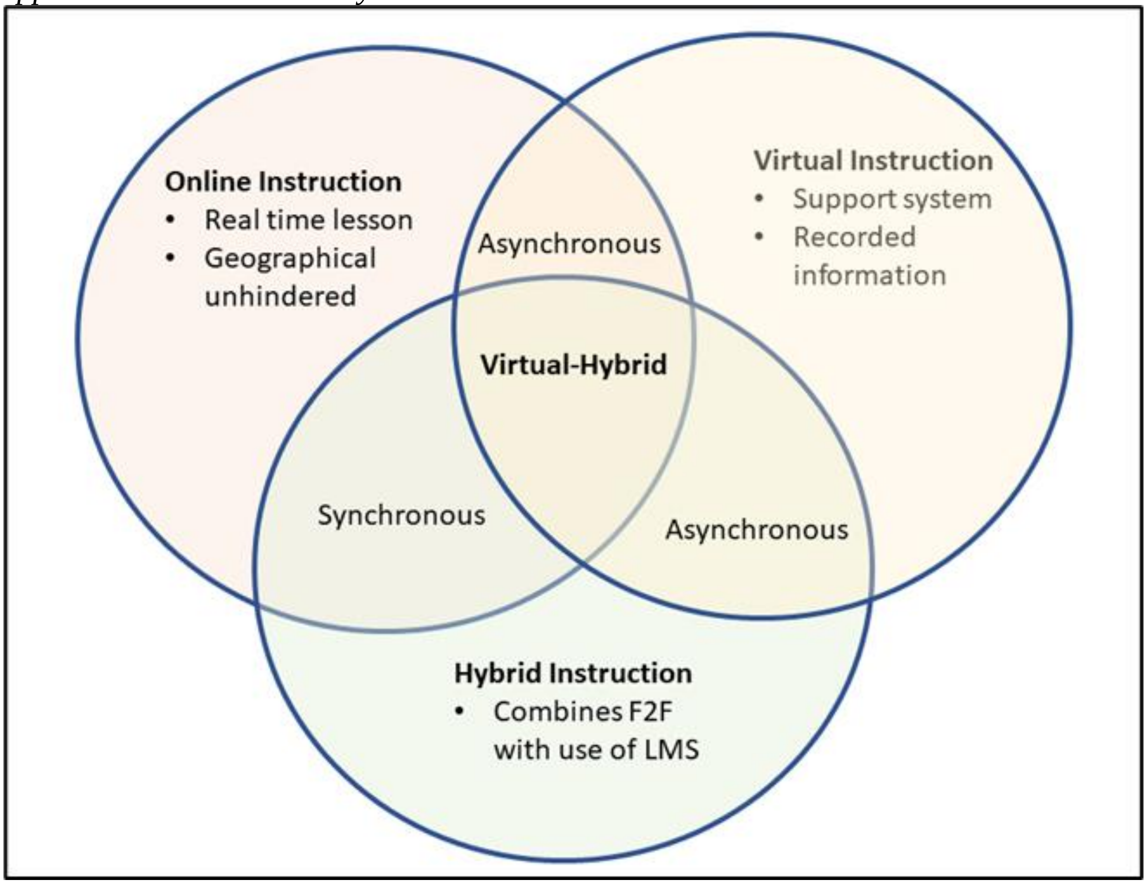
Collaborative-Partnership

This relationship between science teachers and science researchers supports both parties in their personal goals (science research literacy, data collection) and in a blended goal (citizen science platform) leading to a long-term, mutually supportive engagement (Hendricks, LaMothe, Halstead, Taylor, Ofner, Chase, Dunscomb, Chael, & Priest, 2018; Niehoff, 2018).

Virtual-Hybrid PD

This method for professional development utilizes various instructional delivery methods. Distance learning is primarily asynchronous (Signer, 2008) with the main mode of interaction through discussion boards and some hybrid online courses use both face-to-face time and asynchronous learning (Martyn, 2003). My work focuses on maintaining the synchronous, hands-on, authentic laboratory learning by replication of the lab environment in the participant's home/workspace and harnessing the power of virtual conference platforms if face-to-face sessions are not able to be conducted. Unlike currently trending distance learning (Garrison & Kanuka, 2004), the live time will be performed in keeping with the core of hybrid instruction available learning management systems (LMS) like Schoology.com and digital libraries such as LabXchange.org are used to support comprehension and create a collaborative science environment asynchronously (Figure 1).

Figure 1
Approaches to Electronically Connected Instruction.



Notes. The virtual-hybrid method developed by the LTI+ creates an authentic laboratory immersive versus commonly used simulations. Participants and instructors have the paired sets of equipment and materials to make it possible for hands-on research to be completed in informal research spaces.

Literature review

In the current era, advancements in science, technology, and associated health-oriented fields are evolving at lightning-fast speeds. Employment in life, physical, and social science occupations is projected to grow 5 percent from 2019 to 2029, faster than the average for all occupations, and will result in about 68,200 new jobs. (Life, Physical, and Social Science Occupations. Occupational Outlook Handbook, 2020)

Science teachers will need increased science research literacy to be comfortable treating the classroom as a space for authentic science practices. With higher-stakes exams, the focus on this research literacy includes teacher goals, in addition to student ones, through the learning and teaching of hands-on science (Hofstein & Lunetta, 2004; Trautmann & MaKinster, 2005). Moreover, advancements for the scientific research community are also a current trend. As funding in both educational and scientific research relies more on collaborative work or cross-curricular design, scientists working with science teachers would benefit both worlds (Brooks et al., 2011).

In response to the content of the documents retrieved and reviewed, I identified three broad themes in the literature that illustrate science research literacy development in science teachers as a product of their collaboration with scientists and their participation in both face-to-face and virtual-hybrid professional development. Below I describe the pedagogy, structure, and culture of scientist-teacher collaborations and science teacher professional development in the following literature review. Unfortunately, there are gaps in the literature on the development and implementation of in-service science teacher training in authentic research experiences.

Collaborative-Partnership among Scientists and Teachers

To address the creation and sustainability of collaborative-partnerships between science teachers as education experts and scientific research experts, the developers should build from the understanding that each brings certain experience and knowledge to the table (Kesselheim et al., 1998; Gosselin, Levy, & Bonnstetter, 2003) and that both parties receive and give support (Bergman & Schooley, 2003; Kim & Fortner, 2007) for the betterment of their respective fields. As funding in both educational and scientific research increasingly relies on collaborative work or cross-curricular design, scientists and teachers will work in partnership for the benefit of both fields (Brooks et al., 2011) and rely on each other's expertise to support and enable their work in the laboratory or classroom (Gosselin et al., 2003). By working together, the participants can find commonalities that best use their individual knowledge strengths to solve integrated problems together (Vyas, van der Veer, & Nijholt, 2013; Kamalipour, Kermani, & Houshmandipanah, 2014).

Throughout the literature reviewed here, the complex nature of interactions among science teachers and scientists was often addressed through the lens of classroom performance and made it challenging to find studies specific to these collaborative interactions between the two field representatives. However, the extant literature demonstrated how teachers learned how scientists used socio-scientific issues to make connections to real life. The literature also showed how teachers could use their science research literacy to make abstract scientific knowledge concrete for their students and noted that relationships between scientists and science teachers positively affect the learning and teaching of high school science (Bergman & Schooley, 2003; Roehrig, Michlin, Schmitt, MacNabb, & Dubinsky, 2012). Through collaborative partnerships teachers develop effective authentic science teaching techniques and scientists develop communication skills to allow them to sustain and form partnerships. Scientists that worked with science teachers to enable their laboratory research (Gosselin et al., 2003; Ebenezer, Columbus, Kaya, Zhang, & Ebenezer, 2012; Munson et al., 2013; Faber, Hardin, Klein-Gardner, & Benson, 2014; McLaughlin, Broo, MacFadden, & Moran, 2016), sought to promote and investigate the synergy between high school faculty and higher education scientists and educators (Bergman & Schooley, 2003; Gosselin et al., 2003; Munson et al., 2013). Studies using qualitative and/or quantitative measures identified best practices for these collaborative-partnerships that include collaborative creation, submission, and/or dissemination of materials through journals and conferences (Bergman & Schooley, 2003; Munson et al., 2013) and the usability of practices to other sciences or classes (Miller & Kastens, 2018). To a lesser extent, scientists—or more often graduate students—engaged in the development of new curricula, aligning their research to the teacher's pedagogical requirements (Gosselin et al., 2003; Trautmann & MaKinster, 2005; Shein & Tsai, 2015; Ufnar & Shapherd, 2019).

A drawback to these transdisciplinary engagements is the need of a bridge to span the fields of science and education through a new curriculum or style of teaching linking laboratory research and the classroom standards requirements (Supovitz & Turner, 2000; Roehrig et al., 2012; Morrison, 2014; Snitynsky et al., 2019). This bridging of new, more detailed content with current curricula is what teachers often undertake during collaborations with or following PDs led by scientists. With curricular needs in mind, the teacher in the study by McLaughlin and MacFadden (2014) was tasked with the design and implementation of lessons that would induce scientific thinking by her students. Too often the scientists would model how things were done in the lab (Brooks et al., 2011; Koomen et al., 2014) or allow teachers to observe or interview them (Brown et al., 2014; McLaughlin & MacFadden, 2014; Morrison, 2014) instead of being motivated to collaborate with educators to combine required curricula and research content for authentic science inquiry. Much of the literature cited here highlights the imbalance between the science teacher and the scientist. However, in the previous example, the classroom students' work supported the scientist in restructuring a museum exhibit increasing the public audience's understanding of a paleontological display (McLaughlin et al., 2016). In this example, the students acted as citizen scientists and a museum representative was the mediator between class and scientist in the classroom. Another example noted unexpected benefits for the science partners who identified methods to put theory into practice (Munson et al., 2013), while a recent article highlighted how students can benefit from such interactions (Hagan, Whitcraft, & Henriques, 2020).

Sustaining a partnership requires effort from both parties, however teachers seek collaborations more often than scientists (Kesselheim et al., 1998; Ufnar & Shepherd, 2019). Further, while habits can more readily transfer from lab to school, factors such as cost, time, and access can impede teachers' ability to observe scientists (Trautmann & MaKinster, 2005; Brown et al., 2014; McLaughlin et al., 2016; Mentzer et al., 2017). However, even with the best of intentions teachers can still be placed into a role where the only experts in the room are the scientists and information will still flow unidirectionally (Trautmann & MaKinster, 2005; Ebenezer et al, 2012; Brown et al, 2014; Koomen et al, 2014).

Summary: Collaborative-Partnerships. As teachers seek out collaborations or partnerships with scientists, all collaborators should be prepared for some learning. While scientists and science teachers bring tools and ideas to the table, teachers often need support to feel comfortable with the content required to bring authentic research into the classroom that is both aligned with required standards and will increase student understanding. This review illustrates the delicate balance between collaboration and professional development. The overlap is inherent and difficult to split when the work is done well. Teachers who completed collaborative workshops with scientists exhibited stronger content knowledge and enhance research literacy in their classrooms, resulting in new materials that support scientific research and school testing standards (Bergman & Schooley, 2003; Trautmann & MaKinster, 2005; Roehrig et al., 2012; Miller & Kastens, 2018; Ufnar & Shepherd, 2019). This success could be due to the teacher's ability to share curricular needs with the scientists and having them met through PD projects that could be modeled and moved into their classrooms (Roehrig et al., 2012). Moreover, advances in public communication skills for the scientific world (Patel, DeMaine, Heafield, Bianchi, & Prokop, 2017) are a benefit to the researchers well beyond the parameters of the collaboration.

Professional Development for Science Teachers

Brown et al. (2014) presents research identified methods to improve Scientist Teacher Partnerships (STPs)—and not assess participant work. The results demonstrated that regardless of success, teachers perceived the experience gave various forms of educational or personal support. The greatest strength of the PD, uniformly noted, was the scientist-teacher interaction as this allowed for a transdisciplinary collaboration required for professional growth. Incorporating the curricular needs of the participants into the learning units was key to increasing teachers' research literacy. Further, a post-collaborative discussion with guided questions, Munson et al. (2013) uncovered new benefits during their culminating event that could lead to improved instruction for their [scientists at universities] students. This finding supports the idea that society will benefit from students' engagement in authentic science practices. Collaborations between science teachers and professional scientists would drive this engagement through PD experiences. Finally, the most striking thread of commonality through this review is the use of hands-on and inquiry-based learning for science teachers (Kesselheim et al., 1998; Munson et al., 2013; McLaughlin & MacFadden, 2014; McLaughlin et al, 2016). By engaging with scientists, especially in the spaces where their science happens, teachers took on the confidence and mantle of their scientific mentors (Ebenezer et al., 2012; Faber et al., 2014), more so than when only didactic educational means were employed (Miller & Kastens, 2018).

Examination of work in the development of science teacher PDs has revealed that they often occur in informal science learning settings, in research settings (e.g., laboratories, field locations) and while others have also utilized more formal science classroom spaces. Participants are immersed in the process (Ebenezer et al., 2012; Faber et al., 2014; Roehrig et al., 2012) of authentic research experiences in authentic research spaces with scientists (Brown et al., 2014). While location is one factor for successful PD, teachers who were immersed in the PD multiple times (Roehrig et al., 2012; Munson et al., 2013) saw a greater impact on teacher learning and subsequent classroom outcomes (Morrison, 2014; Shein & Tsai, 2015). However, it is important to note that the length of PD—ranging from a couple of weeks (Brown et al., 2014) to annual workshops held over several years (Roehrig et al., 2013; Mentzer et al, 2017)—was not always significantly associated with success. Rather, teachers had enriched science research literacy when science teacher had control over the type of research that personally interested them (Shein & Tsai, 2015; Hatch, 2018) or the scientists valued the teachers' feedback (Gosselin et al., 2003; Munson et al., 2013; Faber et al., 2014; McLaughlin et al., 2016). Furthermore, the cultural behavior was similar to the mentoring type seen in academic research laboratories. This behavior was reproduced in a variety of ways, including the science teacher progressing to the level of mentor to future teacher participants (Ebenezer et al., 2012) or by acting out the role of scientific mentor in the classroom while allowing their students to explore questions during class and laboratory sessions (Brooks et al., 2011).

Moreover, empowering teachers to provide input during PD programming gives authorship and approval rights to the teachers, fostering a sense of belonging within the authentic science research space (Shein & Tsai, 2015). Immersive professional development may be a key strategy for increasing teacher's science research literacy. By participating in workshops and PDs, co-run by scientists and science education professionals, teachers may find that connecting bridge to be a confidence builder. However, a new obstacle in bringing teachers and PD facilitators together has hobbled the United States since March 2020. the presence of COVID-19.

To align with current CDC Guidelines for keeping teachers safe and reduce the "occupational spread of COVID-19" (Centers for Disease Control and Prevention [CDC], 2020) alternative formats for delivering effective professional development workshops must be identified. The growing trend in higher education offering both face-to-face and online courses has been increasing (Garrison & Kanuka, 2004). Unfortunately, the need for traditional secondary education teachers to shift to virtual formats precipitated early and with little or no training. This situation has resulted in displeasure from parents and students with teacher perspective in the backseat (https.//educationdata.org/online-education-statistics/). In previous iterations blended learning has been utilized to not only create a space for learning not bound by geography, but to also serve as a scaffold before learners enter a classroom (Boulay & Raalte, 2014).

When the online component of a blended course or program is developed, an integral factor is the interaction of the participants. Too often virtual or online pieces are relegated to video or digital engagement (i.e., discussion boards or chats) (Keefe, 2003; Martyn, 2003). Other programs included questions and answers with topic-specific professions via video chat, following a demonstration (Pretorius, De Beer, & Lautenbach, 2014). Through examining a virtual versus hands-on comparison, some of the messiness of bench science is lost and accuracy may reign, (De Jong, Linn, & Zacharia, 2013) however it removes the authenticity of placing the tools of scientists into the hands of the learners.

To survive during these times of physical and social separation, training programs must be able to pivot and retain authenticity. When multiple, supportive facets of professional development are engaged even if teachers do not go on to utilize the skills in their classrooms, they may move on to mentorship roles and support others in related pursuits (Pretorius, De Beer, & Lautenbach, 2014). Through interaction of an online network, ComPratica, El-Hani and Greca (2013) illustrated that the having teacher's voices heard and allowing for engaging with peers and researchers was important for success and that by fostering a bridge between classroom and research, both sets of professionals will benefit from the relationship. Development of a community of peers engaged and interacting serves to support the learning and allows the participants to have their voices heard and given value (Garrison & Kanuka, 2004). Interaction between peers and professionals along with the development of community was noted as key to success in blended or hybrid models of professional development (Garrison & Kanuka, 2004; Pretorius, De Beer, & Lautenbach, 2014).

Summary: Professional Development. In developing PD, which is more transdisciplinary than unidirectional in benefit, literature has shown a need for a third-party participant. A pedagogical and content bridge between the world of science and science education is required to allow the bidirectional flow of socio-cultural habits. The bridge professional gives more substantial access to the (science) research literacy knowledge and allows the teachers to focus primarily on their coursework while incorporating the authentic science experience into their lessons. In longitudinal projects (Trautmann & MaKinster, 2005; Roehrig et al., 2012; Munson et al., 2013; Ufnar & Shepherd, 2019) professional bridge personnel are an integral part of the system that reinforces scientific mentorship and bring fresh aspects to the scientist-science teacher interaction. Also, scientists need to learn how to better interact with a diverse student body, recognize the importance of understanding audience background, and school curricular needs to better scaffold science experiences when working with teachers (Supovitz & Turner, 2000; Faber et al., 2014; Miller & Kastens, 2016). Additionally, within the past 20 years, there has been an increased use of videoconferencing technology for student engagement in classrooms and now more recently teachers are utilizing various forms of technology to have real-time meetings. The needs for virtual forms of engagement have skyrocketed with the 2020 COVID crisis. The growing base of technology allows for interaction and communication between teachers in a variety of geographic locals (McConnell, Parker, Eberhardt, Koefler, & Lundeberg, 2013). The core piece still missing is the hands-on activity. In developing a workshop that includes a kit for PD participants to use during the online sessions, I contend that teachers will have an equal grasp of the scientific techniques as a face-to-face workshop. Using a combination of available platforms will give science teachers access to both peers and collaborative scientists.

Gap in literature/research

For teachers to promote a scientific atmosphere, the literature in this review points to training that fosters authentic spaces in the school setting. Working in collaboration with scientists offers teachers ways to scaffold laboratory experiences that address the needs of their students and models scientific communication and behaviors (https.//www.nextgenscience.org/faqs). As a result, classroom teachers can foster a sense of science as a community practice at the same time as contributing to scientific research data (Lunetta, Hofstein, & Clough, 2007).

Findings from research were conducted on professional development (PD) and specifically the Scientist-Teacher Partnership (STP) for science teachers scaffold workshop programs, research collaborations, and professional development experiences for science teachers (Brown et al., 2014; Munson et al., 2013). These specialized PDs can solidify the long-term transference of science research literacy including content knowledge, habits, technical skills, and components of scientific inquiry to be utilized successfully, and in alignment to standardized assessments, into their classrooms. Teachers had increased their ability to use scientific inquiry (Koomen et al., 2014) in their classrooms with more confidence and grew in their adaptive abilities to work with diverse learning styles and modeled their learning during the PD, to mirror the guided inquiry lead by scientists. “Best practices” have been identified in multiple studies (Faber et al., 2014; Munson et al., 2013) with scientifically immersive techniques and the development of strong scientist-science teacher collaboration being common themes for proposed long-term success. But to not be remiss in noting the current public health concerns of Coronavirus Disease 2019 (COVID-19), avenues to translate these practices to a virtual-hybrid platform are being developed (Fitton, Finnegarn, & Proulx, 2020) to maintain the authentic, hands-on laboratory experience. I contend that further research must be done into not only the means of changing the way science is taught, but how it is utilized, by teachers, in the classrooms (Hasni, Bousadra, Belletête, Nicole, & Dumais, 2016).

CHAPTER 3

HISTORICAL OVERVIEW: LABORATORY TRAINING INSTITUTE PLUS

Laboratory Training Institute (LTI)

This ethnography traces the Laboratory Training Laboratory's development into the Laboratory Training Laboratory PLUS through a longitudinal case study spanning almost a decade. For the purpose of this ethnography I am comfortable framing as a case study, examining the evolution of the LTI into the LTI+, likening it to the qualitative study in science teacher professional development completed by Roseberry and Puttick (1998) who noted that "the strength of a case study is its attention to rich and textured detail; it allows us to see activity and interaction that a different approach might pass over." (p. 674) and further as a cumulative case study which serves "to aggregate information from several sites collected at different times… and will allow for greater generalization without additional cost or time being expended on new, possibly repetitive studies" (Shivakumar, K., 2012). This chapter will follow the journey of participants from the Laboratory Training Institute (LTI) through to the Laboratory Training Institute-Plus (LTI+).

The LTI launched its in-lab research training with 15 Greater-Urban City high school students in Spring 2013. This authentic way of learning to design authentic research projects was a new method, differing from other programs of the time that focus more on a lecture and observation format. Cooperative pairs of instructors trained the high school students in a dedicated lab space. Post-doctoral researchers, interested in faculty careers, were identified for the scientific leads and with a background of over twenty years (at the time) in science education, I was paired with them to not only help guide the students but act as a mentor for the scientist trainees for the 30-hour session held over ten weeks.

As a science educator, I could not help but wonder what if we could train high school science teachers in the same way and support them in conducting classroom research in alignment with district standards. That fall, over ten Saturdays, the LTI worked with 4 local high school science teachers, but it was a transformation moment when Colin held up an experimental sample and asked, "What can I do with this, on Monday, to help my students learn something about fruit flies?"

Shortly after, Colin and I met on a semi-regular basis to map out a basic project for him to use in the classroom. Working together, with research scientist lead, Siobhan, we were able to combine the protocols with the Urban City curriculum. Two of the original four science teachers took part in the first classroom research project and their students presented their findings at a science symposium hosted by LTI. Hearing the pride as they spoke about their findings, it was clear that this new approach of collaboration between science teachers and scientists was of real benefit for students and teachers alike.

Between the initial session in 2013, and 2018 the LTI hosted three more science teacher professional development programs. The final one funded by the international Biology Collective (pseudonym). This was meaningful not only to be able to provide materials and stipends to the participants, but it also identified the training being done for teachers as notable by a scientific society. Ten science teachers were selected through a general application process with the primary requirement being a statement relating to how the PD would support their work in the classroom. Science teachers were brought into the designated LTI lab and spent the first 4 sessions split between topic-based lectures given by scientists and laboratory benchwork projects led by former professional development science teachers. The fifth session was originally earmarked for the participants to deliver a short lesson, but as the week had progressed I wanted to address a growing concern that students could do authentic research.

I reached out to ten former student participants, who were happy to switch from learners to mentors. The young scientists were each paired with science teacher, playing off the original concept of scientist-science teacher collaborations, and walked their partners through a protocol of choice. The teachers were delighted to work with the graduates and the students had an authentic experience engaging the public in scientific research (Figure 2). Additionally, having the opportunity to engage with other science teachers and scientists in a collaborative environment would lead to further iterations of the LTI+'s professional development concept.

Figure 2

Immersive Professional Development Through Interaction with Scientists

Notes. Giselle and Kevin-Charles working with LTI graduates in the lab and PD participants engaging with scientists and LTI graduates informally discussing ways to bring research into their classrooms.

Soon after the successful professional development session, the LTI Scientific Director received an award from the Elon Musk Health Facility (pseudonym) to support a three-day PATHWAYS (pseudonym) conference bringing together researchers and educators from across the county. The weekend was filled with panels, seminars, and hands-on demonstrations for both scientists and teachers. Collaborative projects were developed and on the final day, local students were invited to work with the scientist-science teacher teams and present why their projects should be used in classrooms (Figure 3). Hosting scientist-science teacher pairs from New Jersey to California gave the opportunity to see firsthand if the core concepts of this collaborative system would be transferable to other cities outside of Urban City (Li, J. & Pilz, M.; 2023). This would also have a future impact on the design of the new LTI+ curriculum.

Figure 3
PATHWAYS Conference

Notes. PATHWAYS participants engaging at Urban City's Museum of Dinosaurs (pseudonym). Urban City students learn from collaborative teams in an authentic laboratory space on the University campus. The PATHWAYS participants.

During the interim, of the 2018-2019 academic year, science teachers from all the previous PD's and the PATHWAYS conference participate in classroom projects tipping the scales with over 1000 local high school students participating in authentic research projects, plus an additional 50 students in other states. In previous years, the students and teachers would be invited to the LTI to present their work but the shear number of students scientists prompted the LTI's External Advisory Board, including institutional leaders, faculty, education faculty, and researchers from both biomedical and social fields, to prompt the LTI to host the symposium at the Washington Conservatory. Additionally, the LTI program directors were supported by the Institution's leadership team and with advisement of external advisory board for 1 day/week outside the walls. with leave of time to launch the LTI+ because the LTI had expanded beyond the capacity of the original institution and its stated mission.

Laboratory Training Institute- PLUS (LTI+)

Spring 2019 is when the Laboratory Training Institute- PLUS was incorporated as a new Urban City public 501(c)3 nonprofit and my co-founder and I entered into a local University's annual business education plan competition, winning two of the three prizes awarded. This was the seed funding to get the LTI+ off the ground. Given that we were known in Urban City for biomedical research training, our social capital gained LTI+ traction in building collaborations for in-school and out-of-school programs in the Urban City region. We were happy to know that all of the young student scientists and their teachers would continue to have access to authentic classroom research programs. As the calendar began to fill for programming in 2020, news of the pandemic began sweeping around the globe.

Once the coronavirus state-of-emergency landed in the United States it was only a matter of weeks before schools, universities, and research laboratories shut down access to students. One by one the program hosts contacted the LTI+ to cancel sessions. It was a dark time for both research labs and science classrooms. Not to be deterred by this seemingly insurmountable obstacle, we thought outside the box and then using the collaborative style that served us well in the past to solve this problem. We developed a new and exciting method of teaching authentic biomedical research through kits sent to students and teachers at home. The LTI+ reached out to the participants of the PATHWAYS conference, knowing that students would meet their early research training goals for acceptance into laboratories. Twenty students nationwide participated in the inaugural Undergraduate Bridge program, summer 2020. This new virtual-hybrid model brought depth to the transferability of LTI+ programming. Through labs@home, online learning management systems (LMS), and virtual conferencing platforms the LTI+ was able to synchronously put authentic research projects into the hands of young scientists across the country. In addition to the undergraduate program, the LTI+ launched a series of labs@home summer camps for middle and high school students. Because of the demand during lock-down, we reached out to former PD science teacher participants and LTI graduates, now in college isolation, to invite them to join the LTI+ team and scientist-science teacher collaborative partners.

Immersive training took place online and the LTI+ supported these engaged instructors in becoming comfortable with making labs@home and inviting student scientists to do the same. As a team we did troubleshooting on the fly, figuring out solutions quickly because there was no reference to lean into. As the instructors gained confidence the discussion became focused on the upcoming academic year. These instructors found ways to blend their engagement styles, learned how to keep students in the moment during the sessions, and encouraged the students to share their findings during presentation days. Once the school year began, the science teachers, that completed the immersive training through the virtual-hybrid summer programs were excited to share this new learning method with their students.

CHAPTER 4

METHODOLOGY

Social context

Drawing on the socio-cultural context of scientist-science teacher collaborations, I identify best practices used to create cooperative networks of scientists and science teachers. Scientists working alongside teachers allows for enhancement of both fields through mutual learning and teaching (Mansour, 2015). With teachers having science research literacy advancements made through collaboration with professional scientists, the cultural reproduction of science practices fosters early student interest regarding inquiry-based studies (Munson, Martz, & Shimek, 2013). I assert that once engaged in the practice of scientists, teachers take on the role of scientific mentor, much like that of the principal investigator in a research laboratory. As students engage in pre-professional training in the classroom laboratory, the cultural reproduction of science research literacy and scientific habits more closely align to that seen in professional research settings (Claussen & Osborne, 2012).

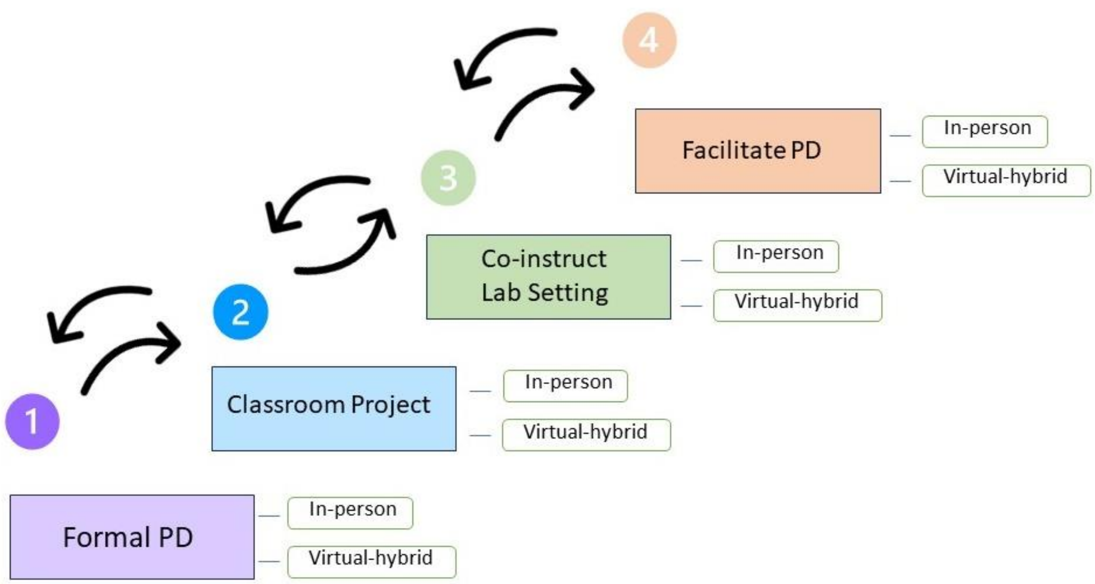
As the science education director of an informal science research training program, I work directly with faculty-level research scientists to identify points of interaction between the scientific research world and in-service teacher learning. My professional interest is in the development and improvement of professional development (PD) programs for science teachers to support students' critical thinking skills and the application of authentic research experiences to address real world concerns. Interspersed within my science education background, I have worked in various academic research laboratories each with researchers at various stages of training, from high school students to post-doctoral researchers. By merging my content knowledge and pedagogical knowledge I have developed a collective toolbox from which I draw the ability to teach in formal and informal spaces. This set of tools enables me to lend a classroom-like structure to PD sessions held in a laboratory and supports my ability to recreate micro-laboratories within classroom settings. Additionally, through my professional work, I have been able to pilot collaborative PD models involving science teachers engaging with research scientists. Through these initial interactions, it was clear that scientists can model authentic science research practices, through instruction, for science teachers learning to utilize these methods in their classrooms to meet rigorous science standards (Koomen et al., 2014).

While studying in a master's program for Math and Science in Secondary Education, I embraced opportunity to take novel coursework at local museums and aquariums. This opportunity, to study like a researcher and not just within the walls of a classroom, resonated with me. Having learned earlier that I preferred visual and tactile learning, laboratory work was a joy. But I also found that when I could put my hands into the work the understanding was that much deeper than if I tried to only read about the topic. Leading a local research training program opened the door to sharing the experience of working and collaborating in a research laboratory with science teachers. Since 2013, I have worked with 17 teachers in the lab and over 100 in science professional development and in informal education venues. These participants were from various scientific and educational backgrounds. Focusing on the in-lab participants of the teacher-training, some teachers started to move lessons, ideas, and concepts from the lab to the classroom. Through this transition, I found myself more curious about how they interacted with the materials and concepts. A few have re-created the training lab in their home classrooms by design, but this study is designed to look through an interpretivist epistemological lens, to see how far they have taken the attitude and atmosphere of the lab into their schools.

Settings

For this study, participants were observed in several locations. Not all participants were observed at each location. Some participants were observed in only 1 to 3 environments and others in 4 to 5 settings. It is of importance to note that the immersive training is not strictly linear, purposefully designed to allow reengagement back into the training at various points as represented in the model shown in Figure 4.

Figure 4
Model of Dynamic Progression



Note. The immersive professional development designed by the LTI+ supports science teachers at every level and through various engagement options.

Roles of participants shift from setting to setting moving from participant-learner (attendee at first PD) during initial engagements to participant-instructional (participant has worked with their own class students and moves on to co-instruct for LTI/LTI+) role.

1) Laboratory Training Institute site located either within the Urban City limits or 10 driving minutes outside of Urban City, accessible by public transit. This professional development runs from 3 to 5 days for 3 to 5-hour sessions.
    a. This is a fully developed, immersive professional development.
    b. In this setting I was an active observer, only engaging if there is a gap in training method critical to understanding a scientific concept. This allowed time for note-taking and critical observation.
    c. Senior instructors were the primary leads for this session.
    d. This session was run in Winter 2022 and due to the restrictions set by the COVID pandemic, the professional development session was moved to a virtual-hybrid model.
2) At collaborating institutions hosting 5-day 30-hour summer outreach programming for students in middle- through high school.
    a. This is a subsequent stage of immersive PD where selected participants co-instruct and further learn by doing. Participants are selected based on interest and availability.
    b. Senior instructors were the leads for this session.
    c. I was strictly an observer.
3) At the schools of participants in the Urban City Metro-Area, for single class sessions, up to 4 class sessions to complete a full data-set project.

    a. This context also took place via Google Classroom or other learning management systems as necessary for public health.
    b. I was an active observer, when classroom students had a direct question regarding the experimental technique, I responded.
    c. These observations took place during the 2022-2023 academic year.
    d. Participating schools are all be under-resourced school districts that are designated as Title I and located in the mid-Atlantic region of the eastern United States.

4) Via host programs or science education PD events within Urban City.
    a. These programs were various lengths of time, 45 minutes for a single engagement up to 5 hours spread over 3 engagement meetings.
    b. Participants were interviewed and made aware of additional classroom projects for future engagement and observations.
    c. I was the lead instructor for some events or programs and entered field notes into a personal log following the sessions. Permission to audio record was requested. For the other programs, instructional participants lead the sessions as an immersive training layer.

5) Laboratory Training Institute site is within the Urban City limits or 10 driving minutes outside of Urban City, accessible by public transit.
    a. Participants engaged in immersive learning-by-doing PD by co-instructing undergraduate level laboratory training sessions. These programs run for 30 hours.

b. I was an active observer helping to guide and focus the instructional participants for the optimal learning experience of the students.

c. Student learning objectives and goals were not the focus of this research.

6) As allowed by administration and temporal constraints, an initial observation was made in each of the participant's classrooms prior to their immersive PD.

    a. An initial observation generated a baseline for the participant in their home classroom and served as an observational comparison following the PD and implementation of new habits, skills, communication in aligned with required curriculum.

During the extended public health crisis, in 2022, face-to-face programming was suspended, and professional development was launched in a virtual-hybrid format with lab stations being sent to the participants. This LTI+ train@home method was also employed to safely engage instructional participants in the immersive training sessions for student learners. All virtual-hybrid sessions ran with LTI+ as the host and were recorded with participants and parent's (if participants were under 18 years of age) knowledge. No information or data on individual student learners were collected as a part of this research. The virtual hybrid sessions can be accessed using a variety or combination of devices. cell phone, tablet, or computer. All the programs conducted a lab-safety check, including those that ran while maintaining social distancing practices.

Participant Selection

The primary participants of this study are life science teachers, including middle- and high school levels of life sciences. For this study, I define life science courses to include middle- and high school level classwork covering content which include development of living organisms, life cycle, organisms interacting with their environment, organisms at a cellular level, health science, biology, and anatomy/physiology. The participants span a range of academic levels, including vocational/technical/academy, general, honors, advanced placement (AP) and/or International Baccalaureate (IB). Participants self-selected to take part in a teacher-training program (PD) run by the Laboratory Training Institute of Urban City. All names and locations were assigned pseudonyms for the study.

Participants for this ethnographic research were recruited based on the procedures identified by Arcury and Quandt (1999).

1) Define participant characteristics (age, gender, level of education, years teaching, subjects taught) then report on inclusion and exclusion criteria.
2) Generate a site list, including schools, neighborhood, and district.
3) Contact the “gatekeeper” (p. 129) at the site to identify location characteristics and statistics, including advanced placement (AP), (IB) vocational, magnet, charter, etc.) and student population (grade, gender, ethnicity, standardized exam scores, etc.).
4) Recruitment at site, shared information with the gatekeeper to disseminate to site teachers explaining the workshop (duration, materials, etc.).
5) Create a table to record the characteristics of participants selected through recruitment process (Table 1).

Profiles

Characteristics

Ideal subjects for this study were in-service science teachers in possession of a minimum bachelor's degree. Subject matter and experience in research science was not a disqualifier. However, interest in life science, biological science, health science, environmental science, or biochemistry were required. Age, gender, grades that they have or currently teach, and number of years in service were identified but were not qualifiers for selection. Applicants with informal science education or formal classroom teaching experience were encouraged to apply. While not a qualifying characteristic, types of academic institution or schools were identified, along with the applicant's role in the school or program. Following the success of the pilot programs, applications were accepted from PA, NJ, and DE. For this study, ten participants were selected. Research participants' characteristics are found in Table 1.

Table 1
LTI+ Professional Development- Participant Demographics

Instructor	Teacher	Age/ Gender*	Race & Ethnicity*	Highest Degree held	Years taught (formal)	School- type	Hours in formal PD (LTI/LTI+)	Participated in classroom projects (years)	Co-instructed as immersive PD in laboratory
1	Kevin-Charles	44/M	Black	Master's	20	Public- Neighborhood	21	3	✓
2	Marisa	38/F	Black	Master's	4	Charter- Academy (Private, religous)	6	1	
3	Brian	33/M	White	Master's	10	Public- Neighborhood	6	3	
4	Imma	46/F	Black	Master's	23	Public- Neighborhood	6	2	
5	Madison	43/F	African-American	Master's	6	Public- Neighborhood	6	1	✓
6	Collin	56/M	White	Master's	28	Magnet	30	10+	✓
7	Giselle	29/F	Black	Master's	6	Public- Neighborhood	15	5	✓
8	Jonathan	43/M	White	Master's	16	Magnet	3	6	

*Self-defined

Notes. Participant demographics including gender and race were self-defined.

Professional Development Participants

The five formal professional development participants (Figure 5) included in this research all teach biological or life sciences classes in Urban City. All but one is from the public school district Two are males and three are females. Three of the five participants are Black, one is White, and one is African American. All genders and races are self-identified. All participants have obtained at least a master's degree. At the time of this research, their experience as educators in middle- and high school classrooms ranged from just over two years to over thirty years. One participant took part in a previous five-day professional development run by LTI but was not able to incorporate the classroom projects formally. This PD was the opportunity they were waiting for to reengage with LTI+. Additionally, one participant of a previous 90-minute workshop, PD event joined the classroom project and was included in the second round of interviews. Finally, four of the participants had direct or indirect knowledge of or engagement with LTI/LTI+ prior to this study. This could be in the form of programming run at their schools in which they were in the role of observer or through interaction with colleagues that had a previous connection with LTI/LTI+.

Of the initial nine professional development registrants, three opted out of the research for distinct reasons and one was unable to attend the session during the 2022 session. The second of two prior professional development participants began the classroom project but due to COVID-related technicalities also opted out of the research.

Teacher Scientist Instructors

The instructional leads for the main research PD are two former professional development participants (Figure 5). They have been co-instructing immersive programs and facilitating classroom research for between 5 and 8 years, at the time of this writing. They are at the highest level of immersive PD, taking on the role of mentor and collaborative instructor for other science teachers. Teacher scientists will be recognized as science teachers that are adept in balancing content knowledge and pedagogy as they relate to authentic research. The final two interviews were conducted with two teacher scientists, both urban city science teachers each with a master's degree in education. This training of additional teachers has been identified as the upper tier of the immersive training. One instructor is a black female, who has been teaching for less than 10 years and the other is a white male with over 30 years of teaching experience. Their races and genders were self-identified. Both instructors were participants in previous iterations of LTI professional development workshops and have been running collaborative LTI and LTI+ projects in their classrooms for at least five years.

Figure 5
LTI and LTI+ Professional Development Participants

Notes. LTI 2013 inaugural 30 hour PD participant. Colin; B. LTI 2018 PD participants. Giselle and Kevin-Charles; C. LTI+ 2022 PD participants Kevin-Charles, Marisa, Brian, Imma, and Madison, collaborative scientists, and teacher scientist instructors Giselle and Colin.

Recruitment

Beyond recruitment on site, I posted flyers and advertisements on various social media sites and using my available social capital requested that various collaborating institutions, programs, meeting coordinators, collectives, and other science-education platforms post a call for applications. The initial call was for a three to five-day teacher workshop designed to develop science research literacy and make it translatable for the classroom. Course materials and programming aligned with local and NGSS standards and collaboration with peers and scientists were emphasized.

Professional Development

The original LTI training session evolved over the last seven years of iterations, which included refining protocols and techniques to enable science teachers to have the skills to transfer the projects to their classrooms. Learner participants were reintroduced to basic research laboratory tools and techniques including pipetting, the need for understanding dilutions, and solution making. Drosophila melanogaster (fruit fly) was introduced early as a model organism and discussion was supported by vetted internet sites to explain their use in the study of various diseases including cancer and diabetes. With each level of increasingly immersive training, additional vocabulary, and science content for use of basic scientific tools and techniques were added. This iterative process intends to build confidence and increase the comfort of using technical terms during sessions as an instructor-participant. Frameworks for lectures and technical skills were provided with the goal of participants adding their own style while staying true to the material and context. Participants were encouraged to build-out materials to address the questions, needs, and concerns of their classroom population’s neighborhoods, families, and/or culture. This approach is intended to promote culturally relevant experiences within the context of the scientific one. Science teachers were offered opportunities to collaboratively engage in the development of lessons which overlap the curricular requirements of their school and district.

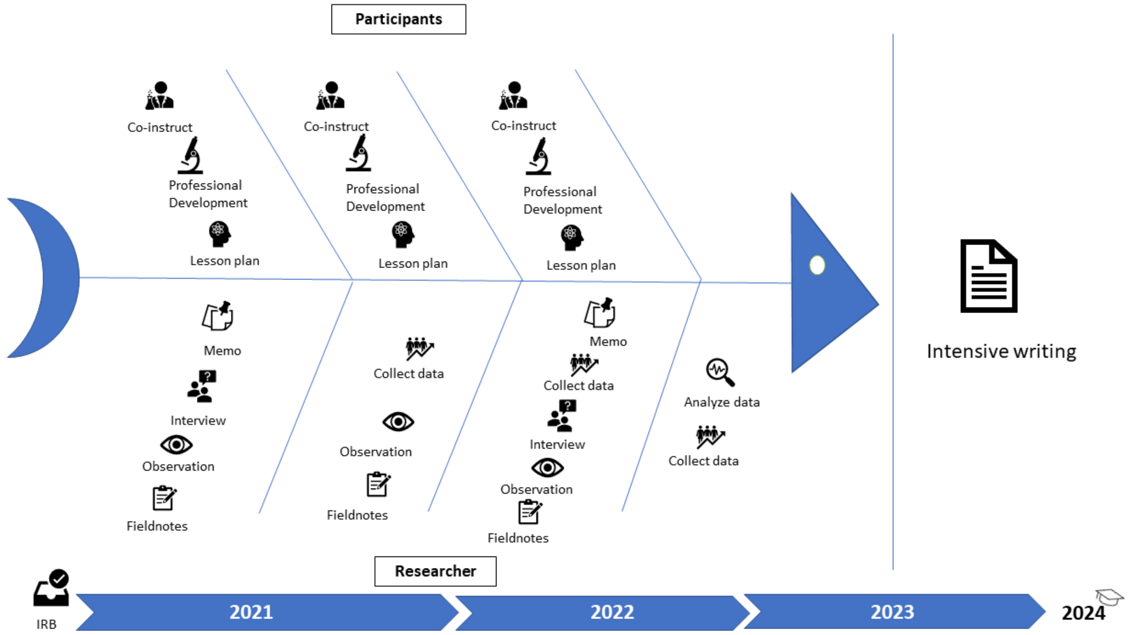
Accounting for the challenges of the pandemic, the professional development session for this research was moved from the end of 2021 to early 2022 allowing PD participants time to recharge over winter break. LTI+ designed this recent PD to be virtual, using a hybrid design initiated for their programs starting in 2020 at the peak of the global crisis.

Timeline

Laboratory Training Institute- Plus (LTI+) facilitated the professional development training sessions to run for 9-hours and the call for participant application launched in late spring/early summer 2021 (Appendix A shows the evolution of the PD call for applications). Participants worked with collaborative scientists to run Face-to-Face and/or Virtual-Hybrid, 5-day summer outreach programs in collaboration with various host institutes located in and around Urban City. These sessions were designed to run in either a face-to-face or virtual-hybrid format. Participants began using the protocols and curricula designed through the immersive training, in their home classrooms (Appendix B) following LTI+ programming. Some participants were co-instructors of a 5-day, summer camp LTI+ programming and then a 30-hour, undergraduate-level, laboratory training program in 2022 or 2023. The culminating immersive training was marked by participants leading a teacher PD in 2021/2022. Observations were made at the laboratory, host institutions, and participant classrooms, either in person or via an LMS. Observations in classrooms consisted of at least one laboratory lesson. Observations, in all settings, were made until I was satisfied that the story can be told with an organic flow and within the limitations of the academic year (Figure 6).

Figure 6

Research Study Timeline



Notes. Fishbone timeline highlights the participant's and the corresponding researcher's activities from 2021 through 2024.

A multi-subject ethnography of science educators, was performed over the research period which will include observations, during the following, non-linear events.

1) A three-day immersive PD, led by collaborative team consisting of a research scientist and a science education professional with both laboratory and classroom experience,
2) observations of participants engaged in science teaching within a classroom science learning space,
3) observations of participants engaged in science teaching within an informal learning space such as a research laboratory, virtual research laboratory, or research camp, and

4) observations of participants engaged in facilitation of PD for other teachers, to be held at school district approved school sites or through other science education workshops.

Using an ethnographic lens, as a means of qualitative research, allowed the researcher to be a part of the project and not just a passive observer. This method of study allowed for cultural and environmental components to be accounted for during the study (Brandt & Carlone, 2012).

The University's Human Subject Institutional Review Board approved the research timeline (Appendix C), and further approval from site administrators was garnered at the initial stages. Participants attended a pre-training meeting to discuss the project and invite them to become participants in this research. Participants and I addressed setting up a neutral location for the interviews.

Data Collection and Analysis

As an ethnographer I am the instrument for data collection (Guba and Lincoln, 1982) and I utilized a variety of means to capture the interactions either in face-to-face and/or virtual-hybrid settings, based on safety circumstances. To set the stage for observations and eventual peer review, I provided thick description of the settings, participants, and engagement in field notes (Guba & Lincoln, 1982). Data was collected by different means to address my three research questions (Appendix D) from various field studies. at the participant's schools, Laboratory Training Institutes sites, during PD sessions, and summer program host institutions. I identified patterns in their methods of instruction, interactions with students and scientists with the goal to detail differences, if any, paying particular attention in final phases to detect any changes in science research literacy in the participants classroom setting. Once findings emerged from the media-recordings, and observations, I conducted a literature search to see if corroborating data has been published and included in writing my analytical memos. In speaking with collaborative scientists and PD instructors, I listened for insight into participants' developing science research literacy through story-telling and informal interviews. Prior to observations, interviews, or other forms of data collection the subject(s) reviewed an informed consent document (Birt, Scott, Campbell, & Winter; 2016). Below I describe in detail my methods for data collection analysis.

Interviews

Interviews were held with the science teacher participants to examine their expectations and outcomes, to inform decisions in the creation of future PDs, and for identifying the strengths or weakness of the current model. One pre-interview per science teacher participant was executed prior to the start of the most recently scheduled PD and one post-interview per science teacher participant at the conclusion of the most intensive PD they choose to complete. Participants from earlier cohorts and those completing the classroom project during this period were interviewed. For comfort of the subjects, interviews were conducted at a neutral location during "off" hours and not during the academic time of day. Efforts were taken to not simply discuss the events of co-instruction but to be formal interview questions (Appendices E, F). Participants were asked for permission to audio recording interviews and during instruction times. Science and research are known to have a language (Wallace, 2004) of its own and is part of the research culture. As such, it will be treated as an anthropological ethnography where "language is the primary medium for the symbolic content of culture" (Black, 2017, p.

47) and interview questions will be couched in science research literacy terms. All interviews will be transcribed for further data analysis.

Observations and Field Notes

As situations in classrooms, training labs, or virtually arose in which I played the role of active observer, my goal was for all participants and PD leads to behave as naturally as possible. My field notes were recorded within a few hours of concluding the session or lesson. As situations allowed, I made on-going notes to be written within 24 hours of the jottings (Emerson, Fretz, & Shaw, 1995).

I planned to observe each participant one time in each setting for those participating in one or two PDs. For participants engaged in three to five PDs, I conducted one observation for the first two PDs, and two observations for each PD thereafter. In each, I took the role of active observer and allowed for interaction with collaborative scientists, science educators, and peer-participants. As a science educator with over fifteen years of work in scientific research spaces, I focused on identifying how teachers take up the vocabulary and positioning of the scientists. Attention was paid to how the culture of laboratory research was reflected in the science teachers' stance in the classroom and noting any advancements in science research literacy.

Fieldnotes were written as soon after field interactions as possible. Jottings taken in a notebook served as a guide to separate observations pertinent to the study from "background noise". Environment notes were taken to help define the space in which science teaching and learning is taking place. Visits to field-site were guided by questions linked to this research study to maintain consistency between participants.

In-process memos

Analytical memos were written at intervals following observations or discussions with participants. These memos allowed me to have reflective periods to mentally discern any patterns or identify a line of questioning I wished to further investigate (Emerson, Fretz, & Shaw, 1995) and through my writing see past my own preconceptions (Richardson, 2000) and see my everyday with new eyes. I also returned to the literature to begin theorizing my findings.

Artifacts

Artifacts included lesson plans (pre- and post- PD), student assessments or assignments, and classroom lab exercises. Artifacts were collected and coded. The following items were requested from prior to the PD, during development, and following the PD used for comparative data. The items requested included 1) lesson plans and course syllabus, 2) lecture notes and complementing slideshows, and 3) laboratory assessments.

Data Analysis

Constant comparative analysis was completed on all collected data, including interviews, observations, fieldnotes, and memos. All collected data was sorted and put into initial groups, with definitions or descriptors aiding in clarification with patterns identified (LeCompte, 2000). For each code, I created a definition in a master file. On the first pass through the data, I coded both inductively (guided by participants' words) and deductively (guided by the literature), developed axial coding, then created categories, and developed these into themes. To support sense-making, I analyzed all the teachers together as one "case" rather than viewing each teacher as a separate case study.

Additionally, through evocative writing (Richardson, 2000) I gained insights into the construction of science research literacy by the participating teachers and my own practices as a facilitator.

Trustworthiness and Credibility

Credibility

Data from ethnography is unique, and results are not easily transferable to other contexts. Also, my findings are my own interpretative analysis. However, to maintain good-will between the ethnographer and subjects, subjects were able to participate by member-checking transcriptions to ensure accurate representation and overall feeling as it was perceived by the interviewer (Mero-Jaffe, 2011). Prior to data collection the participants were able to review an informed consent document (Birt, Scott, Campbell, & Winter, 2016).

Dependability

An audit trail was generated as a means of dependability. This written recording outlined the stages of the project and pinpoints steps where choices were made in the research design (Guba and Lincoln, 1982).

Peer debriefing

Once codes were identified from the data another graduate student from the department was asked to code portions of the data. We then discussed differences in our coding. This process allowed for new perspectives and clarification of my original codes (Mertens, 2014).

Informal Member Checks

Following participant interviews, a few minutes were spent to review any notes that I had taken to ensure that I captured the correct feeling from the speaker (Tobin & Begley, 2003; Mertens, 2014). This procedure was not simply a means of maintaining good-will between subjects and research, performing member checks of transcriptions ensured accurate representation and overall feeling as it was perceived by the interviewer (Mero-Jaffe, 2011).

Validity

By spending at least, a year working alongside participants and engaging within the research-culturally rich spaces enabled me to collect longitudinal data analysis. Additionally, all observations took place in scientifically natural locations (LeCompte & Goetz, 1982).

Triangulation

Triangulation in this research served to "offer completeness" (Tobin, 2004 p. 393). Due to the natural of this ethnography I will use various sources of data to create a rich tapestry and more complete view of the enactments. This data may include interviews, observations, artifacts, jottings, and member checks.

Ethical Considerations

As the Co-Director and Chief Learning Officer of the Laboratory Training Institute-Plus and Education Director of the Laboratory Training Institute, I will not have a role of authority over participants. The Chief Scientific Officer and Co-Director of the Laboratory Training Institute-Plus and Scientific Director of the Laboratory Training Institute will serve as the primary "manager" and is the point person to discuss possible joint funding opportunities with the participants once the research was concluded. Siobhan Murphy, Ph.D. (pseudonym) will not be included directly in the study to minimize conflict. Selection of the professional development session was participant driven.

My role in the proposed study will be as ethnographer. All participant schools signed a Materials Transfer Agreement in place with the Laboratory Training Institute and agreements in place that no obligations for grant participation were expected. Participants reviewed a consent form that was based on those from the Temple research administration pages. Participant school administrators were informed that by participating in this ethnography, no promises are being made for future grant collaboration. The consent addressed who will and will not have access to the data.

All data was password protected and de-identified and stored on a private computer. Codes were used to identify transcriptions of interviews. A key of codenames (pseudonyms of the participants) is kept in a separate password protected file.

CHAPTER 5

FINDINGS

Science teachers and schools, nationwide, are being tasked with aligning curriculum to standards designed to engage learners as pre- career scientists. This comes with intrinsic challenges not limited to finances and classroom population burdens but can include the pre-professional training for science teachers. Through this ethnographic study I aim to critically address the needs of science teachers through a series of professional development sessions by asking.

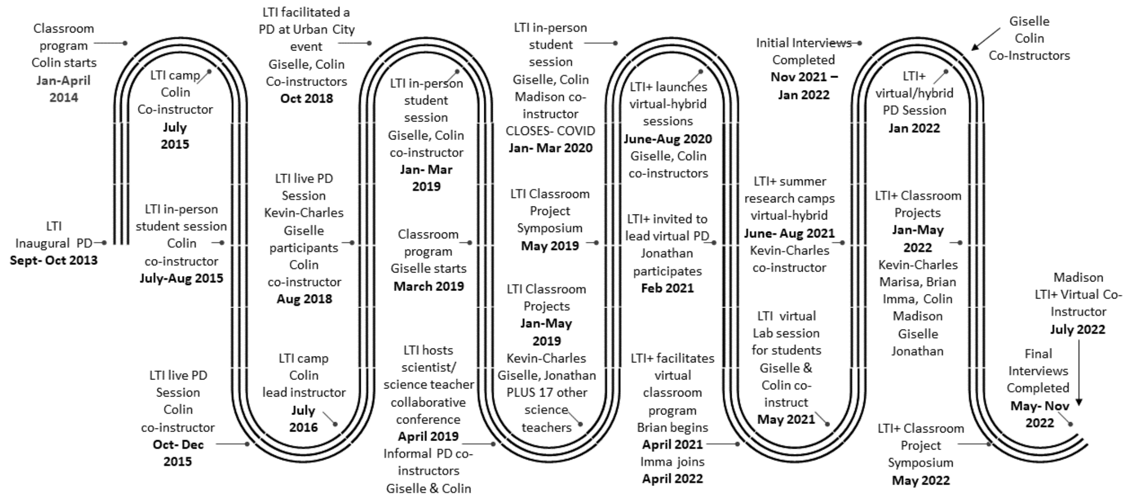
1) How is science research literacy conveyed via immersive professional development?
2) How will teachers use their science research literacy skills to enhance their teaching of science?

The Laboratory Training Institute (LTI) had its inception in 2013 with the launch of its first research training program designed for high school students in the Urban City catchment area. It quickly grew to include a science-teacher focused program through which the student scientist population exploded in the region to over 1,000 student scientists in 2019. Exceeding the capacity of LTI, and under the advisement of the LTI external advisory board, LTI+ was incorporated with a formal release of time and effort from LTI in the same year. All classroom, out-of-school time (OST), and teacher training were suspended from LTI. Launching in 2019, LTI+ developed all hybrid, virtual, and live programs for current outreach programs.

Participants in this research were members of the 2013 and 2018 cohorts along with members of the virtual LTI+ professional development which resulted in a new platform for training brought on by the outbreak of coronavirus (www.who.int). The 2022 professional development (PD) series, presented by the LTI+, began with a three-day virtual research@home workshop. Use of these lab-in-a-box training systems has been proven to promote biology learning and has been found easy to use for learners and designed to prepare at-home student scientists for an authentic research experience (Hanley, C. D., Ho, J., Prichard, C., & Vanderford, N. L., 2022) mirroring the research that has been conducted in dedicated research spaces (Ruiz-Whalen, D. M., Aichele, C. P., Dyson, E. R., Gallen, K. C., Stark, J. V., Saunders, J. A., ... & O’Reilly, A. M.; 2023). LTI+ has been developing research stations (lab-in-a-box) for use during home learning since 2020, launching at the height of the COVID pandemic (Waddell EA, Ruiz-Whalen D, O'Reilly AM, Fried NT., 2021). Ten science teachers were originally enrolled in the PD, but this reduced slightly by the time of the PD, one participant withdrew from the session due to conflicts in time obligations. The remaining nine participants were supplied with PD materials aligned with each one’s topic of interest. As a member of the LTI/LTI+ and the ethnographer, I explained that all research selections would be self-selected to support the participant's community. A hallmark of the LTI+ is to allow participants to engage in meaningful research and to define for themselves what constitutes community.

Each member of the cohort received a training kit for use during the PD and future classroom engagement. Following the initial formalized PD, the cohort number reduced to five teachers, self-selecting to participate in the classroom informal professional development. The LTI+ supported classroom projects were precursors to the post-PD interview. Two additional instructors took part in this research as former PD participants and currently serve as instructors. The final research participant was enrolled in a 90-minute workshop hosted by LTI (Figure 7).

Figure 7
Nonlinear LTI→LTI+ Professional Development Timeline



Notes. Nonlinear timeline highlighting when study participants took part in immersive professional development. Once a participant completes the classroom project, they have been retained in following academic years.

This research was grounded within a socio-cultural theoretical defined by the hands-on activities the participants engaged in during the learning process, giving them ownership over their projects and allowing for a multidirectional flow of information. Archer et.al. developed the idea of science capital growing from socio-cultural capital into its own form of currency. Further allowing the trained to parlay upon their capital as they progress through stages of professional development (Archer, Dawson, Dewitt, Seakins, & Wong, 2015). Additionally, this dissertation focuses on shared laboratory practices, as well as the cultural context and background of the teachers in this study.

In the following chapter, I present a multi-subject ethnography performed over the course of the immersive training and carried into the teacher's home-classroom provides qualitative data. These findings are a result of analyzing a series of observations, pre- and post- interviews- with the participants-, and a collection of artifacts, to show reflections in science and socio-culture changes that took place within each of the subject's home-classrooms. Classroom research projects, led by participants, and instruction of other science teacher participants were defined as immersive trainings beyond the formalized PD. Data, from the interview, observations, and collected artifacts, were triangulated for validity. That is, multiple sources of data were used to corroborate key findings and to substantiate conjectures.

Following the discussion of the participants, I define terms associated with science research literacy as it pertains to incorporation into the classroom and as levels used for tracking growth among the participants. Finally, I will describe the emergent themes that have been identified following the review of the data. The themes that appear in this chapter are ones that serve to address my research questions.

Three major themes that aligned with my current research questions were identified, mapped across my two investigative questions, and moved forward for deeper exploration. The first theme will examine several ways that science research literacy becomes authentic for science teachers. This will be explored through meaning making of the research allowing their students to guide the questions. The second theme explores how the participating science teachers position themselves as "teacher scientists" through engagements with other participants, in their interactions with community members, and how their footing shifts as they become comfortable in fine tuning protocols to suit the needs of their students. The third and final theme delves into the participants' incorporation of science research literacy into their classrooms, including the examination of the transition from simulated science to hands-on engagement, the design of micro-labs to mirror authentic research spaces, and the ability to involve their students in citizen science via a virtual platform.

Key Themes

Theme 1. Science Research Literacy Becomes Authentic

Investigative Question 1. The use of "literacy" has come to occupy many fields of study including digital, finance, health, and math but the core meaning revolves around the ability to communicate through various form of language, actively listen as part of conversation, and be able to a conceptual understanding the topic. As literacy of any kind is developed, the learner's bank of knowledge grows. Through pre- and post- interviews with the study participants, I delve into what the participants' prescribed definition of science research literacy was and will examine reasons for change, if any.

Prior to the PD, the participants defined science research literacy in several ways including 1) as something specifically related to the reading of science [articles], but with the purpose of doing something deeper with the data and 2) information such as extending the research or producing new questions. In these examples, the participants speak of scientific research readers in general terms. Below Brian and Jonathan speak about reading scientific articles and finding ways to use the data.

> So I would assume that it has to do with actually reading research for the sake of pulling data and the explanation behind it. Also, learning how to deal with the vocabulary and the terminology behind it. (Brian. Pre-Interview)

> Okay. So it's the ability to read and synthesize the information to understand what is being talked about, as far as the scientific topic or topics. And how one might approach thinking about these scientific topic or topics going forward. And what kind of questions have been answered, what kind of questions still are waiting to be answered, and what kind of questions have not been asked yet? (Jonathan. Interview)

There were cases that took this concept of understanding what was written and were more focused on how students might work with the readings. Colin and Marisa spoke about how through science research literacy, students can make connections to their surroundings and feel empowered by what they are doing.

> For me, what it means to me would be that my students or anybody, because it's a community thing, that anybody could be able to read some scientific data or research and understand what the data is showing and how it relates to their community or the problem that the experiment was going at. So, I think it should be something that it should be available to everybody. That's what literacy means to me is that everyone can read and understand it, and it's in terms that they understand. And yet, it could be still a hard concept, but we're not necessarily talking down to them. (Colin. Interview)

> I guess I would say science without the fluff and I guess I say that a lot because sometimes we can't get caught up in all these terms...I guess a science understanding, an academic understanding of science, but it has a lot of fluff. It's not always in the easy to understand way that kids can say, "Oh, that's what you were trying to say. (Marisa. Pre-Interview)

Above, Colin and Marisa have both shared the importance of students being able to get to the root of research through reading and how the language of science should not be a barrier for understanding deep scientific concepts.

For Madison, a shift in defining science research literacy occurred following the LTI+ PD and classroom project. What made these interviews interesting is that Madison is a classically trained scientist who had only just completed a science teacher residency program. Madison had begun immersive training, in the LTI lab, but this was abruptly halted when the pandemic closed laboratories and schools. Her mind-set has clearly shifted in terms of research and the types of research that exist.

> Madison: How I put this? Having an understanding of a question that was asked and how it was investigated. Just understanding those basic

components in order to understand the value of whatever the data might be. (Pre-Interview)

Madison: Science research literacy. I love this question because one of the things I really want to do is expose the kids to reading scientific journal articles. Not going super hard, but at least teaching them what those sections mean, how to read... I want them to not be afraid of it or intimidated by it, but instead be curious to find out what some of these terms mean.

Dara: So, when you say the terms, you're talking like the scientific terms?
Madison: Scientific terms, yeah. Yep. Scientific terms. So they feel comfortable. But I want people to make decisions based on truly understanding what it is you're being told, what is you're reading, and then you decide how you want to feel about it. But the world we live in is a science world, I mean, that's where we are right now. And I feel like they'll be left behind if they don't have that. And I feel like now's a good time to start. (Post-Interview)

The pre- and post- discussion above highlights Madison's focus moving from having a grasp of the basics to being able to work with the data into a more visceral concept. This shift could be seen as a reflection of her pivot in careers from an academic scientist to a science education professional. She wants to empower her students to push back and take ownership over what they are reading versus following along with what was already written by a professional scientist.

Kevin-Charles' academic journey was the almost the opposite of Marisa, having started his undergraduate work in the sciences and yet had not been trained in a laboratory, he pivoted into education and has been teaching for over 20 years. His deepest connection to scientific research has been through participation in two professional development programs (LTI and LTI+), engaging his students in citizen science, and becoming a co-instructor for LTI+. Co-instruction is another level on the continuum of informal immersive training. Not flying solo, but having shared responsibility allows for learning to happen in conjunction with teaching. Having moved through various stages of immersive training we can see below how his perspective on science research literacy changes following the most recent formalized LTI+ professional development series.

> Kevin-Charles: I think science research literacy is really being able to interpret data... scientific literacy is really about how you pull information from the data that you're collecting. (Pre-interview)

> Kevin-Charles: For me, science research literacy is the understanding of science content that is peer reviewed, that is vetted properly, and not just propaganda or people's beliefs or thoughts. It's definitely have some tests and validity to it based on some real scientific work. So for me, whatever you are using as scientific research, it has to be properly... There has to be some kind of experiments, there has to be some data that supports whatever thing that you're studying. Your theory or your hypothesis has to be valid, in a sense. So looking for that validity within their research, that's kind of how I determine, for me, if this is something that I would want to use. So that literacy and understanding how to decipher what is real and what is not when it comes to... And then something that you want to test to see if this is true or not. Long as there's something. (Post-interview)

The above pre- and post- response from Kevin-Charles shows a dramatic shift towards thinking like a scientific researcher. However, both he and Madison present the concept of pushing back against what was written in existing research.

Kevin-Charles uses terms like “vetted” and Madison “curious” when sharing views on science. These are both common phrases that could be used in describing scientists who engage in authentic science research, I have previously noted that authentic science research is something beyond just content knowledge but includes the use of tools and mental engagement oftentimes used to describe scientists. Tying this to science research literacy, I examine the ways in which the participants step outside prescribed, repetitive curriculum and share the research experience with their students. To scaffold this, the participants were given prompts prior to the PD session. The responses were shared with the instructors and technical team at LTI+ to create personalized lab-in-a-box kits for the PD participants.

> Prompt #4. What dietary supplements/nutritional components are of interest to you?
>
> Prompt #5. Have you or your personal circle been impacted by cancer (Type) and/or diabetes (Types)?

These prompts mirror those science teachers are asked to share with their students. Even when PD participants engaged in LTI+ team member-led projects prior to the professional development, these questions were posed to draw their students into the decision-making process and positioning them as owners of the project. However, it was always important to be supportive as this type of authentic research in the classroom is new to most science teachers. In the case of Brian and his colleagues, they learned that many of their student's families had been impacted by color cancer, so they wanted to research this disease and were comfortable having LTI+ select the junk foods for their students to test.

> I know our team... is very excited to work with you and our students on this research. I met with our science team, and we thought it would be very interesting to look into colon cancer with the wild type flies... And we were discussing the food. It may be a good idea for you to choose the food for them. We thought it could be a great experience to compare data across classes! (Brian Artifact-email)

The classroom project that Brian was talking about happened prior to the formal LTI+ PD and while he and his colleagues were not ready to define all of the parameters of the project, they were invested in having it give their students ownership and creating a sense of collaboration between classes.

By using a personal factor to drive the research it takes on deeper meaning for the science teachers and their students. The researchers will bring their histories, cultural relevance, and biographies to “inform the process of meaning-making" (Creese, & Blackledge, 2012). The PD participants shared common threads, with many of them having been impacted by breast cancer and/or diabetes. This personal connection to the research project empowers the participants to step outside of laboratory projects where everyone gets the same answer but it rarely, if ever, has an impact on them. Additionally, by implicating diet and nutrition into the research the projects take on a wealth of context and meaning for the individuals and communities. The concept of health has been linked to food globally and all cultures have traditions that have been passed down to get well and stay healthy. Exploration of food choices in a research-based environment gives early scientists an outlet to learn through hands-on approaches versus the health/junk dichotomy portrayed in social media and casual conversation (Bisogni, Jastran, Seligson, & Thompson, 2012).

As noted by the earlier highlighted prompts, the LTI+ PD participants selected nutritional supplements prior to the session and were surprised to receive individualized lab-in-a-box kits tailored to their selections. Participants selected foods, vitamins, herbs, or nutritional supplements that they had personal interest in researching. Imma wanted to research something she had casually heard about.

> Apple cider vinegar... Because you always hear that that’s supposed to make your stomach healthy. I wonder. (Imma. Pre-interview)

Brian, who had in the past utilized junk foods in classroom projects, identified food additives and diet supplements but left the final selection up to the LTI+ team.

> Dara: You listed for your nutritional supplements, protein powders, food coloring, and artificial sweeteners... So, if you don't care which one it is, we will surprise you and put it into your kit.
>
> Brian: Okay. I'm excited. Yeah. (Brian. Pre-Interview)

Following the formalized PD, in which Brian examined the impact of protein powders on development and behavior of fruit flies, Brian reverted to researching junk foods with his students as a way of giving them a deeper connection based on common foodstuff they may be snacking on.

Once the participants have completed the initial level of immersive training (PD) LTI+ supported them as they transitioned the research to their classrooms. Using the same framework, a collaborative discussion informs the type of project best suited for their students and can even have personal meaning to the teacher. By facing the diseases that impact their families and communities, they can take some control back and gain ownership over the projects while knowing they have contributed back to the body of research surrounding the topic. Kevin-Charles takes a cultural approach to participating in the design of his classroom projects and blends this with personal history over which he wants to gain a deeper understanding.

> I think because of the demographic of students that I work with, and because of me being an African American male, I want to understand what is the prevalence of African Americans, particularly African American males, who are affected by diabetes and particular forms of cancer, particularly like... for me, my family has testicular and prostate.
> I envision my students developing a more hands-on approach to science. This will connect to my current classroom pedagogy because it will foster a deep knowledge and practical approach to science (Kevin-Charles. Artifact- Application 2019 LTI)

From the above we see that Kevin-Charles involved his students in the project development and had deep personal ties to the research. This motivation to connect cultural relevance with research was also observed during an immersive instructional setting. Kevin-Charles and I were facilitating a virtual-hybrid session in a city in Upstate. Keeping students engaged is key in situations where the instructors are not in the room and to check that the student scientists were ready he used an African phrase and response.

> Kevin-Charles: I need y’all to quiet down and pay attention. When I say, “Ago!” I need you to reply, “Amay!”. This will let me know that you are ready to move on.
>
> Kevin-Charles: Ago!
>
> Student Scientists (in unison): Amay

It is interesting to note that the students were of the same identified background as Kevin-Charles and all of the students behavior was more mindful following this interaction. In the excerpt below, Imma took a different approach with her students. By placing the power of research into the hands of her students, she was able to have her students see the impact of common, student-consumed snacks on development and behavior. She is a healthy eater and by having her students do the research, they could better inform their own choices.

> Dara: So, what are some of the things that you might help guide or prompt the students?
>
> Imma: We would probably talk about diet and health, what it means to eat healthy, what things do we eat that are healthy and those things that they eat that are not healthy. Because there's a trend always amongst a group of kids, the things that they eat. Last year was Takis. (Post-Interview)

Imma can adapt the research variable to focus on what snacks her students are currently eating while keeping the experimental techniques standardized. Each year the students would be able to personalize their research, increasing student engagement.

In areas like Urban City, students do not always admit to having a love of school and certainly not science. Madison has hopes that by bringing authentic research into her classroom, this will provide the spark for the next generation of scientists.

> What I did know though is that they did want to do some hands-on stuff. What that was, they didn't know. I think that they really enjoyed doing the hands-on stuff with the flies. It was totally, totally worth it to me to introduce that to them because it was completely outside of anything they were probably thinking of. And then it also taught them some skills. So if there were some secret science lovers in there, now they got exposed to something that hopefully will grow. (Madison. Post-interview)

As Madison commented above, it is not always about a specific hands-on experience, but more of an overall authentic atmosphere. She knew that not all of the students would like flies and that was okay. But sharing this type of research, she believes, would capture the curiosity of at least one student. As the participants, like Kevin-Charles and Madison continue to utilize not only the materials and conceptual components of the LTI+ professional development, they also know that they have a growing network of colleagues who will support them as they grow into the research topics, branch out into other areas, and cheer them on as they impart their research to the public while inviting more citizens to the science bench.

Theme 2. Transitioning from Science Teacher to Teacher Scientist

Investigative Question 1. As I mentioned above, some of the participants enrolled in the LTI+ professional development session had prior connection with the program. Marisa had previously been a science teacher in the same high school as Giselle. In 2019, Giselle was attending a scientific symposium hosted by the LTI at the world-renowned Washington Conservatory (Figure 8) in the heart of Urban City. The LTI's network of collaborative science teachers were able to see their student scientists present their research and speak with peers, professional scientists, and engaged science educators at this full-day event.

Figure 8
LTI Student Scientists on the Steps of the Washington Conservatory

Notes. 2019 LTI science symposium at the Washington Conservatory. Over 500 local student scientists had lunch with local STEM Professionals, listened to engaging STEM speakers and graduates of LTI, and presented their classroom research projects to peers, science teachers, professional scientists, and the community.

Wanting to provide access to this experience for as many students as possible, Giselle invited Marisa to share the opportunity for guest attendance to her classes.

> I know Giselle, yes. She used to do the program ….it was funny because at that time she had a trip through you guys and she was like, "Hey, can you recommend any of your students that can take on this trip?" And I'm like, "Sure." So, she was like, "Maybe you can give some extra credit or something if they go. (Marisa. Pre-Interview)

By engaging Marisa in 2019, Giselle enacted the type of scientific collaboration professional researchers participate in through the attendance of conferences and meetings. Further scientific behavioral reproduction came in the form of Marisa participating in a preparatory Zoom with an LTI+ scientist. This session was to support Marisa in setting up the experimental variables for the research her class would later present on to the Urban City community.

Scientist. Ok, now angle the camera so I can see the vials.
Marisa. Ah, ok, ok.
Scientist. Don't worry. I am hear to help you keep track of things.
Marisa. Great! I have gotten rusty (reference to performing lab work)
Scientist. We will do it in sections to stay organized.

This interaction continued with Marisa and the LTI+ scientist working out how to best deliver the protocol to her students. They agreed that if Marisa completed one set, then the students would make a comparison set of variables. This way if errors occurred, the students would still have data to discuss in class and during the spring science symposium.

In 2022, LTI+ hosted a similar meeting at the Washington Conservatory (pseudonym) (Figure 9). Madison expressed below that this type of networking was impactful for student scientists.

> I believe they really loved going to the Washington Conservatory, but then it also showed them what other students were doing and how they did their thing and it like, oh okay, wow. So I think it was a great experience. (Madison. Post-Interview)

Figure 9
LTI+ Student Scientists Presenting at the Washington Conservatory

Notes. Student scientists presenting their data to professional scientists and peers at student posters; Students from the LTI+ classroom project schools on steps of Washington Conservatory

One class of middle school students had the opportunity to engage with near-peers, at the event. This modeling by the older students may prove to be a retention factor in maintaining the scientific research pipeline down the road. Imma shared the impact of meeting near-peer student scientists on her class.

> Imma: "...I will say that my students that got to go to the Washington Conservatory (pseudonym) learned so much from being there that they knew what they were talking about. It was awesome."
>
> Dara: Did they go to other posters?
>
> Imma: They went to other posters and they started learning about what they did and connecting things to what they did and just watching them make those connections was just so awesome.
>
> Dara: Oh my goodness.

> Imma:. Where they may not have actually known why they did what they did before. When they talked to the other students, especially the high school students, they made that connection.

What Imma described above is a concept of networking and development as an increase in science research literacy and was reflected in how the professional development participants and instructors interacted. The LTI+ PD was more of a collaborative function than one where the instructors spoke "at" the participants. This type of professional development highlights the habits of scientists and enriches scientific experience for participants like Imma. She appreciated engaging with other science teachers who helped her understand what she could expect during the classroom project.

> One of the things that I really appreciated was how we were told some of the mishaps that could occur beforehand. And then to actually experience that in the classroom and know how to handle it was great. (Imma. Post-Interview)

> Imma was prepared for the classroom work and the knowledge that it happened to other science teachers better prepared her for the project. Working with an instructional team that had been in the role of PD trainee, also made an impact on Madison, who is finding ways to blend her science background with her new role as a science educator.

> I'm trying to break out of the way I was taught, which is hard to do because you think of teaching a certain way, someone's lecturing to you maybe every now and then you get to do something different. And now I'm like, okay, I got to break out of that. ... I love the fact that with LTI+, I was able to talk to some other educators and figure out how do they integrate some of this into their school year... But I wouldn't get that kind of information without the exposure to the people who are also instructors or being trained for the PDs. (Madison. Post-Interview)

In the above we can understand that Madison harnessed not only the content shared during the PD, but the social guidance and collaboration. There was a positive impact on the participants having worked with colleagues and we are seeing that it was transformative to how science teachers can engage in cooperative training.

Theme 2. Transitioning from Science Teacher to Teacher Scientist

Investigative Question 2. The participants and instructional leads had experienced a growth in their science research literacy by way of feeling secure enough in their trainings to modify their classrooms, the research projects, and even the delivery to meet the needs of their student scientist populations. Giselle captures the interest of students by doing research preparation in the classroom where students can see every step of the process. Below she shares a reflection on her personal growth as her science research literacy increased through immersive training.

> So it [classroom lab experience] has changed a lot since doing PDs and even I feel like a little bit more growth coming in. This school year... just conversation with my students has been very more, I don't want to say calm because I'm pretty calm when I talk to them, but not based in any fear concept"
>
> …I never say like, "Oh yeah, I'm a scientist too." I've built that confidence up to even share that and say, "I consider myself a <u>teacher scientist</u>, when I'm not here I'm doing scientists work." And they're like, "Well what are you doing? Well, can we see it? But I'm scared of bugs." And so it has opened up conversation and ways to plug in different things in regards to research..." So I think just building that confidence of like, "Oh, I can actually do this because I know how to do it, I've done it multiple times. I'm trained to do it, I have it in my brain. I know the misconceptions that can possibly come up. I know how to pivot, I know how to troubleshoot." All the little nuggets that I've taken over the past, what, five years, I use them in a classroom." (Giselle. Interview)

Giselle is an active learner and continues to find ways to connect the research to her students and remain engaged with other teachers. Keeping their students engaged in the process and making the research made sense within the context of not only the curriculum but the community, initiated modifications in the original protocols or techniques.

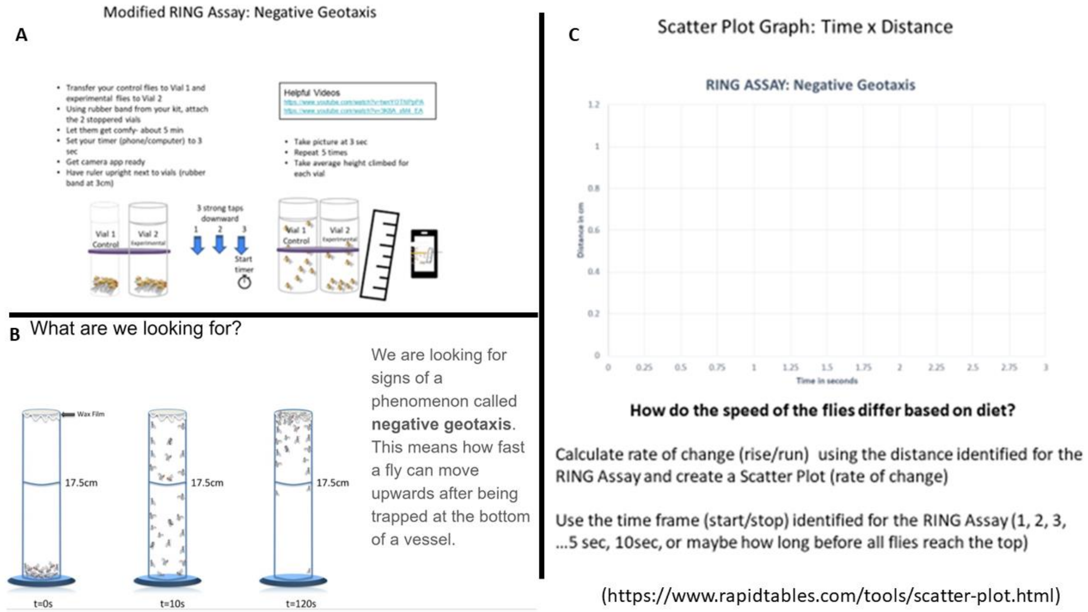
Their underlying goal was to keep the young researchers engaged beyond the basics of the project. Increasing science research literacy builds confidence in technique and troubleshooting like we saw above with Giselle. For Imma there were additional challenges to maintaining access to research while promoting cross-disciplinary collaboration. Below Imma shares that her role at school has shifted. This led to the development of new math protocols, still in alignment with standards, that supported the science curriculum.

> HI Dara!!!
>
> There are some changes taking place at my school that will end in me no longer teaching science. I will be teaching math full time. However, I am still dedicated to this project. I have spoken to Brian from my school. I will be using some of my math time and following whatever project he designs or wants to do with the students and mirroring his class so that more students will have access. Imma (Artifact. email)

Imma was invested in her students still having the research experience and was willing to use her math time to accomplish this goal. To support Imma in her new role, I worked with her to find organic connections between the Urban City math curriculum and the research project. The below figure shows the original science protocol and Brian's adapted version of the LTI+ negative geotaxis behavior assay. As his science research literacy increased, he gained confidence in modifying the original protocol to meet the needs of his students and personal style. Imma's increase in science research literacy was highlighted through a collaboration to develop a cross-curriculum math protocol (Figure 10). She uses the Google classroom platform, and we also created a link that takes the student scientists to an interactive freeware site that allows them to plot the real-time data.

Figure 10

From Science Lab to Math Class

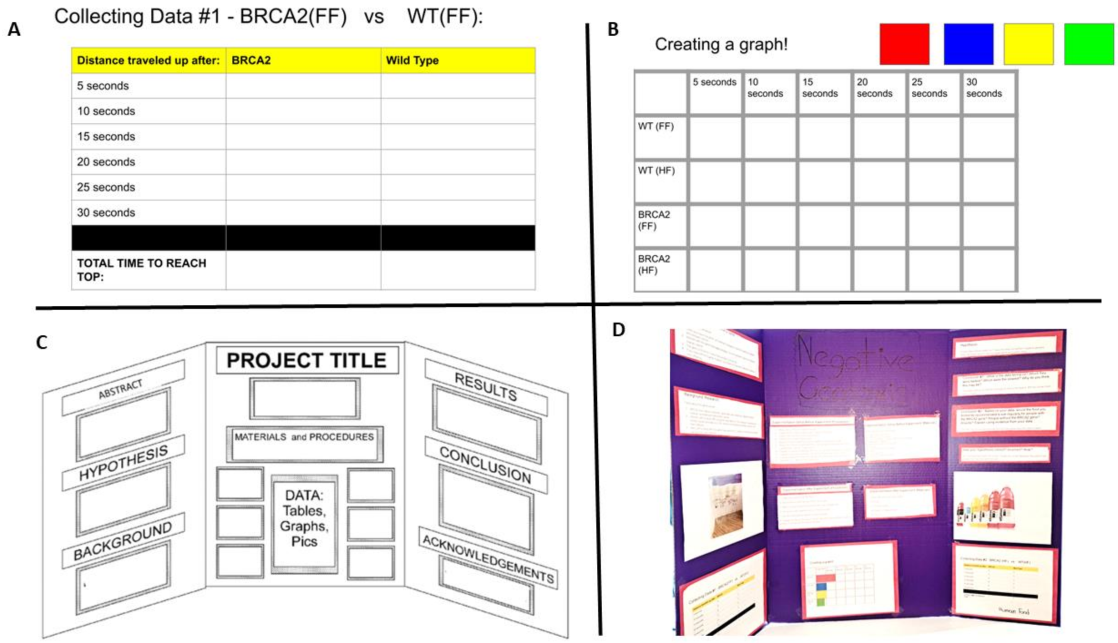


Notes. The original LTI+ behavior protocol that allows participants to examine changes in locomotion; B. The modified version developed by Brian after the LTI+ PD session; C. The math protocol that compliments the behavior protocol. Developed as a collaborative effort between LTI+ and Imma.

Brian also shared his modifications of the science protocol to build out a digital notebook, in-depth instructions of creating graphs to represent data, and interactive Google slides to promote hypothesis development. Brian and Imma cooperatively shared Google slides to support their students in the development of posters for presentations at the symposium (Figure 11).

Figure 11

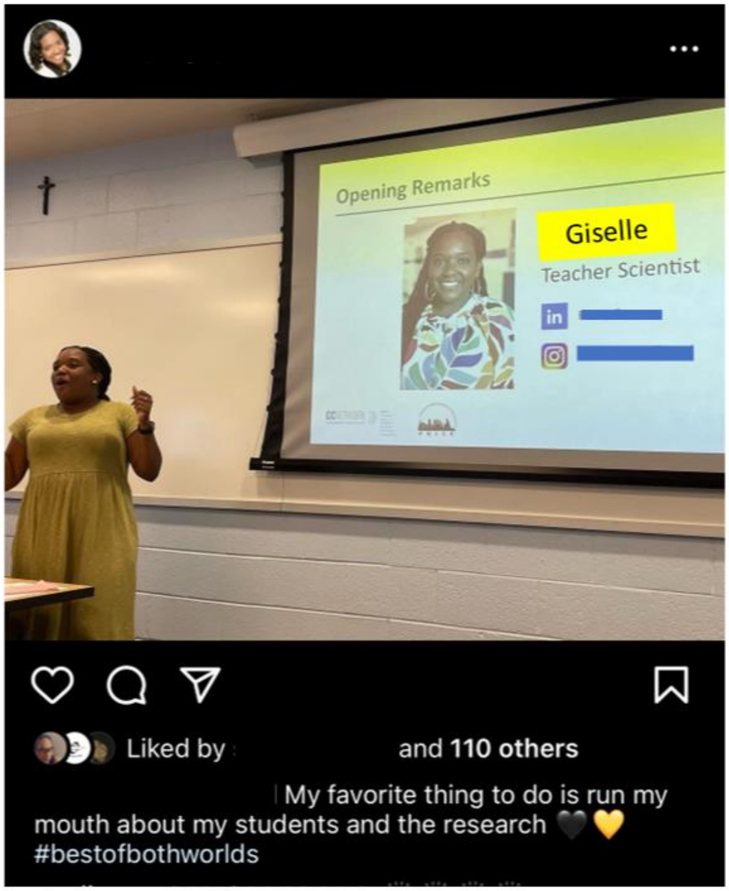
Harnessing Digital Tools to Create Presentation Posters.



Notes. A. Brian and Imma developed a digital notebook to collect data; B. Each experimental variable was assigned a color and by using Google their students were able to quickly create bar graphs; C. The LTI+ general template of what to include on a scientific poster; D. A finished poster from Brian's class

These examples not only frame out how collaboration can benefit early student scientists but also shine a light on how these science teachers are beginning to see themselves in more of a blended role. In 2019, Rushton and Reiss identified a gap paralleling work, which underscores my overarching theme of science research literacy. Markers of an embodiment include habits, arriving at new questions, sharing of knowledge both with the community and professional scientists in which “Considering whether science teachers identify themselves as scientists and researchers as well as teachers of science” (p. 1543). Since facilitating the PD for other engaged science teachers, and through her work at school and with LTI+, Giselle has been a sought-after speaker in the science education community of Urban City (Figure 12).

Figure 12
Teacher Scientist



Notes. Giselle was invited to be a key note speaker at a STEM Educator meeting in Urban City. Her badge identified her title as "Teacher Scientist".

Giselle is a role model for her students and other a champion for collaborative research projects. During classroom observation and through a semi-structured interview it was noted that she has begun to refer to her role as teacher scientist. Through member checking I was able to verify that Giselle had not previously read this term in recent journal articles (Rushton & Reiss, 2019).

> I consider myself a teacher scientist. (Giselle. Interview)

> Dara: When/how did you begin using the term "teacher scientist"? And how do you define that role/term?
>
> Giselle: I began using the team when I stopped putting myself in just one category based on location and realizing that I was constantly being a teacher scientist at the same time whether in the classroom or lab space. I think in 2021... An educator that can differentiate and scaffold all while conducting authentic research (Member check-email)

Above, we can see the marked increase in science research literacy and just about hear the pride in herself as she includes herself as a representative of both the science education and scientific researcher fields.

Additionally, when focusing on sharing scientific content with the community, Kevin-Charles also re-positioned himself in a new role. Kevin-Charles had taken the 2022 LTI+ professional development as a refresher to an LTI session he participated in 2018. Since 2021, he has been an LTI+ team member and his work with other co-instructors, in the classroom, and at science-focused events have all contributed to the development of his science research literacy. The following semi-unstructured, post-interview excerpt clearly illustrates the impact of collaborative professional development. Not only is Kevin-Charles speaking as a scientist to the community of parents, but he is also clearly welcoming them and their students to the lab bench as citizen scientists.

> Kevin-Charles: It's actually funny. I just had back to school night and so I had to explain what I do. And so I think, for me, the role I play at my school and just in general, I want my students to be citizen scientists. And so when I introduced LTI+ and what would be doing this year, I kind of always capture them with doing cancer research or studying the effects of diabetes in our neighborhood or in our community, because I'm teaching predominantly African American Black students and I got some brown students, a little bit of sprinkle of Hispanic students. But for the most part, I'm teaching African American students. So really getting them to understand their diet, how they eat. So tapping into that and then explaining to them we're going to be studying. Um Drosophila, they like

"What is Drosophila, Mr. B-W?"

Dara: These are the families of the students or their guardians?

Kevin-Charles: Yes.

Dara: Okay.

Kevin-Charles: Right.

Dara: You're like, "Now they're doing community outreach during back to school night."

Kevin-Charles: Yeah. So explaining that in my class or we would do cancer research as well as studying the effects of sugar. So really tap into diabetes too. And we use the fruit fly to do that. And they're like, "Oh, well, how can..." Well, fruit flies have genes just like humans. And so those genes can be altered by the foods that we eat. And so if you are eating a heavy amount of certain things or even supplements, vitamins that you take, anything that we do, we can study the fruit fly to determine if those effects will change the genes or alter the genes or cause some kind of mutation within them. And now we can use that data to how we can correlate this into humans. And so that's how I kind of explain it.

Dara: I'm beside myself. So it sounds like you gave a science lecture to the community during Back to School.

Kevin-Charles: Yes.

As you can see, I was hit hard by the amazing outcome and how Kevin-Charles seamlessly repositioned himself during back-to-school night. To support this, I lean into the literature and define positioning as a theoretical lens and how this empowers the teacher to accept/adapt the mantle of scientist within the classroom (Hazari, Cass, Beattie, 2015). However, it is important to note that researchers come from a variety of fields. Embarking on this journey, I had the opportunity to be an active observer. My personal and professional network has grown since the start of this research and finding a place between science and education has also been a tenuous balance for me. I position myself in either role as situations arise, not so much code switching but more of a harmonious blend with different notes rising to the surface. A strong note is one that is complex and often implied in both fields. Mentorship.

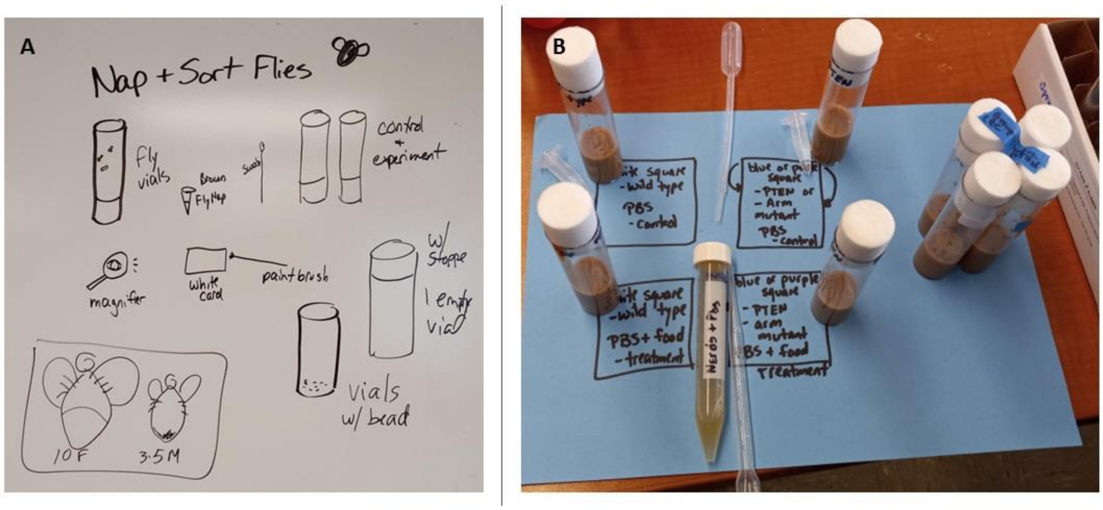
In this final excerpt, Madison calls attention to this concept, while discussing possible directions for her future research questions, allowing this ethnographer to make the familiar seem strange again.

> You know what's odd though? A lot of what I'm curious about these days is not necessarily benchtop work. Because I'm in education, I'm interested in teacher training, for example. How can we better do that? What works better? Mentorship. I'm thinking a lot about that type of stuff because I saw... And this relates even to LTI+. So, you guys are doing PDs where you do things hands on, and you're also at the same time creating this whole community where people can talk to one another and help one another.
>
> That's mentoring without saying, we have a mentor program and making it formal. It's just like, hey, we're a family of people who have the similar interests and we're doing similar things and we can help each other out. And that's important because it makes you stronger as an individual in what you're doing. And it makes other people who learn underneath you or around you, however you want to put it, strong also. (Madison. Post-Interview)

Theme 3. Incorporation of Science Research Literacy into Classrooms

Investigative Question 2. As the LTI/LTI+ community of science educators has been growing and evolving since 2013, it was important to recognize the non-linear immersive training (Abma, Cook, Rämgård, Kleba, Harris & Wallerstein, 2017) that takes place. Formalized professional development sessions are supported through grant awards to the LTI+ and are not held annually. Other awards and philanthropic donations enable the LTI+ to provide enrichment to former participants, if they self-select to engage in the activities. Science teachers that enrolled in the 2022 PD session had some connection to LTI/LTI+ and are motivated to continue through additional levels of immersive learning. Levels can include observation with an LTI+ member leading the project, participation in hands-on professional development, co-instruction with a member of the LTI+ team either in a classroom (Figure 13) or science space, and finally stepping into the leadership role and facilitating programs for other science teachers. This last stage is denoted as one where the science teacher assumes the role of teacher scientist. It is typical for science teachers to stay at a level of comfort.

Figure 13
LTI+ Instructor Support in Classrooms



Notes. As an active observer in the participant classrooms, I was able to support the teachers and their students by providing assistance during lessons. A. Hand-drawn diagrams on Madison's white illustrating the flies and food making, B. A diagram showing how Imma could set up lab stations.

No participants are pushed to take on more than they feel ready for, but opportunities are always offered by way of grant writing or large-scale events. All participants are supported with authentic research access no matter the immersive level. For example, Jonathan below describes the flexibility of the LTI+ training.

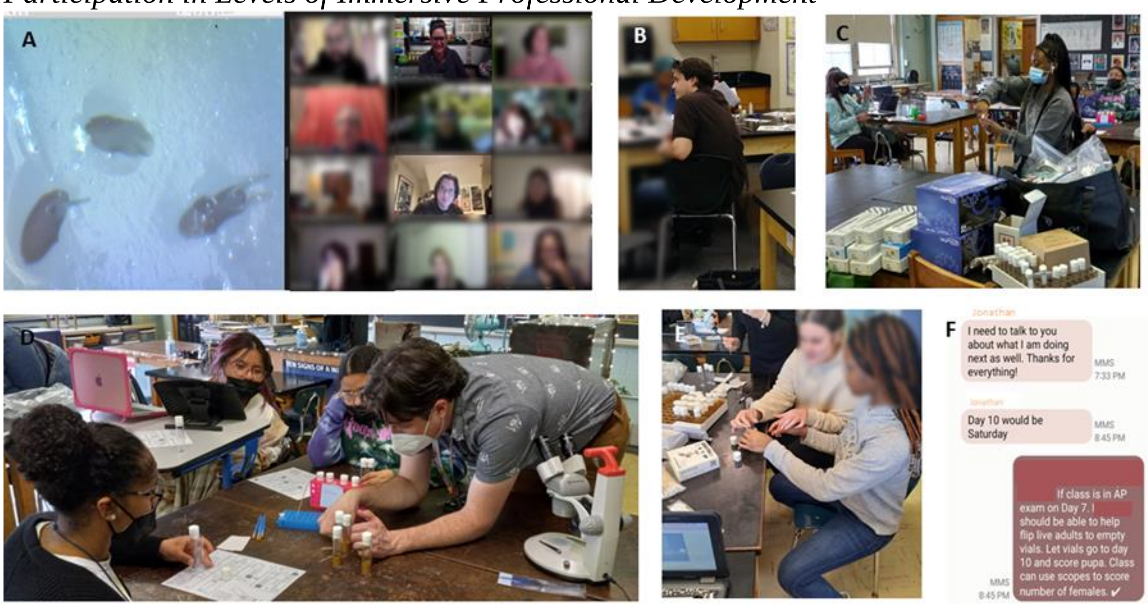
> Dara: And are there techniques that you think... that would further support you in subsequent levels, if you were to take additional trainings?
>
> Jonathan: Yeah, I think it is a build-up sort of thing. So, we had the introduction, and people could go with it right or not. So...

Dara: Yes. Right there. Yup.

Jonathan: ...You have to decide. And then, yeah, I feel like there's always more we can do." (Jonathan. interview)

Above, Jonathan shares that science teachers can use the techniques learned through the LTI+ professional development sessions right away and then build upon the early experiences to introduce more complex projects to the classroom (Figure 14). Having access to LTI+ and additional PDs supports science teachers as community members and provides a network of experienced science teachers and scientists with whom ideas can be discussed.

Figure 14
Participation in Levels of Immersive Professional Development



Notes. Jonathan attending LTI professional development in-person (90 minutes) and part of an LTI+ invited virtual session (3 hours). An LTI+ graduate and senior and Jonathan's school received credit for being a teaching assistant/guest scientist to facilitate the classroom project. Text correspondence between Jonathan and me regarding classroom project.

Two teacher scientists had prior experience working with LTI+ at the height of the pandemic and were trained using conferencing platforms, learning management systems (LMS), and tools for sharing digital images via microscopes equipped with USB access. It was during their interviews that I realized this instructional period also served as an informal, immersive training and supported the science teacher’s virtual classroom experience. As Colin and Giselle noted below, having an opportunity to teach using the LMS strengthened their ability to connect with their students in a virtual classroom space. During a time when most of their peers were struggling to learn virtual systems Colin and Giselle were entering the virtual academic year with some level of comfort using distance learning techniques.

> The COVID and the virtual camps was very helpful because I got thrown into teaching virtually for the whole year after that. So you were kind of my learning how to do this stuff and learning how to do an experiment at home and yet get it across to the kids on a computer and then them doing it and reproducing it and actually learning something from it. So I learned a lot about virtual learning from you before I had to actually do it all myself.” (Colin. Interview)

> The first week of school we did an experiment. I would've never done an experiment the first week of school because I'm like, "I don't know you all, you all crazy." But I feel like teaching students in the Summertime for one week and doing an experiment every single day with them virtually, I'm like, "I can do this with my eyes closed." (Giselle. Interview)

As mentioned above by Colin and Giselle, during the pandemic the world experienced the closure of laboratories and institutions of learning. LTI+ filled the gap in training by developing an online training program, launched in 2020, and designed for high school and undergraduate students. Former LTI+ undergraduate participants moved into roles of instructors, having a strong understanding of the content. All instructors were immersively trained in the virtual hybrid style.

As part of my academic studies, between 2012 and 2018, I received three certificates in developing online programs. This positioned me to ensure LTI+ was ahead of the curve in launching virtual trainings. In addition to supporting student learners, it was clear that LTI+ would follow a similar trajectory to the in-person sessions launched in 2013 with a science teacher professional development running shortly after a student program. The science teachers were still required to meet their Act 48 approved professional development hours, but in many cases the facilitators were also learning how to pivot to a virtual platform.

"All educators holding Pennsylvania public school certification must earn 180 Act 48 hours... every five years to remain in active status" (www.philasd.org). In Urban City, most of these hours are used though district-wide, required PDs with the fewest hours being for content-specific sessions. LTI+ hosts cost-free PDs and provides them virtually to increase accessibility. While these sessions are not Act 48 qualifying PDs, the participants do receive access to a growing network of scientists and science teachers working to provide a platform for authentic research in classrooms. Also, the participants of the 2022 professional development session each received tangibles as at-home research stations which could also be incorporated into their classroom laboratory supplies. Science teachers that applied to take part in the 2022 LTI+ professional development were motivated to attend the three-day virtual session for reasons beyond their Act 48 requirements. During the pre-interview participants discussed their motivation for attending a PD and the underlying reasoning behind their choice was for their students whether directly or indirectly.

> I just want to find a way to help my students who usually don't get an opportunity to experience high order science. So I teach at Mandela (pseudonym), so these students don't get the benefit of an actual science class. So, anything I can do to expose them to real world situations, stuff that's going to really benefit them. (Kevin-Charles, Pre-survey)

> I think it's really important to just develop myself for my students... and I think this is going to help me hone my craft, because I didn't get formal training in science in college (Brian, Pre-Survey)

> You know what, because anything I can do to help students feel more engaged, I'm willing to do it. Right now, because I am a new teacher, I don't have this whole library of things I used to do and I can pull out. So anything I could do that's not just them writing, that will get them active, make them think about stuff that's real, I want to do it. So to me this is something that would be something they could relate to and they would find interesting. (Madison, Pre-Survey)

As Kevin-Charles, Brian, and Madison noted, their motivation was tied to the possibility of direct benefits for their students in their classes, in addition to the benefits to their own growth and knowledge. Below, Imma noted explicitly that she was looking to increase her own skills, but also that her students would benefit from the PD as well.

> I'm a science and math teacher and science is my weaker subject, so I'm always looking for professional development that'll help me become a better science teacher for my kids. And also, I know that one of my colleagues did LTI+ last year and the kids seemed really excited, so I wanted a little piece of that. (Imma, Pre-Survey)

During the pandemic, hosting the PD via Zoom was essential for the health and safety of the instructors and participants. To facilitate an authentic experience all participants received a complete research station, designed to match the instructor's materials. The goal was to create a sense of being in an actual laboratory environment, while working from their homes but keeping the concepts and techniques user-friendly. LTI+ wanted the participants to have the capability of transferring what they learned in the virtual hybrid PD to their students through concepts and techniques as authentic experiences versus currently available digital formats. Prior to the imposed virtual learning brought on by the 2022 pandemic, public schools used online video access or subscription software programs to illustrate scientific principles. Interactive science meant drag and drop or responding to questions with correct/incorrect answers versus asking novel questions. During in-person academic years, some science teachers go beyond their budget allocations and purchase access to digital learning tools for their students. Below Kevin- Charles expressed his frustration in using simulation vs laboratory experiments for complex scientific concepts and Marisa shares that the expenses for NearPod, an interactive software, comes out of pocket.

> Right now, I don't have it [laboratory instruction], but we the school district... this is why I adopted this thing called ExploreLearning. Gizmos has a lot of simulations, so we do... right now, we are just getting into cellular respiration and photosynthesis, so how I navigated this process is to use... on the Gizmos situation, even though I want to use real world and hands-on experience, I don't have the resources. (Kevin-Charles. Pre-Interview)
>
> Marisa. ...I have them where they're watching something like a Nearpod. I paid for Nearpod.
>
> Dara. Okay.
>
> Marisa. So, have them use Nearpod where it's an interactive video" (Marisa. Pre-Interview)

With limited budgets, it was imperative to include equipment and materials during the PD, not only for use "in the moment" but to use in their classrooms. While most would agree that Urban City teachers are resourceful with the ability to support young learners as they are required to provide authentic science access in the classroom with little funding. Science teachers must include authentic experiences focused on a future job market in the STEM into their lessons, capturing their student's attention and harness engagement, hoping to model what professional scientists do in the field, effectively opening the flood gates to the research pipeline.

But what happens if you aren't from one of the public schools in a partnership with an out-of-school program sponsored by a university or from the private and charter school sectors with access to funds directly earmarked for STEM programs? In cities like Urban School District, funding for science labs would be part of the discretionary funds allotted per student, ranging from $200 to $300 per high school student. (philasd.org). This amount is also pulled from to support "...staff, supplies, textbooks, computers, extra-curricular activities, parent outreach, etc." (p 5). These are schools where you hope to have a motivated science teacher making magic happen! Below, Marisa and Brian explain the effort they make using their own personal time and money to ensure students can engage in performative science experiments.

> Yeah. I did a lab the other day with the eighth graders because we were finishing the last text and they were studying animal behavior and so I got the snails. I really literally spent $50 at PetSmart ...buying snails, buying a bowl, buying the gravel, the stuff to put in the water ...the other night, eight o'clock I was literally in there 45 minutes, 15 minutes before they were closing to buy all of the snails. (Marisa. Pre-Interview)

> ...in terms of getting the materials, I'll get them myself. I'll just bring them in. I'm lucky enough to have inherited the science room, so I have a lot of beakers and things like that, the actual tools, but in terms of the materials, I tend to just find them myself and bring them in. (Brian. Pre-interview)

Intrinsically driven educators like Marisa and Brian are the ones that find professional development programs, like those facilitated by Laboratory Training Institute-Plus, to bring the missing authenticity to their students. These science teachers not only have the onus of preparing students for the wide battery of standardized assessments (Keystones, AP exams, PSSAs), but also the rapidly evolving district-wide science standards. The most recent of these changes will bring Urban School District into close alignment with Next Generation Science Standards via Pennsylvania's Science, Technology & Engineering, Environmental Literacy & Sustainability (STEELS) Standards (pdesas.org), which include as one of their three dimensions. Science and Engineering Practices. These describe what scientists do to investigate the natural world and are reflected in the curriculum Urban City science teachers, like Kevin-Charles are required to cover in class.

> It's progressively getting closer. I think now it's more toward NGSS, and they have a lot of the parameters and framework around NGSS. I think we are going to officially change and adopt a new curriculum, I think, after this year. It's been a long time. It's been a long time. (Kevin-Charles. Pre-Interview)

The STEELS parameters further highlight the needed development of lab-in-a-box research stations to increase student voices and access to equipment used in STEM careers, in classrooms like Kevin-Charles'. LTI+ understands the budget and time restraints placed on the teachers at the Urban City school district and by creating complete research stations, to support eight lab groups per class session, teachers could spend more time focusing on authentic research experiments instead of sourcing materials and methods. Lab-in-a-box is not just a set of consumables for a single class session. LTI+ was able to build research labs for the PD participants to utilize in classroom projects. These included racks, micropipettes, and microscopes capable of imaging data, and boxes of lab consumables, as noted by Jonathan below and seen being held by research participants (Figure 15). This access to equipment, materials, and instructional information empowered the science teachers to transfer what they learned during the PD into their classrooms.

> You gave me a ton of equipment last year. (Jonathan. Interview)

Figure 15
LTI+ Classroom Laboratory Equipment

Notes. A. Giselle unpacked her research station to show her class B, C Kevin-Charles and Marisa picking up their research materials at LTI+; D. Colin has been working with LTI/LTI+ since 2013 and donated back equipment to help other teachers, only accepting items to further grow his classroom research laboratory.

One of the influences of the LTI+ on classroom culture as it pertains to science research literacy is the mirroring of protocols, set-ups, and information delivery. The LTI+ uses printable, digital note-packets for a self-learning component and the PD participants were able to use them to facilitate the protocols with their students. The PD offered protocols that were new to several of the participants, including a behavioral assay. In previous iterations science teachers utilized LTI protocols that aligned to development, cell division, and fertility and now the LTI+ has grown to include the study of disorders impacting mental health/stress and diabetes, along with further a rich cultural connection through diet. During the PD instructors and participants reviewed print materials and set up research materials in tandem. This allowed for a fluid question and answer period between the teacher scientists that have been completing classroom research for several years and the new professional development participants.

Through Zoom, lab “stations” were described and organized and seen replicated in classroom observation sessions. “Stations” that mirror those from the PD were recreated by several science teachers for use in their classrooms (Figure 16).

Figure 16
Modeling Research Station Set-Up

Notes. A, B Professional Development instructors explained the printed lab station image included in the lab-in-a-box kits and then demonstrated how to set-up a station for a research group. C, D Brian and Imma had similar stations prepared for their classroom projects, using small bins as miniature version kits.

Once the science teachers transfer the PD training to their classroom, they have completed another level of immersive training, and are poised to take ownership as a scientific leader in their classrooms. As Imma noted below that by having the training facilitated by other science teachers who have been working with the LTI+ protocols for years, she had access to their experience and through the virtual-hybrid training was better prepared to address how to react if the model organism (fruit fly) gets loose in the home or school laboratory.

> And me being afraid of fruit flies, knowing ahead of time that some might get away, it happens and it happened, but I was prepared and I didn't freak out because I had the experience of working with them in my home and I was already a little more comfortable than I was even to the year prior. So the hands on experience was definitely plus for me. (Imma. Post-Interview)

As Imma shared above, comfort and confidence grew as science teachers continue to conduct classroom experiments with their student scientists. They are better able to pivot and adapt when something unpredictable happens, quite like a professional researcher would in the laboratory. As confidence grew and science research literacy increased, teachers began to exhibit additional scientist traits including asking new questions or addressing specific needs of their students. Prior experience enabled these science teachers to mold the professional development content to meet requirements for their classes.

Challenges

Even with the noted confidence growth in participants like Imma, working with fruit flies is a large challenge for many science teachers. One of the original LTI+ PD participants chose to withdraw from the classroom project due to fear and discomfort working with live insects in the classroom. Fortunately, the LTI+ team was able to support their students in the classroom, but this was an unexpected burden for the program. This teacher was prompted by the administration to complete the project. To avoid this, future participants will need to complete a more comprehensive application and intrinsic motivation will be a driver.

Additionally, the limitations of a virtual-hybrid professional development session were noted by Imma when asked what challenges she had during the post-PD interview.

> Well, not really being a science person, and that's my self proclamation, but I think the fact that it was virtual for me was a little challenging. So I appreciated having the materials. I definitely appreciated that and the time and the care that you guys put in to putting that together and explaining what it was. But I would've probably gotten a lot more out of it had it been more face to face, hands on.

This highlights the strength of the curriculum, but also the hurdles that could be seen using a virtual-hybrid model for some. It is important to note that during the subsequent, immersive training in the classroom, I walked her and her first class of students through the project. When asked if she wanted me to stay for the second class, she noted,

> "I saw how it was done and how you were ok if things messed up. I can do this."
> After that class, I went back to check on Imma and found her smiling hard. She shared that she "felt better" and "even for a not science person, she could do it".

This interaction makes it clear that the support into the classroom is an integral part of the immersive training system.

At the time of the research, an early barrier to achieving this was the COVID pandemic. Limiting access to face-to-face training required this innovative shift to a virtual-hybrid model. Initial PD set for late 2021, with a return to schools, science teachers were suffering from Zoom-burnout and once the PD was rescheduled, 10% of the original cohort had withdrawn.

Once the teachers were able to bring the LTI+ projects in the classroom, time became one of the greatest limitations to this study. As the teachers navigated the transfer from the virtual-hybrid training to live laboratory work in the classroom they understandably took care and caution with the protocols. Unfortunately, the battery of standardized exams shortened time to complete classroom project presentation for spring symposium, leading to some teachers feeling frustrated with the project results and limited time for in-depth discussion of the findings. The LTI+ will work to address these severe time constraints and confer with potential participants and current science teacher community members prior to scheduling large events in the future.

Summary

This ethnographic study examined the impacts of immersive professional development on the science research literacy skills of teachers in Urban City. From the five participants the Laboratory Training Institute's 2022 professional development session, the two former PD participants who are currently lead instructors for LTI+, and a science teacher who participated in a ninety-minute workshop, but has completed projects in his classroom since 2019, I was able to identify several sociocultural behaviors that developed through the various levels of immersive professional development. These led to increases of the participant’s science research literacy and the incorporation of science research literacy in the classroom (Figure 17). Changes can be noted in the pre- and post-evaluation within an important feature being that while not all participants had equal increases, they were all on a continuum of growth (Appendix F). While plotted on against an X-Y axis, it remains a visual representation of the qualitative, ethnographic data collected throughout the research process (Appendix G). The three underlying themes that emerged from the comparative analysis indicate that there is a continuum of hallmarks by which science research literacy is conveyed through immersive professional development with a network of collaborators and the increase of science research literacy enhances the teaching of science in the classrooms of Urban City.

Definitions

Low Levels of Science Research Literacy

Low levels of science research literacy expressed by teachers are defined as ones where laboratory-based experiences are driven by simulations, the goal for all students to arrive at the same outcome or focusing on broad concepts not directly relevant to the teacher's or classroom community.

Low Incorporation of Science Research Literacy

Classroom success is delineated by all students reaching the same definitive answer following a series of prescribed steps. Low incorporation is defined as a classroom setting where available authentic projects are dropped into the curriculum as an add-on or bonus experience versus aligned with curriculum. In cases where access to professional scientists is provided, the method of choice to bring the research experience into the classroom is guest-speaker led.

High Levels of Science Research Literacy

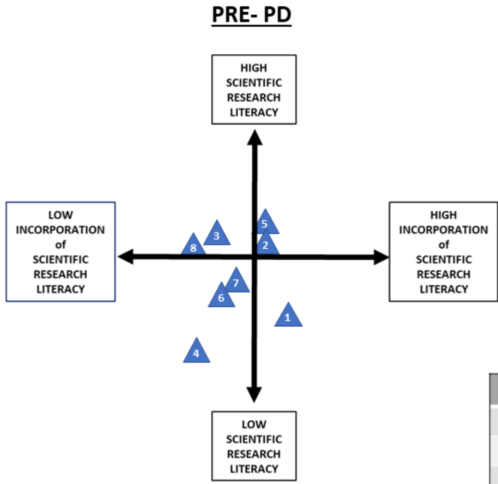
High levels of science research literacy expressed by science teachers are defined as the ability to engage in scientific discourse with their students and/or the public, have a voice in the creation of scientific projects for their classrooms, and collaborate with professional scientists to create impactful, authentic research experiences aligned with the district curriculum. (Brody, Dalen, Annett, Scherer, & Turner, 2012; Evans, et al., 2017)

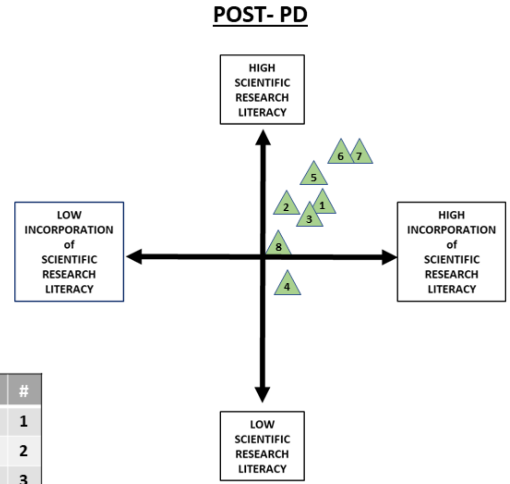
High Incorporation of Science Research Literacy

Classroom success is defined by students leading the research questioning following a collaborative discussion with prompts from the teacher. Students are empowered to address different questions and share differing end results within the framework of the class, working independently or as a laboratory group. High incorporation is defined as a classroom setting where available authentic projects are curriculum-aligned and support student success on standardized exams. Students may develop their research projects over periods of weeks to months and present them as capstone projects. In cases where access to professional scientists is provided, instructors will assume the role of collaborator and explain to the guest scientist the overall project with students sharing their research goals or outcomes directly. Exceedingly high science research literacy extends beyond the classroom into the community with teacher scientists asking novel questions and conducting independent research projects in science and/or social science fields.

Figure 17

Changes in Science Literacy Variables





Participant	#
Kevin-Charles	1
Marisa	2
Brian	3
Imma	4
Madison	5
Colin	6
Giselle	7
Jonathan	8

Notes. Changes can be plotted on a continuum. These are not static points and do not move at the same rate. All of the research participants showed increases in SRL and they adopted a variety of the hallmarks of "scientist". Pre-PD was accounted for each participant at the point where they were introduced to LTI or LTI+. Post-PD was uniform for all participants following the 2022 science symposium. The most significant growth in Colin and Giselle could be attributed to prolonged engagement with LTI/LTI+ and continuing informal training with peers and professional scientists.

CHAPTER 6

DISCUSSION AND IMPLICATIONS

Discussion

The start of this investigation began well before the formalization of the study questions. As a researcher with a blended professional background, I wondered what my place in academia would be and would the development of an immersive professional teacher training program be supportive or discouraging for Urban City science teachers. Using the lens of science research literacy this dissertation addressed the ways in which science teachers obtain the habits of professional scientists and how these are translated into classroom curricula. The necessity of impactful science teacher professional development was examined in Chapter 2 (Bergman & Schooley, 2003; Munson et al., 2013) noting the need for collaboration and not only engagement with professional scientists, but also in a manner that allows for a sharing of knowledge between the content providers and pedagogical experts.

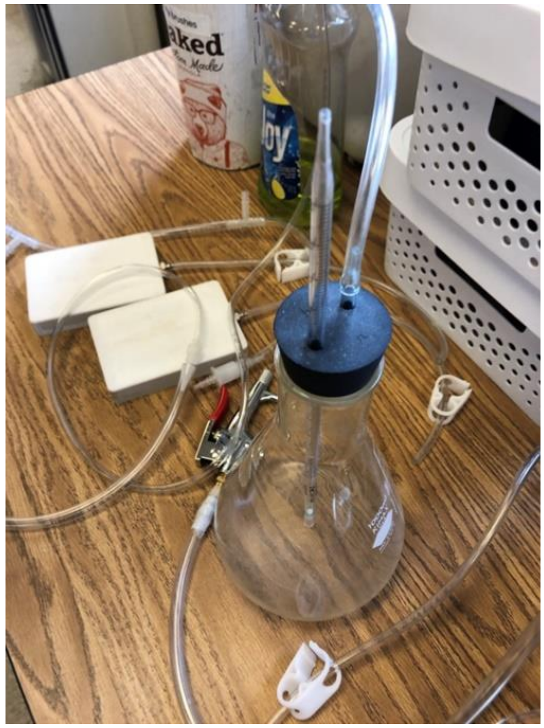
This ethnography elucidates the need for mindfully curated professional development in science education through a socio-cultural lens promoting the cultural reproduction of science research literacy. The themes that emerged from the data and discussed in Chapter 4 serve to shed light on my original research questions and spotlight gaps that have either been addressed in this work or will be addressed with future research. Aspects of these findings align with previous literature on increased engagement of science teachers when participating in professional development led by scientists. What made the familiar different again is this study's contribution to science teacher professional development programming by having the science teachers take ownership of the research beyond the knowledge of the professional scientists. What were my takeaways?

I learned that science research literacy is a skill set as laid out in Chapter 4 through which science teachers participate in a series of formal and informal immersive professional development trainings, enhancing their science capital. Leaning into grounded theory, new discoveries about development of successful professional development programs for science teachers can framed. The positioning of science teachers through changes in their science research literacy were analyzed in the three themes I identified, and these serve to support my two research questions. The themes that emerged from the data are ones that follow an increase in science research literacy as a function of iterative levels of professional development starting with the changes seen in the classroom during LTI+ project sessions, followed by the confidence of applying LTI+ professional development techniques to the specific needs or interests of the class, and finally how increased science research literacy enacted a shift, large or small, in positioning from science teacher to teacher scientist.

Theme 1. Science Research Literacy Becomes Authentic

Investigative Question 1. With an increasing science capital, participating science teachers are better equipped to utilize the LTI+ curriculum which has built in flexibility so that it can adapted it to the needs of their students and resource access (Figure 18).

Figure 18
Authentic Research Equipment in Classrooms



Notes. Colin has been an LTI/LTI+ community member for over 10 years and has been growing his classroom lab to closely mirror the ones uses in the LTI+ research lab. When working with fruit flies his students can use a CO2 system to put them to sleep versus a liquid anesthetic.

During the formal PD session, professional scientists discussed how *Drosophila* (fruit flies) can be used to model both developmental and behavioral outcomes. The scientists shared journal articles and higher-level protocols with the LTI+ team, who in turn modified these to be science teacher friendly while retaining the rigor of execution and data collection seen in traditional laboratory experiments. The LTI+ team is comprised of scientists, science teachers, and teacher scientists that collaborate to ensure communication remains open. Once the protocols have been drafted for teachers, the instructors, who have trialed all the protocols prior to the professional development session, were able to make practical suggestions to the participants like. "I know that they are pupa, but I like to get the kids involved by calling them crispies”, “When you tap the fly vials, don’t tap too hard or everything will stick to the food!”, or “If you have one student that is afraid to move the flies, then have them buddy-up". The instructors then demonstrate each basic protocol, sharing the infographic-like directions.

During the demonstration, one instructor will troubleshoot to further support the participants. Once everyone has tried a protocol the instructors are able to answer specific questions about the experience and because the LTI+ have different science backgrounds, ranging from environmental science to honors anatomy and physiology they are well situated to share points in the curriculum where parts of protocols can be emphasized. If the class is talking about nutrition, focus on researching the foods used in the project. If mitosis (cellular division) is the topic of discussion, then a developmental project would be a good fit. In today’s stressful climate, many students are interested in psychology or mental disorders. These teachers can focus on a behavioral assay. All these options and more have been brought to the forefront through frank conversations with the growing network of LTI+ science teachers (Duffy & Gallagher, 2017).

This type of communication connects to what some people mention as "authorship", where teachers are working to make the LTI+ "their own" in the classroom. Eisenhart and Allen, (2016) posited that “the figured world of schooling provides symbolic material for the authoring of a person’s position in school. Whereas “subject position” is given by society, “identity” is self-authored, although it must be recognized by others in order to be sustained. As individuals begin to see themselves and be recognized by others as having a particular identity-in practice, they come to invest themselves in the identity, accumulating emotions, motivations, orientations, and skills associated with it (Holland et al., 1998; Holland & Skinner, 1997). They come to have a stake in the identity and in maintaining it." (p. 189). While the Urban School district has defined subject positions for the teachers, the participants are doing this self-authoring work in their identity as developing teacher scientists. They are recognized for their scientist teacher identity in practice, and they invest in this identity (Carlone, 2012).

Theme 1. Science Research Literacy Becomes Authentic

Investigative Question 2. As shown in Chapter 4, Imma worked with LTI+ to create a new math protocol, Brian helped his students identify the impact of diet on fruit flies carrying the gene for colorectal cancer, and Kevin-Charles made a pivot from studying cancer genes to exploring the connections between diabetes and diet with his students. Giselle, who teaches environmental science had started with a basic LTI+ protocol using junk foods that her students brought to class and now her students not only study the impact of naturally insect-repellant plants on fruit fly development, but they grow the plants in class as part of a yearlong project (Figure 19).

Figure 19

Modifying Protocols to Meet the Needs of Environmental Science

Notes. A. Plant starters that a cooperative LTI+ partner provides to Giselle's class, B. The plant stand for growing the plants. Giselle's students are required to maintain these plants as part of their overall project grade, C. The modified LTI+ experimental set-up including the extract made from the plants.

Theme 2. Transitioning from Science Teacher to Teacher Scientist

Investigative Question 2. The LTI+ is giving teachers the opportunity to see how to integrate content and science literacy to replicate the ways in which a scientist or science lab works. asking testable questions, designing experiments, collecting and analyzing data (Claussen & Osborne, 2012; Koomen et al., 2014). By training science teachers through immersive professional development sessions, the LTI+ has gained invaluable collaborators and by them choosing to stay and continue to work side-by-side with the program’s team members is a direct complement to the methods employed. Former science teacher participants are now teacher scientists and share the language or scientists and teachers alike. They are bridges between the fields and conduits for communication allowing for both scientific researchers and science teachers to learn from each other in a collaborative fashion, building on the knowledge that each brings to the table (Brooks et al., 2011; Mansour, 2015; Rodriguez, Campbell, Volin, & Moss, 2023).

Through this research I was able to confirm something that LTI+ had supposed. It is best to meet science teachers where they are comfortable and to support them in ways that are beneficial to them and their students. While some teachers have become not only comfortable with the role of teacher scientist but have also advanced their science research literacy in a way that empowers them to communicate effectively with students, the community, and professional scientists, others prefer the impact or perceived importance of having a scientist remain in a leadership position. Hosting a scientist in the classroom provides intimate access to professionals in a field being promoted by standardized assessments. Baynam (2010) posited that by bringing engaging scientists to speak to undergraduates this would increase the chances of students to want to follow in that path. Inviting scientists to speak at one's institution or program either live or virtually (Fig. 16a) is, in fact, a cultural effect of the field and in doing so can lead the audience to generate new questions and model appropriate ways to share scientific content. Jonathan, who participated in two separate PD's had been transparent in his preference to have scientists engage directly with his students and even noted how the Skype a Scientist (www.skypeascientist.com) format allows students to meet international researchers. Jonathan did get caught up in the experience, jumping in to help his students and celebrating them as they collaborated on laboratory techniques.

> Jonathan. Skype a Scientist, when I did use it, was phenomenal, and I've wanted to again. Because you have scientists coming in from anywhere in the world. (Interview)

This model has been used in all fields of research to enter discourse, learn, engage with experts on new topics (Van Zee, E. H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J.; 2001) and share discovery through communication (Fleming, 2019). It remains an important aspect of scientific communication, albeit indirect, and can lead to deep conversations in the classroom beyond the visit. This shared communication could also be interpreted from collaborative engagement via text, outside of classroom time as science teachers prepare for the next steps of the experiment with their students.

Theme 3. Incorporation of Science Research Literacy into Classrooms

Investigative Question 1. At the onset of this research, a global pandemic was not considered in developing a collaborative science teacher professional development series. The pivot was made without the support of literature, which has since begun being published (Hanley, Ho, Prichard, & Vanderford, 2022; Waddell, Ruiz-Whalen, O'Reilly, Fried, 2021). Through LTI, I was able to track the previous iterations of professional development and note the points of organic evolution needed to further support science teachers in meeting the growing requirements of State’s Department of Education. The most recent goals will see Urban City brought into close alignment with national standards for science education with the expectation that science teachers will be prepared to tackle phenomena-based and STEM career driven lessons in ill-prepared classrooms. Historically, when a scientific research program seeks to run a professional development for teachers the time is often limited to lectures by scientists or prescribed research projects in alignment with goals of the hosting institution or funding agency (Mentzer et al., 2017). Even more disheartening is when funding for those projects runs out or even when the professional development program reaches its conclusion, science teachers are left to their own devices trying to figure out how to transition the things they learned into feasible classroom materials. LTI+ sets out to change the trend and designs professional development *with* science teachers *for* science teachers.

Creating a system through which science teachers can know they are being heard is integral to sustainable success in the classroom, for the programming, and for the students. This collaborative system gives both the science teachers and the professional scientists the ability to share their personal strength while gaining new skills (Vyas, van der Veer, & Nijholt, 2013; Kamalipour, Kermani, & Houshmandipanah, 2014). Ensuring that participants of professional development geared towards increasing science research literacy have access to both scientists and seasoned teacher scientists was the secret sauce. By redefining professional development as formal and informal immersive situations of learning, science teachers remain supported as their science research literacy increases over time and through lived experiences. The goal of the LTI+ professional development was not having all the participants reach a certain level of science research literacy at the same time. It is designed to allow for organic growth and is made from a dynamic fabric that allows the science teachers to be flexible, finding the right fit for themselves at any given point. There will always remain room for growth for teachers and LTI+ alike.

As science teachers increase their science research literacy, they will have the tools and network available to meet the needs of the changing science curriculum in Urban City. Professional development through LTI+ extends beyond the formal session and as new standards are identified, science teachers have gained a network to discuss new needs for their students. This continuous feedback loop strengthens the authenticity of science in the classrooms and enhances the potential for program development through LTI+. Additionally, as science teachers gain confidence, they may opt to further their training with LTI+ and support more science teachers in bringing authentic, hands-on scientific research to their classrooms. Taking on leadership roles (Trabona, K., Taylor, M., Klein, E. J., Munakata, M., Rahman, Z., 2019) will serve to further increase science research literacy and enhance their science capital (Archer, et al, 2015).

The Unexpected

As illustrated in previously in Figure 12, an unexpected outcome emerged while focused on increased science research literacy in the classroom, it was noted that teacher scientists were also become community representatives in the shared space of science and education. In Chapter 4 we saw Giselle be invited to an Urban City conference to speak about bringing authentic research into classrooms, but looking again through photographic data it was noted that several LTI+ collaborative teachers are bringing about a call to action in the community. Kevin-Charles and Colin have both been seen at Urban City outreach events talking with parents, students, and teachers about the importance of authentic, hands-on, culturally driven research in schools. Going beyond the limits of Urban City, Giselle was invited to co-present with collaborators and LTI+ at a National Science-Education conference in the nation's capital. Her experiences with LTI+ programming and the shared stories about her personal growth, along with that of her students compelled audience participants from other states to inquire about collaborations and how these types of curricula can support citizen scientists outside of Urban City (Figure 20).

Figure 20
Science Research Literacy Goes From Classroom to Communities

Notes. A. Kevin-Charles and LTI graduate/LTI+ instructor introduce students as young as third grade to fruit flies during an invited event at an Urban City science museum; B. Colin at a table event encouraging Urban City students and undergraduates to learn more about LTI+; C. Giselle presenting at a National Science Education conference.

Implications

For Further Exploration on Student Impact

Although students played a role as citizen scientists in the classroom projects and were guided by their science teachers/ teacher scientists their impact following the professional development was only touched upon as a derivation of the focused data collection. This dissertation calls for a deeper examination of student outcomes, including impact on science and math standardized test scores and self-efficacy pertaining to personal growth as a scientist including peer and near-peer collaboration.

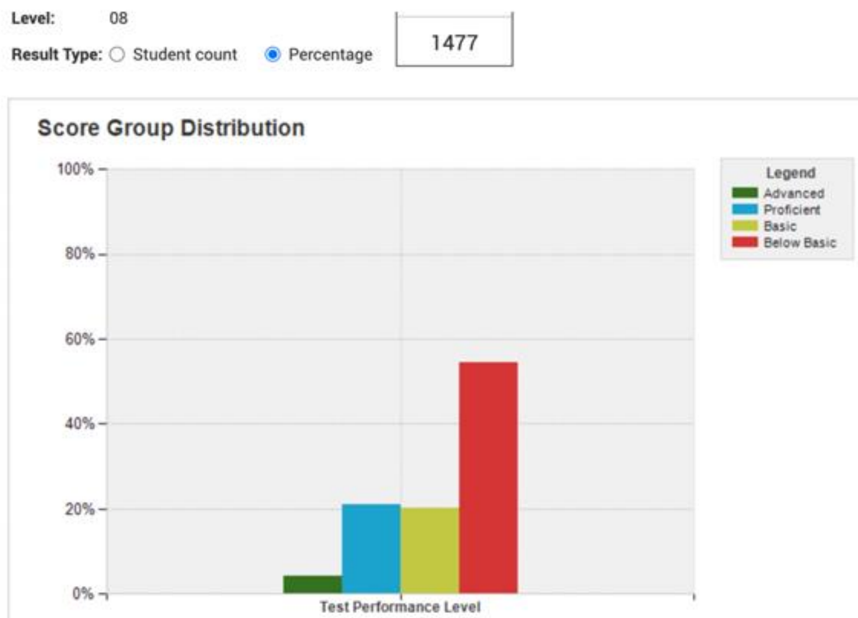
The participants who engaged in the in classroom immersive training were asked to talk about how they would incorporate LTI+ protocols into their future classes. One school had multiple participants complete the classroom project. While Imma was vocal in her self-identifying as a non-science person, it was clear that she wanted her students to have this research experience.

> Imma. I don't see exactly where they [LTI+ protocols] fit in our curriculum unless we connect it to just the organization of living things and not classification, but yeah, classification of life and we are studying reproduction maybe or I don't know. If I can't find a way, I'm still positive that it works because our PSSA scores were not so bad last year. I think

> having done this and not connected it to the curriculum, I don't think it did our students a disservice at all. I think they learned more from this that they actually could (Figure 21).

Figure 21

Math PSSA Comparative Scores Following Immersive Classroom PD



2022 PSSA Math Results

Grade	Total Number	% Advanced	% Proficient	% Basic	% Below Basic	% Proficient and Above
3	114,714	20.9	26.9	23.4	28.9	47.7
4	114,822	17.0	25.3	26.8	30.9	42.3
5	116,489	12.2	23.3	33.5	31.1	35.4
6	115,844	13.3	18.9	28.8	38.9	32.3
7	118,357	9.7	17.4	30.0	43.0	27.0
8	119,039	6.8	15.7	27.1	50.3	22.6

Notes. 2022 Math PSSA scores for Imma's class, following the LTI+ classroom project, and the 2022 PA percentile retrieved from www.education.pa.gov/DataAndReporting/Assessments/Pages/PSSA-Results.aspx

It is important to note that Imma collaborated with her school colleague, Brian to coordinate student work, as we see above, she concluded where to include the authentic research piece, from LTI+. It wasn’t until the student scientists presented their findings at the symposium event that Imma learned how the project impacted her students beyond test scores.

> Imma: Like I said, I tied it to the scientific method, so I was able to give my kids a little multiple choice quiz on what part of the scientific method.
>
> Dara: Awesome, that's great.
>
> Imma: And with the posters, yeah, I was kind of like, I'm glad they're done. These look nice. Yeah, good job. But I will say that my students that got to go to the Franklin Institute learned so much from being there that they knew what they were talking about. It was awesome.
>
> Dara: Did they go to other posters?
>
> Imma: They went to other posters and they started learning about what they did and connecting things to what they did and just watching them make those connections was just so awesome.
>
> Dara: Oh my gosh.
>
> Imma: Where they may not have actually known why they did what they did before. When they talked to the other students, especially the high school students, they made that connection.
>
> Dara: That's right. They're so much younger.
>
> Imma: And they learned, and they were so thrilled to be one of the few middle schools there. That was awesome, because there were mostly high school students. They might have been the only-
>
> Dara: They were the only middle school.

Student efficacy in feeling or thinking like a scientist would need to be further examined as illustrated through both Imma's reflection on the quantitative PSSA data and her observations and discussions with her students following the symposium event. The last open additional doors to explore the near-peer aspect of scientific mentorship (Clarke-Midura, J., Poole, F., Pantic, K., Hamilton, M., Sun, C., & Allan, V, 2018).

For Further Exploration on Scientist Impact

Another key group identified in this research is the scientists. They were pivotal in disseminating the content during the professional development sessions and expanded their roles from working through an intermediary to one-on-one project development with some more advanced research participants (Ebenezer et al., 2021). Giselle, who has been part of the LTI/LTI+ community since 2018 worked directly with the lead scientist of LTI and volunteer scientist of LTI+ to bring the citizen science research to her church. Working directly with a professional scientist and having them join the community following Sunday services opened an avenue for the church members to discuss scientific observations from their neighborhoods and have frank discourse regarding diabetes and how to ask questions of health professionals. Members of the Community Unity (pseudonym) Baptist Church in Urban City (Figure 22) spent time analyzing data, having a scientific presentation related to diabetes, and sharing their individual experiences and knowledge of diabetes including handed down recipes. Having Giselle bring a scientist to her church has opened additional engagement opportunities and research avenues.

Figure 22

Citizen Scientists Conducting Authentic Research

Notes. Giselle at her church as a co-facilitator, working with LTI+ to bring citizen science to her community.

Her immersive training in both science education and scientific research spaces expanded Giselle’s science research literacy and she is currently a member of a scientific research team helping local, Urban City, scientists address connections between cultural groups and Human Papilloma Virus (HPV). She designed an educational intervention (Figure 23) to open conversations at her church.

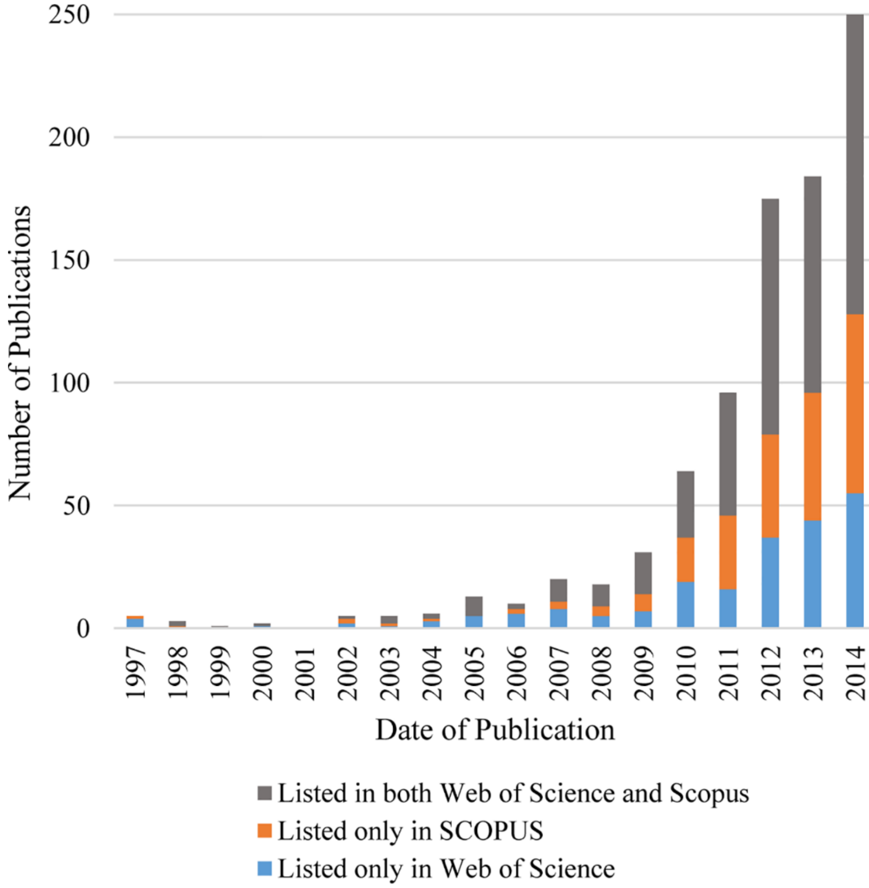
Figure 23
Teacher Scientist Collecting Data for Laboratory Viral Research

Notes. A Giselle re-engages with her church's congregation to share an educational intervention about HPV. This is a grant funded project and Giselle is completing this work with a team of scientific researchers. B. A text thread including responses from LTI/LTI+ Scientific Director and me regarding initiation of data collection in the community.

The scientific researchers are interested in learning from the community and Giselle is contributing a new perspective to laboratory and public health research. These hallmarks are a growing trend in citizen science as institutions recognize the need for melding competencies and knowledge into a unified language (Bela, G., 2016).

As the citizen scientist movement extends into peer-review (Figure 24) (Follett, 2015), there are still gaps in the literature that discuss the direct contributions science teachers make to the scientists in the scientist-science teacher collaborative relationship.

Figure 24
Growth of Citizen Science as a Research Method



Notes. The growth of published peer-reviewed articles in citizen science (1997- 2014). Reprinted from "An analysis of citizen science based research. Usage and publication patterns." PLOS. doi.10.1371/journal.pone.0143687

Collaborative programs, like Shanahan & Bechtel described still frame the high school science teachers within a quasi-learner space and while the teachers were seen as experts in their field, and to an extent science, they were still "downplayed, backgrounded, or undervalued" (p. 379). It should be noted that the small groups of LTI+ scientists were focused on the success of these collaborations and knew that they could learn from the science teachers in addition to helping mentor them in content execution in a research environment. Working in research laboratories, alongside scientists promoted their science research literacy, their confidence in being able to flex with open-ended research in their teaching and knowing that their expertise is valuable (Figure 25).

Figure 25
Exchange of Ideas

Notes. A. Colin and Giselle with three collaborative LTI professional scientists at a student presentation event. B. Colin fusing his pedagogical knowledge with the LTI content. C. Colin brainstorming with an LTI/ LTI+ scientist in the LTI training laboratory. D. Colin and LTI Scientific Director and Principal Investigator discussing what data connections can be made and how to best discuss with student scientists. E. Colin's classroom research experiment preparations through which each student will arrive at a novel, unique data output.

Throughout the interview, Colin kept bringing the discussion back to collaboration, and it was important to hear how Colin emphasized his experience as a learner and his contribution.

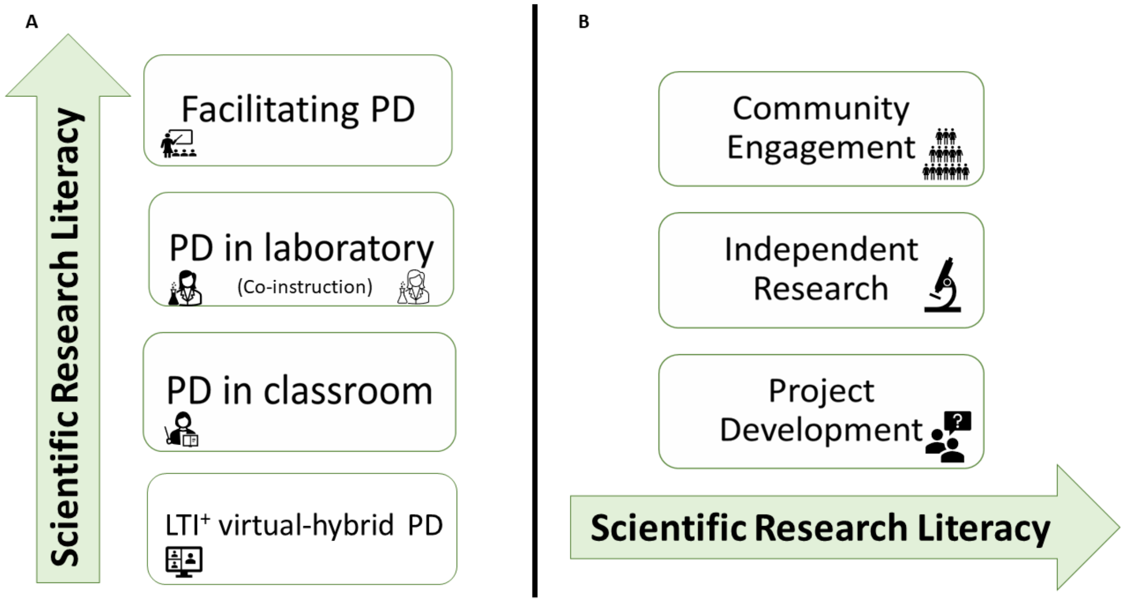
> Colin. Well, what I was going to say was I think what works best is if you have the collaboration. For me, I really enjoy the collaboration of the teacher and the scientist in "LTI+" because I feel like you're helping me reach another level myself. I'm learning from you, and you're learning from me. So I'm learning the more technical side of the information, and I'm expanding my knowledge of the scientific content. But then I'm teaching you how to take that information and bring it down to a different

> community, an out of the box kind of thing. So I think it's the perfect match up, and I think that's what makes your program great. I think that that's why so many people are drawn to it because you have people in the scientific community being drawn to it, and you have people in the educational world being drawn to it. Now what we're trying to do is we're trying to work together to excite the next generation of people. I think that that's really the key, I think.

Summary

The research's findings suggest a hybrid professional development curriculum was necessary to maintain flexibility during times of public health stress and to meet the needs of teachers in the Urban City School District. It was critical to science teacher participants that the professional development be flexible to these needs, but that the curriculum also have aspects to allow for specialization in classrooms. Engaged science teachers and teacher scientists want to ensure the highest-level authenticity for their student scientists and have the confidence to make the research their own. to make their own. Increasing science research literacy is a continuum of scientific independence and growth occurs on a sliding scale. Even more amazing is that science research literacy is not contained by school walls and as it increases, extends out into the community (Figure 26). These findings have solidified my understanding that success is not measured in a binary fashion when it comes to access and support in a growing, collaborative community of scientists and educators. As a teacher scientist or scientist teacher, my understanding of how people learn is a framework for why this has been successful.

Figure 26
Growth of Science Research Literacy



Notes. A. Science research literacy increases as science teachers progress through iterative, immersive professional development trainings. B. Science research literacy can extend beyond the classroom as PD participants become engaged with the research and share it with their community, often addressing new questions brought on by previous research.

Final Words

Building collaborative professional development programs is a dynamic endeavor. As a bridge between the fields of benchwork science research and science classroom experience I have listened to the science teachers, appreciate the criticism along with the compliments, and understand that the development of these programs is also on a continuum and will continue to improve and change the way science teachers interact with biomedical scientific research to make it meaningful in the classroom.

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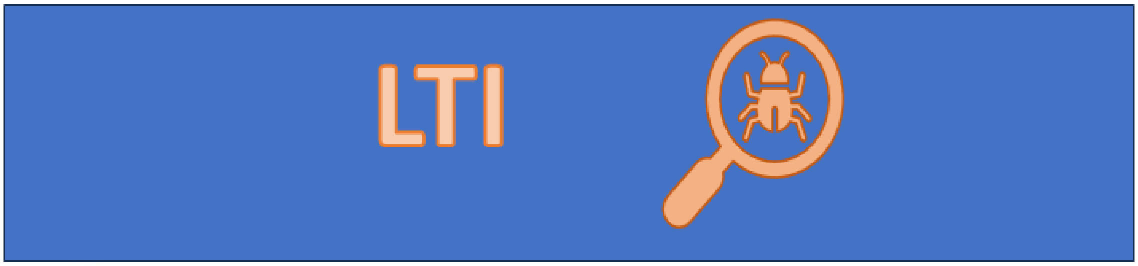
APPENDIX A

CALL FOR PD PARTICIPANTS



Exciting news!

We are officially launching the application for the

2018 Summer Teacher workshop.

This 1-week workshop is funded by a grant awarded by the [redacted]) and run by the [redacted]

- Selected participants will receive a small stipend and materials for use in the laboratory & home classroom.
- The will work with the participants through the 2018-2019 academic year as the protocols/techniques are transferred into the classrooms.
- We will be selecting 8 to 10 participants for this workshop.

The application link is below (Google Form) and the **cycle will close June 15th**.

This is a competitive application with applications reviewed by educators and scientists.

[redacted]

Please share this link with science teachers that you feel would contribute to the ISP and benefit from this workshop.

- **Date & Time:** August 6- 10, 2018 M-Th 10a-2p and F 10a-4p
- **Location:** [redacted] commuter only)
- **Workshop Size:** We will be selecting 8 to 10 participants for this workshop.
- **Primary Focus Group**: High school; Biology (any level)
  - Others also considered: Health-related, "STEM", & middle school life-science
- **Project focus**: Dietary effects on development in fruit flies.
  - We will use various techniques, including observation of wing vein development, to screen supplements against genes in cancer signaling pathways.
- **Topics:** Cell division/apoptosis, transduction pathways, and cancer will be discussed.
  - Diet/nutrition will be linked to these discussions.
- **Practical:** On day 5, participants will engage a mock-lab-class (of former ISP graduates) in a hands-on activity to gain insight on how to bring the project into their classrooms.

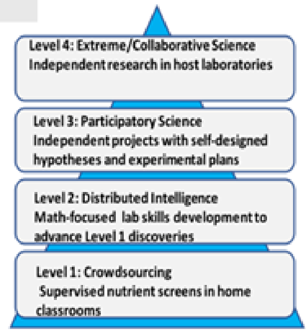
If you have any questions, please contact the

Notes: Call for Participants LTI 2018

LTI

Citizen Science for Biomedicine

Apply on-line BY March 1, 2019



This inaugural [redacted] conference provides collaborative opportunities for teacher and scientist teams to co-develop curricula.

GOALS

1) Engage, educate, and include HS students in research while complimenting standardized curricula (General, Honors, AP), and
2) Provide statistically significant data that address and inform scientific foci in host research laboratories.
3) In workshops & breakout sessions, teams will develop research programs for use in HS classrooms.

[redacted] FOR TEACHERS

Adapt your classroom to recreate a research laboratory!

- Participate in workshops to address state and national standards in scientific education through the introduction of research practices into your classroom laboratory.
- Learn laboratory skills and data analysis techniques that you can use in your classroom.
- Gain expertise in teaching advanced research concepts in general- through AP- level classes.
- Develop collaborations with teachers from across the country!
- Set your classroom up as a [redacted] Laboratory!

[redacted] FOR SCIENTISTS

Adapt your primary research program to citizen science!

- Use [redacted] Programming to develop research projects that will be conducted in high school classrooms.
- Collect large data sets geared towards addressing specific hypotheses via crowdsourcing.
- Participate in workshops to learn evaluation, IRB protocol development, and methods to enhance Broader Impacts.
- Develop micro-lectures on your science for use by high school teachers & students.
- Plan multi-PI grants.

Joint Workshops & Collaborative Breakout Sessions

- Inclusion as an approach to broaden research questions and address disparities in health and research.
- Approaches to enhance research literacy in the context of a standard science curriculum.
- Development of classroom lab activities that address primary research questions.
- Collaborative writing for joint publications.

[redacted] FOR UNDERGRADUTE STUDY

Sunday, April 14th

- Work with scientists and science teachers to coordinate the transition from HS to college research projects.
- Continue the 'pipeline' of research at your academic institution.
- Create collaborative networks with other colleges/universities.

HOW TO APPLY

- Applications are available at:

Notes: Call for PATHWAYS 2019

LTI+

EXCITING NEWS!

We are re-launching the application for the
[redacted] cost-free PD for science teachers
Questions: [redacted].org

Participants will receive:

- Materials/small equipment for use in the laboratory and home classrooms
- A thank you gift card, for participating in full workshop
- Support as protocols/techniques are transferred to participant's classrooms

6 to 10 participants will be selected for this workshop
This is a competitive application reviewed by scientists & science educators
Option to take part in a PhD thesis project
graduate student does NOT select applicants
Graduate student does NOT review applications.
This is not part of the review process
Teachers can be formal/informal, middle/high school, Philadelphia preferred
(public, private, charter, vocational, technical, parochial)

Date & Time: 1/28/22 (5p-7p) and 1/29/22, 1/30/22 (9a- 12noon)
Location: Friday- ZOOM; Saturday/Sunday ([redacted])
Participants: 6 to 10 participants
Primary Focus Group: High school: Biology (any level), General Science, and Middle school life-science **Others also considered: Health-related, environmental science, "STEM", & chemistry
Project focus: Dietary effects on Development using fruit flies as a model organism **We will use various techniques, to screen supplements against genes in cancer and diabetes signaling pathways.
Topics: Cell division/apoptosis, transduction pathways, and cancer/diabetes will be discussed. **Diet/nutrition will be linked to these discussions.
Techniques may include: pipetting, microscopy, solution preparation, fly work, data analysis, and internet research

Notes: Call for Participants LTI+ 2022

APPENDIX B

CLASSROOM EXPERIMENT PROGRAM: SCHEDULE OVERVIEW

Pre-Program.

1. **Students pick up kits**
2. Safety worksheet→ reviewed by teachers
3. Familiarize yourself with the protocol
4. **PLEASE keep box in cool area…room temperature is good!**
5. **Do not open the box (yet)**

Getting Started.

1. **Students pick up fly vials this week to keep them "fresh" and "easy to use"**
2. Unpack the box.

Making our sample vials.

1. *Intro quiz*
   Protocol
2. 1mL dH2O out of 15mL screw-cap, conical tube --> 1.5mL snap cap microfuge tube
3. Use mini mortar/pestle to grind up food samples SUPER fine.
4. Use 0.5mL mark on snap cap tube to "measure" 0.5g of food--> into 1.5mL snap cap microfuge tube.
5. Make treatment vials
6. Allow to "dry"/set until next week. STORE IN ZIP BAG with FLUG ON
7. Show Tap-Tap-Flip and label the stopper
8. HW. PRACTICE Tap-Tap-Flip
9. HW. Research the foods and have each student identify what they think is the healthy or unhealthy component/ingredient is?
10. HW. Pix of lab stations/ #ScienceSelfie

Experiment. DAY 0
Moving the adults.

1. Have them show you confident tap-tap-flip
2. Flip flies into dry treatment vials from last week
3. HW. Write Hypotheses… Use presentation template

Experiment. DAY 7
Move flies into empty vial→ freeze

1. *mini lecture*

2. Flip flies into empty fly vial → freeze overnight→ use magnifiers to examine and create an image of your fly
3. KEEP THE VIALS WITH TREATMENT AND CONTROL
4. HW. Work on methods slide
5. KEEP Vial in room temperature area. You will be scoring the pupa NEXT WEEK

Experiment. DAY 14
Data.
1. *mini-lecture*
2. Score pupa and eclosed adults
3. Enter in Google Sheet and create a graph in group presentations.
4. HW. Work on data slide, conclusion, and what your next project would be

CLASS FOLLOW-UPS.
1. You will receive a data set for control.
    a. Have students compare both fertility and mortality data sets.
2. Use loupes to examine phenotypes of their mutant flies
3. Data in Google Sheet and group Slides
4. HW. Analyze the data… what do the groups see?
5. Draw conclusions!
6. Next steps!
7. Practice and get slides set up.
8. HW. Practice with groups.

Invite us to hear presentations… SHARE your data across classes (each class has a different gene but the same test-foods)
1. Presentation Day!!

APPENDIX C

APPROVED TIMELINE FOR RESEARCH ACTIVITIES

Activity	2021				2022				2023		
	SP	SM	FL	WN	SP	SM	FL	WN	SP	SM	FL
Observation- immersive teacher training via face-to-face OR virtual-hybrid instruction		X	X	X	X	X					
Observation- Science teachers present classroom model following PD			X	X	X	X					
Face-to-Face OR Virtual-Hybrid - Science teacher professional development (PD)		X	X	X	X						
Science teachers co-instruct 5-day camp		X				X					
Science teachers co-instruct UG-level program *one of two		X		X		X					
Memo writing		X	X	X	X	X					
Teachers develop assessment/lesson plans (curricula) for classroom/program, inquiry-driven laboratory research project.	X	X		X	X	X		X			
Fieldnotes		X	X	X	X	X					
Interviews: teachers		X	X	X	X	X					
Collect and organize data					X	X		X	X		
Analyze data						X	X	X	X	X	
Intensive writing							X	X	X	X	X

APPENDIX D

ALIGNMENT OF RESEARCH QUESTIONS, DATA COLLECTIONS, AND DATA ANALYSIS

Research Question	Data required to answer the question	Data analysis technique
1. How is science research literacy conveyed via immersive professional development)?	Observations of teachers in 5-day PD Observations of teachers in classrooms implementing curricula Observations of teachers in academic institutes implementing curricula Observations of teachers in professional research laboratory (informal learning spaces) implementing curricula Video/audio recording of instructions in F2F and V-H	Constant comparative analysis of fieldnotes. Development of codes, themes, and categories on teacher definitions of research literacy; Analysis of perspective. jotting during observations.
2. How will teachers use their science research literacy skills to enhance their teaching of science?	1. Observations of teachers during immersive co-instruction 2. Observations of teachers in home-classrooms or program before during and after PD. 3. Artifacts used by teacher before, during, following training series (Powerpoint presentations, worksheets, homework assignments, laboratories)	Development of codes, themes, and categories on teacher definitions of research literacy; Analysis of perspective. jotting during observations; Constant comparative analysis of interview transcripts; development of codes, themes, and categories around the meaning generated from collaborative interactions; semiotic analysis of graphics and visual aids used and the importance indicated by the different images

APPENDIX E

SCIENCE TEACHER INITIAL INTERVIEW QUESTIONS

1. Can you tell me a little bit about your undergrad studies? You were a science major? Did you have a mentor or senior educator to support you?
2. With an already busy schedule, having converted work to virtual or hybrid platforms, why did you opt in for an additional professional developing training? What prompted you to answer the call for applications to the LTI?
3. Tell me about your current instructional content and techniques. What types of laboratory instruction do you utilize in the classroom?
4. Have you worked in a science laboratory beyond your undergraduate studies?
5. How would you describe a science teacher?
6. What characteristics do science teachers share with ones you would consider non-science teachers?
7. What is your definition of a scientist?
8. How would you describe the scientific research process?
9. How would define science research literacy?
10. What is a common term a scientist would use?
11. How does a scientist dress?
12. (Given the parameters of the PD) What scientific question would you want to address during the PD?
13. What is a typical scientific question your students would ask?
14. What makes a science teacher a “better” lecturer than say a professional scientist?

APPENDIX F

SCIENCE TEACHER FOLLOW-UP INTERVIEW QUESTIONS

1. What did you find challenging about the training? What came easily for you?
2. What components of each level of immersive training prepared you for the subsequent trainings? What are the techniques (didactic, hands-on, or other) that would have further supported you during subsequent levels?
3. Now that you have met and worked with a scientist, what is your definition of a scientist?
4. Having completed at least one level of immersive training, how would you describe the scientific research process?
5. Which skills and/or techniques are you going to bring into your classroom and why these in particular?
6. What kind of science research skills do you want your students to learn and which ones do you value the most?
7. What is a common term a scientist would use?
8. How does a scientist dress?
9. Now that you have completed the PD, what scientific question would you want to address?
10. What scientific questions would you prompt your students to ask?

APPENDIX G

HALLMARKS OF SCIENCE RESEARCH LITERACY: CONTINUUM

LOW SCIENTIFIC RESEARCH LITERACY

- Focused on protocols→ access to tools is important (but unaware of what tools exist)
- Rote memorization
- Everyone in lab gets same answer
- Engagement with science is only through the literature.

HIGH SCIENTIFIC RESEARCH LITERACY

- Engage with scientists as peer collaborators
- Come up with research questions
- Present to parents, community
- Science communication
- Protocols are (become) co-designed
- Using correct metric/scientific labels and tool names
- Using proper science tools to get the most accurate answers
- Encourage diverse answers to research questions

LOW INCORPORATION of SCIENTIFIC RESEARCH LITERACY

- Unable (or unwilling) to teach without support
- Unable to blend scientific research literacy into curriculum
- "Tell me how"
- Don't want it for themselves
- Low effort/motivation information dumping

HIGH INCORPORATION of SCIENTIFIC RESEARCH LITERACY

- Want to answer bigger question not related to exams
- Found ways to fold in authentic experience into curriculum
- Getting students comfortable with vocabulary
- Comfortable layering science
- Celebration of Science

APPENDIX H

QUALITATION DATA PLOTTING: CHANGES IN SCIENCE RESEARCH LITERACY VARIABLES

	Kevin-Charles		Marisa		Brian		Imma		Madison		Colin		Giselle		Jonathan	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Low Scientific Research Literacy																
Focused on protocol	+	●	+	●	+	●	+	●	+	●	+	●	+	●	+	+
Rote memorization	+	◊	●	●	●	●	+	●	+	●	+	●	+	●	●	●
Everyone in lab gets same answer	+	●	●	●	+	●	+	●	+	●	+	●	+	●	+	●
Engagement with science is only through the literature	●	●	●	●	+	●	●	●	●	●	●	●	●	●	●	●
Low Incorporation of Scientific Literacy																
Prefer to teach with support	●	+	+	+	+	●	+	●	◊	●	+	●	+	●	+	+
Unable to blend scientific research literacy into curriculum	+	●	◊	◊	●	●	+	●	◊	●	●	●	●	●	●	●
"Tell me how"	+	◊	+	◊	+	●	+	+	◊	●	+	●	+	●	+	+
Information dumping	+	◊	●		+	●	+		◊	●	+	●	+	●	+	
High Scientific Research Literacy																
Engage with scientists as peer collaborators	◊	+	●	●	◊	+	●	●	●	+	●	+	●	+	◊	◊
Introduce new research questions	●	+	+	+	●	+	●	●	●	●	●	●	●	+	●	●
Present to parents, community	◊	+	+	+	◊	+	●	●	●	+	●	+	+	+	+	+
Science communication	◊	+	●		●		●	◊	●	+	+	+	+	+	+	+
Protocols become co-designed	●	◊	●	+	◊	+	●	◊	●	●	●	+	●	+	●	●
Use correct metric/scientific labels and tool names	●	◊	●	◊	◊	+	◊	◊	+	+	●	+	●	◊	●	+
Use proper science tools to get the most accurate answers	●	◊	●	◊	◊	+	●	◊	+	+	+	+	●	◊	◊	◊
Encourage diverse answers to research questions	●	+	●	+	◊	+	●	+		+		+	●	+	●	+
High Incorporation of Scientific Literacy																
Want to answer bigger question not related to exams	◊	+	●	●	●	◊	●	◊	●	◊	●	◊	●	+	●	◊
Incorporate authentic experience into curriculum	◊	+	◊	+	●	◊	●	◊	+	+	●	+	●	+	◊	+
Get students comfortable with vocabulary	●	◊	●	◊	●	◊	●	●	+	+	●	+	●	◊	◊	+
Comfortable layering science with culture	●	+	●	◊	●		●	●	●	●	●	●	●	+	●	●
Celebration of Science	●	+	●	+	●	◊	●	●	●	◊	●	+	●	+	●	●

● not observed/low
◊ somewhat/beginning
+ yes