A Mutual Exchange of (Mis)Recognition: Exploring the Science Identity Impacts of the Paired Elementary Pre-service Teacher and Undergraduate Science Major Model of Youth-led Science Investigations.

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Abstract

This study explores a novel model of informal science learning (ISL) by pairing pre-service teachers and undergraduate science majors to co-perform youth-led science investigations, addressing a gap in the research on the science identity impacts of such partnerships. Previous literature underscores the transformative impact of ISL on pre-service teachers' science identities and highlights a need for more work surrounding the science identities of undergraduate science majors. The study investigates the following research questions: *1) What science capital and perspectives about science do pre-service teachers and undergraduate science majors bring to co-perform youth-led ISL? 2) Can pre-service teachers and undergraduate science majors recognize each other's expertise while co-performing youth-led ISL? 3) What are the science identity impacts of their engagement in the paired model of youth-led ISL?* Findings reveal diverse experiences, with the pre-service teachers having limited previous experiences with science and the undergraduate science majors having a wealth of previous experiences with science. One of the co-investigative pairs demonstrated mutual recognition of expertise, while the other faced challenges rooted in socially engrained views of science, leading to misrecognition (Avraamidou and Schwartz, 2021). Diverse science identity impacts were observed leading to three distinctive themes: Supported Identities, Expanding Identities, and Identities in Conflict. Implications emphasize the need for mutual learning and recognition in ISL contexts to disrupt the prevalent notion of education as "lesser than" the work of scientists. We suggest structured reflection sessions to enhance relationship building and motivate workshops on science capital pre-ISL engagement to help enhance equitable recognition between partners and the youth. This study contributes valuable insights to designing collaborative ISL programs and promoting positive identifications with science.

Résumé

Cette étude explore un nouveau modèle d'apprentissage informel des sciences (AIS) en associant des enseignants en formation et des majeures de science pour mener ensemble des enquêtes scientifiques dirigées par des jeunes, comblant ainsi une lacune dans la recherche sur l'impact de tels partenariats sur l'identité scientifique. La littérature antérieure souligne l'impact transformateur de l'AIS sur l'identité scientifique des enseignants en formation et met en évidence la nécessité de poursuivre les travaux sur l'identité scientifique des majeures de science. L'étude se penche sur les questions de recherche suivantes : *1) Quel experiences scientifiques et quelles perspectives sur les sciences les enseignants en formation et majeures de science apportent-ils pour co-exécuter l'AIS dirigé par les jeunes? 2) Les enseignants en formation et les* majeures de science *peuvent-ils reconnaître l'expertise de l'autre lors de l'exécution conjointe de l'AIS? 3) Quels sont les impacts sur l'identité scientifique de leur engagement dans le modèle jumelé de l'AIS?* Les résultats révèlent des expériences diverses, les enseignants en formation ayant peu d'expériences antérieures avec les sciences et les étudiants en sciences de premier cycle ayant une multitude d'expériences antérieures avec les sciences. L'une des paires de co-enquêteurs a démontré une reconnaissance mutuelle de l'expertise, tandis que l'autre a fait face à des défis enracinés dans des vues socialement ancrées, menant à une reconnaissance erronée (Avraamidou et Schwartz, 2021). Diverses incidences sur l'identité scientifique ont été observées: identités soutenues, identités en expansion, et identités en conflit. Les implications soulignent la nécessité d'une reconnaissance mutuels dans l'AIS afin de rompre avec la notion prévalente de l'éducation comme étant "inférieure" au travail des scientifiques. Nous suggérons des sessions de réflexion structurées pour améliorer la création des relations, et des ateliers sur le capital scientifique pour aider à améliorer la reconnaissance équitable entre les partenaires. Cette étude apporte une contribution à la conception de programmes collaboratifs en matière d'AIS et à la promotion d'identifications positives avec la science.

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Introduction

Research Context

In recent years, there has been an increase in the development of informal science learning (ISL) opportunities for university students and youth alike, allowing them opportunities to engage informally in science, technology, engineering, and math (STEM) experiences. The increase is likely in part due to the increased recognition of the importance of informal STEM education and the ways it can help to support STEM learning (National Research Council, 2009, 2015). ISL programs include local clubs, community-run activities (such as science fairs, competitions, awards, etc.), designed spaces (such as science museums and centers, etc.) and events (such as festivals) (Archer et al., 2021). The programs with kindergarten to grade 12 students are often performed during school time as a special event, in afterschool contexts, or at specialized locations such as day camps or in museums. Most notably, many studies have documented the positive impacts of out-of-school time ISL, including increased interest in science (e.g. Laursen et al., 2007), long-term engagement in science (e.g. Maltese et al., 2014), and opportunities for identifying with science as something that is "for them" (Barton & Tan, 2010, 2017; Carlone et al., 2015).

Many of these ISL programs are organized through university-community partnerships and are often referred to as science "outreach" programs or built into university courses and called "service-learning" opportunities. As a result, university undergraduate science majors are regularly engaging in ISL programming for youth for various reasons, including to gain science communication skills and to build their resumes (Carpenter, 2015; Fogg-Rogers et al., 2017). While undergraduate science majors may appear to be the natural choice to perform ISL programming due to their inherent science content knowledge, they have little training in working with youth or communicating science to varied audiences (Renaud et al., 2006).

Pre-service teachers, on the other hand, receive a lot of teaching training in their university programs but often have few opportunities to perform or engage in ISL themselves. Elementary school pre-service teachers specifically, are leaving their teacher education programs lacking sufficient science content knowledge to feel confident teaching science (Avraamidou, 2013) or to engage informally in science learning and teaching. Research suggests they position themselves as "non-scientists" and are wary of the subject (Mulholland & Wallace, 2003). Teachers with low belief in their ability to perform and teach science are more likely to avoid teaching it (Harlow, 2012). Fortunately, participating in ISL programs can allow pre-service teachers opportunities to learn about how students think about science, and to gain science content knowledge and teaching skills (Kisiel, 2013; Wissehr & Hanuscin, 2010). Additionally, much research has been done on supporting pre-service teachers' science teaching practice through ISL as well (e.g. Luehmann, 2009), and it has been shown to improve their science teaching self-efficacy and science content knowledge (e.g. Douglass, 2023; Fogg-Rogers et al., 2017; Harlow, 2012; Kang & Martin, 2018). Engaging in ISL, therefore, helps to make science more "thinkable" (Archer et al., 2012) to preservice teachers as something that is "for them" (Archer et al., 2015). This type of thinking is called developing a "science identity" (Carlone & Johnson, 2007), which is crucial for continued engagement in science (Archer et al., 2014; Black & Hernandez-Martinez, 2016). While some studies explore pre-service teachers' science identity development throughout ISL experiences (Adams & Gupta, 2017a; Avraamidou, 2014; Luehmann, 2007, 2009; Rahm et al., 2016), very few look at undergraduate science majors' science identity development through ISL (Cavalcante & Gonsalves, 2021; A. J. Gonsalves et al., 2021; K. Nelson et al., 2017)

Many ISL programs have been known to pair up teachers and scientists, but we know little about the impacts of these partnerships on the identity work for either scientists or teachers. Minimal research has explored the science identity impacts of pairing pre-service teachers and *scientists* together in informal science contexts (Cook & Buck, 2013; Shanahan & Bechtel, 2020).

One study focused on pairing pre-service teachers and undergraduate *engineering* majors to perform an engineering ISL opportunity together with youth but did not explore the identity impacts of such pairings (Fogg-Rogers et al., 2017). Fogg-Rogers et al. (2017) found that the paired model of ISL with youth yielded greater learning opportunities for both the engineering undergraduate students and the pre-service teachers. The novel pairing of undergraduate science majors with pre-service teachers may allow for these two groups to support each other's science content and science pedagogical knowledge development, as undergraduate science majors have little teaching knowledge but lots of science content knowledge and vice versa for the pre-service teachers.

Research Objectives

To address this gap in ISL research and to support pre-service teachers and undergraduate science majors in their science identity development, this study aims to explore the novel paired undergraduate science major and pre-service teacher model of ISL with youth. We created a weekly afterschool science club through an elementary school-university partnership and paired together pre-service teachers and undergraduate science majors to co-perform youth-led science investigations. Using interviews and video diary data co-generated with the preservice teachers and undergraduate science majors, this thesis aims to explore the following research objectives: to learn about the experiences with science and perspectives about science and science teaching that pre-service teachers and undergraduate science majors bring to the program; and to understand how the interactions between these two groups impact their identity work as they engage in a youth-led science project. Before discussing my research, I will first discuss the literature to which this work joins the on-going discussions (Chapter 2), followed by the theoretical frameworks this work is built upon (Chapter 3).

Literature Review

The following literature reviews focus on university partnerships where university students engage with youth in the community through organized programs (Sasson, 2019). Examples include afterschool science clubs, workshops, and family science nights. These programs are often called “science outreach” by the universities and corresponding literature. However, to be more equity-minded, and to avoid implying a deficit in the communities in which we engage, I have chosen to refer to such types of work as “ISL opportunities” instead (Archer et al., 2021).

ISL is the term used to denote STEM learning which occurs outside of the structures of formal contexts within learning institutions (Dierking et al., 2003). While most informal learning opportunities can be simply defined in this way, there is one notable exception: service-learning programs. Service-learning links together academic school learning and providing a service to a community (Fertman, 1994, p. 8). As such, service-learning is an informal learning opportunity sandwiched between formal learning opportunities. Service-learning courses are widely used in Canadian university contexts to supplement formal learning (Taylor et al., 2015). As a result, service-learning is often present in ISL literature.

I will now review the literature on pre-service teachers in ISL contexts, followed by the literature on undergraduate science majors in ISL contexts. Then, I will review the literature on ISL programs who employ the paired science major and pre-service teacher type partnerships, which this research is modeled after. To obtain the included literature for the reviews, a survey of scholarly sources until idea saturation was conducted using the following search terms: (pre-service OR novice OR in training) AND teacher AND (service learning OR outreach OR informal OR museum OR outside of school OR after school OR club OR community) AND (science OR engineering OR chemistry OR biology OR physics OR STEM OR STEAM). The same search was conducted with undergraduate science majors, and then a search was conducted with both undergraduate science majors and pre-service teachers. Rules for inclusion in the literature review(s) were if the article was published after the year 2000 and until present, and if they discussed one or both groups (pre-service teacher/undergraduate science majors) engaging informally in science learning (i.e. some aspect was outside of university context), with or without youth, all other articles were excluded.

Elementary Pre-service Teachers Engaging in ISL

Pre-service teachers are engaging in informal science learning through a variety of university partnerships. These partnerships include: *university-community* (Avraamidou, 2015; Borgerding & Caniglia, 2017; Cone, 2012; Dani et al., 2018; Harlow, 2012; Petillo, 2016; Tembrevilla & Milner-Bolotin, 2019; Wallace, 2013), *university-museum* (Adams & Gupta, 2017a; Clarke-Vivier & Bard, 2016; Kreuzer & Dreesmann, 2017), *university-school* (Avraamidou, 2015; Burke, 2016; Fogg-Rogers et al., 2017; Kang & Martin, 2018; Macdonald, 2010; Marttinen et al., 2020; Rahm et al., 2016; Scharfenberg & Bogner, 2019; Wallace, 2013), and *university-makerspace* (Douglass, 2023; Douglass & Verma, 2022). Through these partnerships, pre-service teachers are engaging in various types of informal science learning programs such as: participating in a STEM makerspace (Douglass, 2023; Douglass & Verma, 2022), science and engineering clubs (Fogg-Rogers et al., 2017; Marttinen et al., 2020; Rahm et al., 2016; Scharfenberg & Bogner, 2019; Wallace, 2013), science projects (Burke, 2016), science fairs and festivals (Avraamidou, 2015; Kang & Martin, 2018; Petillo, 2016), field study and interaction with a scientist (Avraamidou, 2015), public family science events (Borgerding & Caniglia, 2017; Dani et al., 2018; Harlow, 2012; Tembrevilla & Milner-Bolotin, 2019), zoo curriculum development (Borgerding & Caniglia, 2017), and museum tours with inquiry activities (Adams & Gupta, 2017a; Clarke-Vivier & Bard, 2016; Kreuzer & Dreesmann, 2017).

Research on pre-service teachers and ISL tends to describe pre-service teachers learning in service-learning contexts. For undergraduate preservice teachers, the ISL opportunities took place as part of a *required science methods course* (Avraamidou, 2015; Cone, 2012; Dani et al., 2018; Douglass, 2023; Douglass & Verma, 2022; Harlow, 2012; Macdonald, 2010; Spector et al., 2020; Tembrevilla & Milner-Bolotin, 2019) or as part of *optional courses*, such as courses on museum natural history (Kreuzer & Dreesmann, 2017), the history of mathematics (Petillo, 2016), adolescent development (Rahm et al., 2016), and educational psychology (Clarke-Vivier & Bard, 2016). Two studies mentioned training specific to the ISL opportunity only and not as part of a larger course, including short role-play-based training (Kang & Martin, 2018) and half day of mentoring in education outreach, engineering design process and engineering challenges (Fogg-Rogers et al., 2017). While perhaps the pre-service teachers signed up for the optional courses to experience the ISL opportunity, very few volunteer only experiences, such as the context of this study, were found (Fogg-Rogers et al., 2017).

Universities are using ISL opportunities to supplement formal learning, as many pre-service teachers are experiencing university practicums lacking in hands-on learning and opportunities to try-out cutting edge teaching practices they have read about in the theory (Borgerding & Caniglia, 2017; Macdonald, 2010; Marttinen et al., 2020; Rahm et al., 2016). Additionally, engaging in ISL is being leveraged as an opportunity for pre-service teachers to learn about:

1. *equity, diversity and inclusion* in science through engaging diverse learners (Adams & Gupta, 2017a; Burke, 2016; Cone, 2012; Kang & Martin, 2018, p. 322; Marttinen et al., 2020; Rahm et al., 2016) and through exploring the different inclusion and invitation to science ISL affords (Douglass, 2023; Douglass & Verma, 2022);

2. *informal science learning environments* themselves (Douglass, 2023; Douglass & Verma, 2022; Kang & Martin, 2018), as low stakes practice environments (Adams & Gupta, 2017a; Clarke-Vivier & Bard, 2016);
3. *science*, including the nature of science (Dani et al., 2018; Petillo, 2016; Scharfenberg & Bogner, 2019) and science related skills (Tembrevilla & Milner-Bolotin, 2019);
4. *youth* and how to access and assess their knowledge (Burke, 2016; Harlow, 2012);
5. *teaching,* through critical reflection (Dani et al., 2018; Marttinen et al., 2020), building confidence and self-efficacy in STEM teaching (Douglass, 2023; Fogg-Rogers et al., 2017; Harlow, 2012; Tembrevilla & Milner-Bolotin, 2019), practicing pedagogical strategies (Clarke-Vivier & Bard, 2016; Dani et al., 2018; Marttinen et al., 2020; Tembrevilla & Milner-Bolotin, 2019; Wallace, 2013) and engaging with reform-minded practices (Avraamidou, 2014; Douglass, 2023; Luehmann, 2007).

Engaging in ISL is a multidimensional and multi-faceted experience effecting pre-service teachers in a multitude of ways (see Appendix A, table 1: Benefits of pre-service teachers engaging in ISL programming). Most importantly for this study is the effect on pre-service teachers' science related beliefs, attitudes, and dispositions. Many studies discuss attitudinal or belief changes as a result of ISL engagement, including increased science (teaching) self-efficacy and increased science (teaching) confidence (Avraamidou, 2015; Dani et al., 2018; Douglass & Verma, 2022; Fogg-Rogers et al., 2017; Harlow, 2012; Kang & Martin, 2018; Kreuzer & Dreesmann, 2017; Petillo, 2016; Spector et al., 2020). ISL affords pre-service teachers opportunity for reflection on their own practice and position as a (science) teacher, otherwise thought of as their identity in relation to science and teaching (Borgerding & Caniglia, 2017; Kang & Martin, 2018; Rahm et al., 2016; Scharfenberg & Bogner, 2019). As a result, numerous studies discuss identity impacts when pre-service teachers engage in ISL contexts and these will be discussed in the following paragraph

(Adams & Gupta, 2017; Avraamidou, 2013, 2014; Douglass, 2023; Luehmann, 2007; Luehmann & Markowitz, 2007; Rahm et al., 2016).

Engaging in ISL can allow for new "pedagogical imaginaries" to emerge; referring to the ways that pre-service teachers imagine themselves as teachers and the role they would like to fill (Adams & Gupta, 2017a). ISL contexts can afford pre-service teachers agency and the opportunity to see themselves engaging youth in reform-minded science pedagogies, which in turn, allows for ontological shifts in their imagined selves. In light of science education reform, pre-service teachers are able to assume new identities which go against how they were taught: often by teacher-centered methods and with the teacher bestowing their knowledge upon the students (Luehmann, 2007). Teachers are now being asked to assume a central role in student-centered inquiry-based teaching, a role and an identity they have little familiarity with. As a result, they will need developmental support to be able to assume these new "reform-minded identities" (Luehmann, 2007). Trying out new identities is a daunting task, and pre-service teachers need low stakes environments, such as those which are afforded by ISL contexts, to try out these new identities, and to have the opportunity to be recognized as that certain type of person by others and by themselves (Luehmann, 2007). This "recognition work" functions as identity development opportunities and occurs through understanding, interpreting, and recognizing the self as a "certain kind of science teacher" (Luehmann, 2007, p. 385). Opportunities to engage in reform-minded science and science teaching, therefore, should be done with others to provide opportunities for recognition and reflection. Pre-service teachers engaging in an ISL makerspace context, for example, positioned themselves as learners alongside the maker space lab personnel and as a result were able to expand their identities in relation to their future teaching (Douglass, 2023). The pre-service teachers found these interactions with the lab personnel 'exhilarating' and 'empowering' (Douglass, 2023, p. 12) a marked change from the dread that pre-service teachers often report in relation to science

(Douglass, 2023; Douglass & Verma, 2022; Spector et al., 2020). Engaging with others in ISL contexts, therefore, can powerfully impact pre-service teachers' beliefs about themselves and about their ability to engage in science.

A further example of the recognition work Luehmann (2007) described is through the creation of "disequilibrium" (Spector et al., 2020) that ISL contexts cause by challenging pre-service teachers' beliefs about science teaching and learning (Clarke-Vivier & Bard, 2016). It is through these moments of disequilibrium that reflection of the self, the learners, and one's practice can occur. Experiencing success at teaching science, in the ISL context, was integral for pre-service teachers to see themselves as teachers who can successfully motivate science learning and enjoyment in science (Harlow, 2012). Through informal learning-to-teach science experiences, pre-service teachers can develop positive orientations towards science and science teaching (Avraamidou, 2015) which supports their development of "reform-minded science teaching identities" (Avraamidou, 2014). ISL, therefore, can be transformative for pre-service teachers as it has the potential to lead to marked change in how they see themselves, both as learners and as teachers, and in what they believe teaching and learning science can involve (Rahm et al., 2016).

Undergraduate Science Majors Engaging in ISL

Undergraduate science majors, as well, tend to engage in ISL programs through university-school partnerships. These programs include: inquiry-based activities (Carpenter, 2015; Clark et al., 2016; Fogg-Rogers et al., 2017; Grant et al., 2015; Gutstein et al., 2006; K. Nelson et al., 2017; Robinette & Noblet, 2009; Stamp & O'brien, 2005); STEM demonstrations in schools (Carpenter, 2015); science/thesis presentations (Ahn, 2015; Clark et al., 2016; Laursen et al., 2007; Lewis et al., 2018); hands-on activities for youth at the university (Davis et al., 2011; Pluth et al., 2015); and inquiry-based lesson design and co-teaching with in-service teachers (Goebel et al., 2009). Many of these programs serve to recruit more youth into science (e.g. Davis, Yeary, and Sluss, 2012), and as a result, these programs often focus on schools with youth who are underrepresented in sciences, minorities and/or socio-economically disadvantaged in some way (e.g. Carpenter, 2015; Clark et al., 2016; K. Nelson et al., 2017). Most of the above ISL programming required undergraduate science majors to receive some form or training before participation. For example, the trainings came in the form of: full formal courses (e.g. Grant et al., 2015), half-day training workshops on education and engineering design (Fogg-Rogers et al., 2017), or practice work, such as presenting for a practice audience and receiving feedback (Clark et al., 2016). Some undergraduate science majors received support through university faculty mentors and past ISL programming participant mentors (K. Nelson et al., 2017).

Undergraduate science majors cite numerous reasons for engaging in ISL programming, such as:

1. *To gain:* skills for their future careers (Anderson et al., 2015; Fitzallen & Brown, 2017; Fogg-Rogers et al., 2017), scientific knowledge (Anderson et al., 2015), personal gains (such as feeling rewarded or satisfied) (Fitzallen & Brown, 2017; Pickering et al., 2004), science leadership and science communication skills (Pickering et al., 2004), and compensation (Fitzallen & Brown, 2017);
2. *To help and encourage:* students by forging relationships (Anderson et al., 2015; Pickering et al., 2004), and to encourage girls to enter science fields (Frieze, 2005); and
3. *To explore:* an interest in education and teaching skills (Anderson et al., 2015; Fitzallen & Brown, 2017; Pickering et al., 2004); and to explore ISL opportunities themselves as they never had access to it (Bruce et al., 1997), or alternatively, because they did have access to it (Carpenter, 2015).

Undergraduate science majors engage in ISL to learn about science and the communities they serve, but also to learn about education (Gutstein et al., 2006). Anderson et al. (2015) discussed how amongst the general motive of increasing scientific knowledge, undergraduate science majors hope to increase their teaching skills. Engaging in ISL programming is an opportunity to explore their interest in teaching that could not otherwise be pursued due to rigorous academic schedules (Pickering et al., 2004).

The benefits of engaging in ISL programming for undergraduate science majors are well documented (see Appendix A, table 2: Benefits of undergraduate science majors engaging in ISL programming). Medina et al. (2014) found a significant difference in the amount of science content knowledge and science literacy for undergraduates who engaged in informal science learning compared to those who only engaged in science learning in formal environments (e.g. school). Most importantly for this study, the identity impacts of undergraduate science majors engaging in ISL are not often directly discussed in the literature, however there is evidence of changes in attitudes, beliefs, and dispositions. Numerous studies provide evidence towards engaging in ISL contexts impacting the professional identity and career trajectories of undergraduate science majors (Carpenter, 2015; Ferreira, 2007; Grant et al., 2015; Gutstein et al., 2006; Laursen et al., 2012, 2007; K. Nelson et al., 2017; Olesik, 2009; Rao et al., 2007). For example, having the opportunity to try out being a different kind of scientist, one who engaged community youth in science, resulted in some undergraduate science majors altering their career path to become teachers instead (K. Nelson et al., 2017; Olesik, 2009). Carpenter (2015) discussed how engaging in ISL programming with youth provided the science majors with opportunities to reflect on education, their own science learning, and ISL. Their experience further supported their understanding of science pedagogy and youth, including how they learn and about their interests.

One study on female African American undergraduate science majors found that they were often exposed to ISL throughout their elementary and secondary school-aged years through their family members, museum trips, summer camps, science fairs, field trips, and science clubs (McPherson, 2014). In their university years, they continued to engage informally in science learning through student clubs and research seminars, projects, and conferences. As a result of the wide and varied informal science engagement, the undergraduate science majors built a lot of "science cultural capital" which allowed them to navigate the formal science environments of their learning institutions and contributed to their engagement with and persistence in science.

Cavalcante and Gonsalves (2021) found that undergraduate science majors with high levels of science capital, in the form of previous formal and informal science experiences, also have a strong "science student identity". The combined presence of accrued science capital and science identity suggests that the science majors were able to exchange their capital for recognition, from themselves and others, as a "science person". They also suggest that the science majors combined science capital, identities and career goals affect their orientations towards teaching science in ISL programming with youth. For example, one science major who had a lot of science capital and had an easy time learning science, viewed science teaching as a "delivery of concepts": a non-reform minded science teaching orientation (Cavalcante & Gonsalves, 2021).

Gonsalves et al. (2021) found that undergraduate science majors' science experiences and resources contribute to their science capital which accumulates over time across their ever-changing identities ("identity trajectories"). They discuss how the perceived value of the science majors' sources of science capital, once they enter university, influences their science identity trajectories and subsequently their reasons for engaging in ISL programming (2021, p. 1). Additionally, they posit that the science capital accrued by the science majors only prepared them for "one way" of being a scientist – as difficult, hardworking, and isolated – which can cause conflict in those with insufficient science capital (2021, p. 31). I suggest that providing science majors with opportunities to experience different ways of doing science and of being a person who does science, such as through ISL contexts, may allow for different avenues of being, or science identity trajectories, to emerge, as was found with pre-service teachers to occur (Adams & Gupta, 2017b; Luehmann, 2007; Rahm et al., 2016).

Paired Model of ISL: Pre-service Teachers and Undergraduate Science Majors

Some studies with science majors engaging in ISL focused on creating mentorship relationships, with students (Clark et al., 2016; Grant et al., 2015; Pluth et al., 2015), and with teachers (Ferreira, 2007; Fogg-Rogers et al., 2017; Goebel et al., 2009). Ferreira (2007) paired undergraduate science majors with in-service teachers to help them with science/mathematics pedagogical development then the pairs co-taught the created lessons. Interestingly, over one-third of the science majors who participated in reciprocal mentoring switched their career goals to education (2007, p. 107). Additionally, the undergraduate science majors stated they improved their knowledge of science content and teaching, improved their communication skills, and gained confidence (2007, p. 107). The impacts on the teachers were not discussed. Goebel et al. (2009) followed a similar paired model and found that the science majors positively expanded their views on diverse youth, how youth learn, and what science is, as a result of participation in the program.

Fogg-Rogers et al. (2017) paired preservice teachers and engineering students together to co-perform engineering outreach in elementary schools. Not only did the pairings learn from the expertise of the other, but the study also found that the partnerships yielded improved confidence and perceived self-efficacy in preservice teachers. Cook and Buck (2014) created a community of practice to connect university scientists with preservice teachers through place-based inquiry instruction. Preservice teachers found that discussions with the scientists outside of the partnerships, in social settings, to be the most beneficial in helping them become included members of the community. Additionally, they found that working to design projects *with* their scientist partners was an essential aspect of their movement into the community of practice as there was mutual benefit (Cook & Buck, 2014). However, some of the partnerships were less successful as a few of the preservice teachers felt excluded from the learning community as they felt their educational expertise being positioned as inferior to the "real work" of the scientists. Along the same vein, Shanahan and Bechtel (2020) aimed to create a mutualistic partnership between scientists and science teachers where they collaborate to create curriculum resources for physical sciences centers' outreach programs. The study yielded the creation of rich resources, co-constructed from these partnerships, but also a rich discussion of expertise and recognition of expertise. While no one in the study doubted the expertise of the scientists in the partnerships, the expertise of the science teachers was often downplayed or undervalued by both scientists and the science teachers themselves (Shanahan & Bechtel, 2020). Shanahan and Bechtel (2020) and Cook and Buck (2014) found that while partnerships between teachers and scientists can yield many benefits, there is the risk of one group feeling or being positioned as "lesser than" the other in terms of expertise, namely the preservice teachers in their studies. In both the Shanahan and Bechtel (2020) and Cook and Buck (2014) studies, the preservice teachers were being brought into community partnerships in the scientists' place of work (the science centers or the university), perhaps causing an imbalance of power. Our study aims to address this by placing our elementary preservice teacher and undergraduate scientist pairings in a jointly unfamiliar community of practice and location: an afterschool science club. Additionally, literature on the types of partnerships described above did not tend to explore the identity impacts of these types of pairings, a gap in the literature this study aims to fill.

Summary

This chapter reviewed the literature surrounding pre-service teachers and undergraduate science majors engaging in ISL opportunities, both separately and together. While the pre-service teacher literature discussed the identity impacts of this type of work (Adams & Gupta, 2017; Avraamidou, 2013, 2014; Douglass, 2023; Luehmann, 2007; Luehmann & Markowitz, 2007; Rahm et al., 2016), very few studies discussed the identity impacts for undergraduate science majors (Cavalcante & Gonsalves, 2021; A. J. Gonsalves et al., 2021). Furthermore, studies which explored pre-service teacher and undergraduate science major type partnerships, demonstrated a gap in the literature as they tended not to explore the identity impacts of these types of pairings. This study aims to fill this gap by pairing pre-service teachers and undergraduate science majors together to co-perform youth-led science inquiry investigations, and will investigate their previous experiences with science, their ability to recognize their partner's expertise and their own expertise, and will explore the identity impacts of said pairings. In the following chapter, I will explore the theoretical framework upon which this study is built around. Subsequently, the research methodology of this study will be discussed.

Theoretical Framework

In this chapter, I will discuss the theoretical frameworks which have guided my research and analysis of collected data. This research project is set within an interpretivist paradigm as the purpose of this research is to gain further understanding of individual and collective experiences in a paired ISL context, and relies on beliefs, experiences, and understandings as the main data source. Consequently, I am approaching this project with the understanding that learning is a *collaborative experience* (Vygotsky & Cole, 1978) through interactions with knowledgeable peers, as well as that learning is *experiential* (Kolb, 2014) and happens through making sense of present and past experiences. Situated Learning Theory (Lave & Wenger, 1991) holds both of these fundamental understandings at its core and is therefore the theoretical thread which ties this study's multiple frameworks together. As a result, as each new theory is introduced throughout this chapter, it is done so through the theoretical lens Situated Learning Theory affords.

Situated Learning – Legitimate Peripheral Participation

Central to the creation of this study is the understanding that learning is a fundamentally social process (Lave & Wenger, 1991). Lave and Wenger's (1991) theory of *situated learning* reframes learning from what was once considered an individual cognitive function to a *social process* where learning is an outcome of collaboration with others. The theory posits that through social interactions with members of a *community of practice*, coparticipants learn and develop new skills and knowledge together. Communities of practice can be generally understood as a group of participants who "share understandings concerning what they are doing and what that means in their lives and for their communities" (1991, p. 98). These communities can be as small as an afterschool science club or as large as a global religion. When you interact with a new community of practice, you interact with them on the periphery as you are not yet considered a “full member”; this is called *legitimate peripheral participation* (Lave & Wenger, 1991). The acquisition of resources, such as learned skills and knowledge, then allows you to work towards becoming full participants in the “sociocultural practices of that community” (1991, p. 29). Legitimate peripheral participation allows us a theoretical lens to discuss interactions between newcomers and old members of the community including their activities, identities, and the communities of practice as a whole (Lave & Wenger, 1991, p. 29). This is particularly relevant for our study as our preservice teacher and undergraduate science major co-investigator pairs are new to participating in ISL contexts and have yet to establish themselves in this community; they are newcomers. Additionally, it may be important to note that the researchers would position themselves, as well as would be viewed by the co-investigator pairs, as more experienced members of the community.

Situated learning emphasizes that what people learn, do and how they view themselves is situated *within* being a member of a community of practice (Lave & Wenger, 1991). Learning, therefore, takes place in social instances of collaboration amongst members of any level. Successfully working collaboratively with others requires self-reflection about the social interactions occurring – allowing for identity formation (Lave & Wenger, 1991). As the learner navigates through social situations, they must also navigate through the “constructs of human differences” such as race, class, disability, etc., and situate themselves in comparison or contrast (Bell et al., 2012, pp. 273, 269). Consequently, learning is then both derived from social practice *and* is inseparable from identity formation (Lave & Wenger, 1991).

As within all social practices, hegemony – “the dominance of one group over others, often supported by legitimating norms and ideas” (Rosamond, 2020) – is known to alienate full participation of others and shapes the “legitimacy and peripherality of participation” (Lave & Wenger, 1991, p. 42). For example, imagine a science teacher calls on their male students to share their ideas more in class, engages with them more positively and is more likely to give male students academic awards. The female students would feel excluded and unwelcome to participate fully in the science community at their school. This perceived exclusion may additionally permeate into their beliefs about their ability to perform science as they were never given opportunities to succeed like their male counterparts. Communities of practice can, as a result, unknowingly disrupt or limit the possibility of identities of mastery (Lave & Wenger, 1991, p. 42). It is in this way that legitimate peripheral participation brings together situated learning activity and theories about the reproduction of social order (Lave & Wenger, 1991, p. 47).

In conclusion, it is through social interaction in a community of practice that learning can occur (Lave & Wenger, 1991). Participation in a learning community, however, is "always based on situated negotiation and renegotiation of meaning in the world," including of oneself (Lave & Wenger, 1991, p. 51). It is then implied that understanding (of knowledge, of others and of the self) and experience (both past and present) are constantly interacting with one another, and therefore are mutually constitutive (Lave & Wenger, 1991, p. 51). In other words, that understanding of social interactions and the self (i.e., identity) are in constant interaction with previous experiences and skills (i.e., your resources) and they build off and inform one another. Below I explore and discuss theoretical frameworks which inform our study as supported by situated learning theory concepts, namely: learning experiences involving collaboration with others (collaborative learning theory), understanding of the self in relation to communities of practice (science identity theory), resources such as previous experiences and skills development (science capital theory), and communities of practice curtailing possibilities for identities of mastery (under-recognition of science capital and identities).

Collaborative Learning

As learning takes place in social instances within communities of practice (Lave & Wenger, 1991), learning can take place where *collaboration* with others occurs. Collaborative Learning theory builds off this idea of learning and assumes that knowledge is co-constructed in pairs or small groups and that learners are enriched through this joint meaning-making process (Laal & Ghodsi, 2012). Talk, therefore, is central to collaborative learning as it is through conversation amongst peers that learning occurs (Gerlach, 1994, p. 12). When compared to individual learning efforts, collaborative learning has been shown to result in social, psychological, academic, and assessment benefits such as: "higher achievement and greater productivity, more caring, supportive, and committed relationships; and greater psychological health, social competence, and self-esteem" (Laal & Ghodsi, 2012, p. 498). One study found that collaborative learning positively impacted individuals' beliefs about their ability to do science (their self-efficacy) (Fencl & Scheel, 2004). Additionally, structured collaborative learning experiences in science contexts have been shown to foster a sense of belonging and to support inclusive participation, as well as to foster teaching self-efficacy and development of teaching skills in preservice teachers (Clift & Brady, 2005; Gubbels & Vitiello, 2018; Gurvitch & Metzler, 2009). Previous science education research has harnessed these positive impacts of collaboration through the creation of scientist-teacher partnerships in university-community-based communities of practice, as previously discussed in the Literature Review Chapter.

To summarize, collaborative learning is *inherently social*, where meaning-making happens through mutual exploration and feedback in communities of practice; and is *performed by diverse learners* where participants are all diverse with unique histories and experiences (Smith & MacGregor, 1992). Just as within situated learning theory, we find that the social process of working collaboratively with others is inseparable from learning and identity construction as one must situate themselves within the social context in order to work with and learn alongside others.

Science Identity and Recognition

Participating in learning communities, such as the collaborative paired learning setting of this study, involves *identity work*. Identity work is "the actions that individuals take and the relationships they form (including the resources they leverage to do so)" to author their identities over time (Calabrese Barton et al., 2013, p. 38). This work occurs as an individual navigates in and around the rules and regulations of the learning spaces in which they participate (Calabrese Barton et al., 2013). The accumulation of this identity work lends itself towards the formation of *identity* – being a "certain kind of person" within a particular setting or context (Gee, 2000). As this research takes place in a science context, I have chosen to focus on *science identity* (Carlone & Johnson, 2007), but recognize that individuals hold many intersectional identities which are ever-changing, expanding, and inter-related.

Science identity is commonly thought of to be made up of four dimensions: performance, competence, interest, and recognition (Carlone & Johnson, 2007; Hazari et al., 2010). For this research study, I will focus on the recognition aspect of science identity as recognition is one of the most important indicators of persistence, participation, and science career trajectories (Carlone & Johnson, 2007; Hazari et al., 2010; Hyater-Adams et al., 2018; Kalender et al., 2019). Participation in science-related activities, coupled with recognition from others in science contexts can lend itself to the formation of science identities, such as "I am a science person" or "I am not a science person" (Carlone & Johnson, 2007). Recognition must be internalized as self-recognition for identity work to occur (Carlone & Johnson, 2007; Hazari et al., 2015). Building on this, Black and Hernandez-Martinez (2016) argue that recognition can serve as an "intensifier of engagement" for science participation. Being recognized is most powerful when it comes from "meaningful scientific others", such as peers or mentors (Carlone & Johnson, 2007, p. 1195). Opportunities for recognition may be achieved through instances where individuals work closely with one another, such as in small groups (Hazari & Cass, 2018). I argue that a paired collaborative learning setting, where individuals work closely together over several weeks, such as the context of this study, provides both time and opportunity for meaningful relationships to form and recognition to occur.

Sundstrom et al. suggest that placing students in heterogeneous groups may allow for different achievement level students to recognize each other (2022, p. 15). The study found that placing students in small laboratory groups with high-performing and low-performing students allowed for a more diverse group of students to be recognized as being "strong students", compared to in large lecture settings where only a few "star students" were recognized. These results suggest that close and consistent collaboration with others in small groups allows for implicit biases to be overcome (Sundstrom et al., 2022). The research presented in this thesis builds on this idea by pairing undergraduate science majors and pre-service teachers together, two groups who historically have very different levels of achievement in science.

Finally, Avraamidou (2020) described science identity as a continual and intersectional "landscape of becoming" where recognition and emotions are core features. This means that simply being recognized by peers is not enough for identity work to occur. One needs to navigate around their emotions surrounding this recognition, such as *who* is doing the recognizing and what that *means* to them, giving further meaning to the "process of becoming" (Avraamidou, 2020). Avraamidou (2020) explains that these constructs bring forth issues related to inequality, power dynamics, racism, and exclusion, making the personal science identity formation highly political. Before fully discussing the politics of science identity formation and recognition, we will first need to better understand *what* exactly is being recognized (or not) by others. Bourdieu's theory of capital (1986) allows us a theoretical lens for understanding how science expertise can be recognized and valued by others.

Bourdieu's Capital

Capital was first theorized and discussed by Bourdieu (1986), as a way to discuss cultural and social reproduction. Capital is the resources accrued through experience, position and institutions which can be mobilized in different settings or "fields". Capital is multidimensional and can be broadly categorized as economic, social, cultural, or symbolic, each with its subcategories and intricacies. The fields in which the forms of capital can be used or exchanged, each hold their own rules and regulations of the way things are within that space, called "doxa". For example, the doxa of a children's park, where children are allowed to run and scream, is very different than a library, where one must walk and be silent. In these two example fields, very different forms of capital (such as how to act, when to talk, where to go, whom to speak with and how, what to wear, etc.) can be used and exchanged for recognition from others within that space. Finally, there is the concept of "habitus" (Bourdieu, 1986). Habitus, in the context of science capital, refers to the deeply ingrained and socially constructed dispositions, attitudes, and behaviours related to science that individuals acquire through their upbringing and experiences, impacting their engagement, perception, and interactions within the fields of science (Archer et al., 2015; Bourdieu, 1986).

Science Capital: Shaping Science Trajectories

In this research, I will focus heavily on one form of cultural capital, called science capital, first conceptualized by Archer et al. (2015). Science capital encompasses the collective science-related resources an individual possesses, acquired through diverse avenues, be it through *formal* *science contexts* like school science courses or *informal science contexts* such as science-related TV shows, zoo visits, or science clubs. Building on Bourdieu's (1986) theory of capital, science capital is an equally multidimensional construct, including the following forms; cultural science capital (understanding of science, how it works and its usefulness in labour markets), social science capital (who one knows, talks to about science and views themselves in relation to science) and science-related behaviours and practices (the science media and science activities one chooses to engage with, whether formal or informal) (Archer et al., 2015).

Science capital is a form of culturally valued knowledge which supports participation and engagement in science learning fields and therefore affects science identity as well (Archer et al., 2014). It has *exchange* value, through which it can be exchanged with others to gain more science capital and *use* value, where it is used to support participation in and engagement with science (Black & Hernandez-Martinez, 2016). The exchange value of science capital significantly impacts educational attainment, career growth, influence, and economic opportunities, while use value influences social recognition, status, and inclusivity within the scientific community (Archer et al., 2014; Black & Hernandez-Martinez, 2016; Chen et al., 2021; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011).

Science capital, however, is not a fixed value but fluctuates based on the specific scientific space (doxa) in which it is used and exchanged (DeWitt et al., 2016). Different spaces (fields) prescribe unique rules (doxa) regarding exchange and use value, shaping the recognition and utilization of science capital within those spaces. For example, different knowledge and skills (science capital) can be exchanged and used for recognition as a "science person" in a research laboratory than in a kindergarten science classroom. While an individual may excel in one context, without fully understanding the doxa of the other field, they are not likely to be able to use and exchange their science capital to its full potential as there are accepted forms of capital within distinct contexts. Additionally, habitus, shaped by an individual's background and experiences, can significantly influence how one navigates through and utilizes their science capital within science fields or learning environments (Nasir et al., 2006). Diverse backgrounds lead individuals to enter these spaces with distinctive habitus, affecting their perspectives, interactions, and overall engagement with science (Nasir et al., 2006). Science capital is distributed unevenly, influenced by various factors such as socio-economic status, education, cultural background, and access to resources (Avraamidou & Schwartz, 2021; Chen et al., 2021; Lareau & Weininger, 2003; Nasir et al., 2006). In other words, if your habitus and the doxa of the field do not align, you may be afforded different or fewer opportunities to exchange or use your science capital than others whose do align. The hegemonic distribution of science capital results in its concentration among privileged groups, reinforcing existing power dynamics and perpetuating inequalities (Archer et al., 2014; Black & Hernandez-Martinez, 2016; Chen et al., 2021; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011). Individuals from affluent or well-connected backgrounds often have more opportunities to accumulate and leverage science capital (Chen et al., 2021; Nasir, 2011). Science capital is highly valued in educational institutions – particularly post-secondary institutions, which are often the gatekeepers of science-related careers – when it serves its interests and reinforces the existing social order. This hegemonic valuation is then reflected in resource allocation, research funding, career opportunities, and societal recognition, reinforcing the perceived importance of certain scientific disciplines and approaches (Archer et al., 2014; Black & Hernandez-Martinez, 2016; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011). Understanding how science capital is accrued, distributed, recognized, and valued, is crucial for addressing inequities and promoting inclusivity within the scientific community (Archer et al., 2014; Black & Hernandez-Martinez, 2016; Chen et al., 2021; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011). Efforts to challenge biases, broaden the recognition of diverse science capital, and promote equitable access to scientific resources are essential for a fair and inclusive scientific landscape (Archer et al., 2014; Black & Hernandez-Martinez, 2016; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011).

As a result of the above, science capital becomes most valuable, in terms of equitable present and continued science participation, when it is exchanged for *recognition* from science others in that field, as recognition can aid in the formation of science identities (Gonsalves et al., 2021). Lack of recognition of science capital poses a risk of disengagement from science spaces due to a perceived lack of value and opportunities (Archer et al., 2014; Black & Hernandez-Martinez, 2016; Chen et al., 2021; DeWitt et al., 2016; Gonsalves et al., 2021; Nasir, 2011). This study places a focus on how individuals leverage their science capital resources to facilitate identity work and value their existing identities through paired collaborative learning within a science community of practice.

To summarize, an individual's science identity mediates their perception of the value of their science capital and influences the types of science they perceive as valid and worthwhile (Gonsalves et al., 2021). Science capital and positive science identities, therefore, are strongly associated with continued participation and engagement in science when coupled with peer recognition (e.g. Chen et al., 2021; Nasir, 2011).

Other Forms of Capital and Identity

To continue the discussion of recognition, science capital and science identity, it is important to note these are not the only forms of capital or identity. As discussed by Avraamidou (2020), science identity itself is a "landscape of becoming", meaning that identity is dynamic and evolving in nature. Engaging with science is an ongoing, transformative process, rather than static or fixed, and is interactive as well as interdisciplinary (Avraamidou, 2020). Individuals are not simply "science people" or not, they have many facets of identity which are constantly at play (e.g. Hazari et al., 2013). People are multidimensional and their multitude of interweaving, ever-changing identities and capitals can interplay and affect each other (e.g. Hazari et al., 2013; Archer & DeWitt, 2017; Carlone & Johnson, 2007).

Perhaps most significant for the context of this study, is the concept of teacher identity and teacher capital (also often referred to as “professional capital”) (Hargreaves & Fullan, 2015). Like science capital, teacher capital is a subset of cultural capital and encompasses teachers' knowledge, skills, and experiences (Hargreaves & Fullan, 2015). Hargreaves and Fullan (2015) define this professional capital as the sum of human capital (individual teachers' skills, knowledge, and abilities), social capital (the quality of relationships and networks among teachers), and decisional capital (the collective capacity to make effective judgments about pedagogical practices and strategies). Teacher capital emphasizes the importance of ongoing professional development and the collaboration and interactions among teachers to enhance the quality of education and, consequently, student outcomes (Hargreaves & Fullan, 2015). As a result, this research context is as much a teacher capital/identity shaping experience for the participants as it is a science capital/identity building experience, and it must be noted that multiple forms of capital can and will be used and exchanged as it is impossible to separate an individual from their “identity landscapes” (Avraamidou, 2020).

I approach this study with the assumption that the preservice teacher participants are in the process of accumulating teacher capital. What is not as easily assumed, however, is that undergraduate science majors have accrued teacher capital. While no body of research was able to be found directly discussing the teacher capital of undergraduate science majors, there are discussions on scientists entering teaching programs and their development of teacher identities (Hargreaves & Fullan, 2015; Ingersoll & Strong, 2011; Ronfeldt et al., 2013). These studies found that scientists possess deep content knowledge and understanding of scientific principles, providing a solid foundation for teaching science effectively. While the research did not use the exact term “science capital”, we do see research on scientist knowledge and skills being applied to and transferred to teaching careers (i.e. science capital being used and exchanged for teacher capital). For example, Ingersoll, Strong, & Smith (2018) and Hargreaves & Fullan (2012), each discuss that scientific knowledge (i.e. capital) can be utilized in teaching (exchange value), by enhancing the learning experience for students with their knowledge, through using their experience working across disciplines to adapt to new information and technologies. Additionally, Hargreaves & Fullan (2012) discuss how the adaptability (science capital) of scientists *is* a form of teacher capital that helps in creating dynamic and engaging lessons (use value). In other words, scientists and therefore one could assume undergraduate science majors as well, bring a form of teacher capital to teaching experiences through their subject matter expertise, interdisciplinary skills, and collaborative mindsets. Now, as both preservice teachers and undergraduate science majors possess varying levels of both teacher capital and science capital, I am interested in looking at the exchange and use value of science capital and teacher capital, a topic which has not yet been widely researched. This research is motivated by questions such as: How do science majors and preservice teachers use and exchange teacher capital for science capital (and vice versa)? Are preservice teachers able to recognize undergraduate science major's teacher capital (and vice versa)? How do science capital and teacher capital interact? How do undergraduate science majors position themselves and their identity in relation to teaching? These questions around the literature and theoretical frameworks inform my study's research questions, which are presented at the end of the chapter.

Teacher capital and science capital's exchange and use value wield profound influence over educational, professional, and societal aspects, significantly shaping individuals' trajectories within the scientific and educational communities. A nuanced understanding of how capital interacts with doxa and molds habitus is crucial for promoting inclusivity and equity within science education spaces. Additionally, recognizing the intricate interplay between science capital and other forms of capital, such as teacher capital, provides valuable insights into the multifaceted dynamics of the science education ecosystems.

The Politics of (Mis)Recognition

With a fuller understanding of capital and its relationship to identity, we may now resume the conversation on recognition. How is expertise recognized and what is the role of capital and identity in this? Unfortunately, as previously discussed, recognition is not guaranteed, not all science capital is recognized equally, and identity rests heavily on recognition (Archer et al., 2014; Black & Hernandez-Martinez, 2016; Chen et al., 2021; DeWitt et al., 2016; A. J. Gonsalves et al., 2021; Nasir, 2011). Because of this, recognition has been discussed as politicized and found to perpetuate power structures currently in place (e.g., Yosso, 2005). Yosso (2005) suggests that for many, a lack of recognition is not about a deficit (of cultural capital) but that the array of capital possessed by socially marginalized groups is likely going underrecognized and unacknowledged. Furthermore, Avraamidou and Schwartz's (2021) work on the politics of recognition found recognition to be: a) in many different forms, including explicit encouragement to lack of opposition, b) from many sources throughout one's life from family to community to education, and c) strongly culturally dependant and influenced by stereotypes, racism, classism, and other forms of discrimination. As a result, not receiving recognition is not necessarily linked to a lack of capital, and instead could be under-recognition or "misrecognition" of capital (Avraamidou, 2022). Again, this relates to legitimate peripheral participation and the power dynamics which surface in communities of practice, where misrecognition can limit the formation of identities of mastery (Lave & Wenger, 1991). In a study about faculty recognition of students' cultural capital, Thompson & Jensen-Ryan defined recognition as a reflection of what you expected to see and what cultural capital the other is performing (2018, p. 14). In other words, the capital that students outwardly show and possess is being (mis)recognized by faculty members due to their preconceived notions of what capital they are expecting from students. This (mis)alignment affects students' opportunities for further cultural capital development through (under)recognition and (mis)affirmation of their abilities in science (Thompson & Jensen-Ryan, 2018). Furthermore, the study found that positive feedback loops can occur through recognition, where capital is recognized and rewarded with opportunities to further gain more capital (such as research projects, presentations, and publications). This aligns with Bourdieu's (1986) notion that cultural capital facilitates mobility and access to resources (i.e. more capital). There is, therefore, a power imbalance embedded in science capital, as it is a resource through which those in power can control access to opportunities (Lareau & Weininger, 2003). This politicization of recognition shapes participation in science (Avraamidou & Schwartz, 2021). These structures become outwardly problematic as this model of recognition reconstructs power roles found in society and provides unequal (and inequitable) access to science identities and participation in science. One example of this is when faculty only render students *recognizable* when they "demonstrate the attitudes and dispositions in which they have been encultured" to see (Thompson & Jensen-Ryan, 2018, p. 10). Recognition from faculty, however, was found in a study to be less important than peer recognition (Rodriguez et al., 2019). The same study found that (Latina) students found it hard to persist in science fields without peer recognition, leaving them doubting their ability and place in science (Rodriguez et al., 2019, p. 267). Recognition is, therefore, highly political and can either help or hinder the development of science-related identities.

Research Questions

Three research questions emerge from the theoretical and empirical concerns presented in this chapter and the previous literature review chapter:

1. *What kinds of science capital-forming experiences and perspectives are preservice teachers and undergraduate science majors bringing with them to co-perform youth-led ISL?*
2. *Are undergraduate science majors and preservice teachers able to recognize each other's expertise while co-performing youth-led ISL?*

3. *What are the science identity impacts of preservice teachers and undergraduate science majors engaging in youth-led ISL?*

Summary

Learning, framed within a community of practice, is a social activity intricately tied to collaboration and identity construction (Lave & Wenger, 1991). Collaborative learning theory emphasizes the social aspect of learning through the mutual construction of knowledge via social interactions (Laal & Ghodsi, 2012). The notion of science identity delves into how individuals navigate their identities in the realm of science and how recognition from others plays a pivotal role (Carlone & Johnson, 2007). Science capital then elucidates how individuals possess resources in the form of knowledge and engagement with science, which can be mobilized within specific science contexts, often influencing their ability to be recognized, and therefore affecting their possibilities for identity formation (Archer et al., 2014; Black & Hernandez-Martinez, 2016; DeWitt et al., 2016; A. J. Gonsalves et al., 2021; Nasir, 2011). Teaching capital can also be used and exchanged in these ways. Unfortunately, recognition of capital is deeply political and can perpetuate power imbalances, affecting an individual's trajectory within the scientific community through opportunities (or lack of) for identity and capital building (Avraamidou & Schwartz, 2021). These theoretical underpinnings inform my research questions and approach to investigating paired collaborative ISL experiences and the dynamics of capital, identity, and recognition within these collaborative spaces.

Methodology

In this chapter, I will describe the research methodology used throughout the study beginning with an overview of my research context and setting, and followed by a discussion of the participant recruitment, data generation, and data analysis techniques. The rationale for each of these methodological decisions is discussed throughout.

Research Context and Setting

This study took place in an afterschool science club established through collaboration and facilitated by a pre-existing connection between the researchers and the elementary school's science teacher. The chosen elementary school was located within a socioeconomically diverse neighbourhood, where the majority of the inhabitants' backgrounds are underrepresented in STEM program enrollments at the local leading Canadian research university. The underrepresentation of certain demographic groups in Canadian STEM programs remains a pervasive issue with multifaceted implications. Studies consistently underscore disparities in gender, ethnicity, and socioeconomic backgrounds, illustrating a significant gap in representation within STEM fields (Mandinach & Kang, 2016; Maltese & Tai, 2011). Historically, women and individuals from marginalized ethnicities have been notably underrepresented, limiting the diversity of perspectives and experiences within STEM education and professions (Smith, 2018). Additionally, individuals from lower socioeconomic backgrounds face barriers related to access to quality education, resources, and support systems required to pursue and succeed in STEM disciplines (Archer et al., 2015). This means that youth from these underrepresented groups may not typically have access to science capital-building activities, such as afterschool science clubs. Addressing this underrepresentation is critical for fostering an inclusive and equitable STEM landscape. Efforts to bridge this gap involve targeted initiatives aimed at promoting diversity, equity, and inclusion within educational institutions, fostering mentorship and support networks, and dismantling systemic barriers that perpetuate disparities in STEM participation (NSERC, 2018).

Our project aimed to help target this disparity by establishing positive connections between the university and the community, through the creation of our youth-led afterschool science club. Participants in the science club included 4 small groups of 3-4 volunteer youth (grade 5 and 6), each with a paired pre-service elementary science teacher and undergraduate science major from various university faculties. The "co-investigation" approach was adopted, emphasizing collaboration and a youth-led research process, where both youth and co-investigators explored chosen topics together. Youth were empowered to select investigation topics and were paired with co-investigators to guide and support them throughout their inquiries, encouraging autonomy and collaborative learning.

Data was only collected from each group via the pre-service elementary science teachers and the undergraduate science major co-investigators, named “co-investigative pairs”. No data was collected directly from the elementary-aged youth. As each group had a similar experience in overall design, but there was little interaction between groups, it can be assumed that the co-investigative pairings had insights which would be unique to them and their own group’s experiences. As a result, I chose not to study and analyze our data in a large, generalized way, but instead to treat each pair as a unique case or instance of learning, following a methodological approach called the “Case Study” (Creswell, 2002).

Research Approach: Multiple Case Studies

This research study is guided by the qualitative case study methodological approach. Case studies are characterized by research which explores “a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports), and reports a case description and case-based themes" (Creswell, 2002, p.73). This approach works best for this study as it allows for "purposeful maximal sampling" (Creswell, 2002), where I could select cases which focus on the research questions to be explored. As a result, the case study format was selected for this project as it allows for rich descriptions of "unique identity intersections" in a shared science outreach context (Avraamidou, 2013, p. 72). In the realms of identity and science education research, employing a case study methodology proves instrumental in delving into the intricate interplay between identity development and science learning (Barton, 2008). By selecting specific cases, researchers can deeply investigate how students' unique identities, encompassing cultural, socioeconomic, and gender-related aspects, influence their engagement with and understanding of science (Archer et al., 2015). The case study approach allows for a nuanced examination of how these identities shape attitudes, perceptions, and motivations toward science, thereby informing the design of tailored educational interventions (Calabrese Barton & Tan, 2018). Additionally, the methodology offers a platform to analyze the role of teachers, curriculum, and educational environments in supporting or hindering the formation of positive science-related identities (Archer et al., 2013). Through the lens of case studies, researchers can uncover the complexities of identity negotiation within the science education context and develop strategies to enhance inclusivity and equity in science learning, ensuring that education aligns with diverse student identities and experiences (Carlone & Johnson, 2007).

More specifically, I chose to do a multiple case study approach involving the in-depth exploration and analysis of multiple cases to understand and interpret complex phenomena within their real-life contexts (Yin, 2018). Each case represents a unit of analysis, which could be an individual, a group, an organization, or a community, chosen to provide insights into a specific aspect of the research topic. This methodology involves a careful selection of cases based on pre-defined criteria, aiming for diversity and representativeness to capture a broad range of perspectives and variations (Yin, 2018). Comparing and contrasting findings across these multiple cases allows researchers to identify patterns, themes, and commonalities, enhancing the depth and breadth of insights and enabling the development of broader theoretical frameworks. Multiple case study methodology was especially helpful in our context as each group of co-investigators operated essentially independently and therefore, they can each be seen as a unique instance of this project and should not be clumped together into a generalized whole. As a result, the complexity of each individual can be analyzed within their group before looking to the larger learnings which can be found across and between the multiple cases. I chose to look at 2 unique cases for this study, of the possible 4, for two reasons. Firstly, fewer cases give a greater ability to explore and analyze the data in-depth, doing justice to the participants' "richly textured experiences" (Jackson et al., 2007). Secondly, as I was aiming to capture a broad range of perspectives and variations, the two most stand-out cases were chosen (Yin, 2018). One of the cases appeared right away to be a "success", where positive relationships and subsequent science identity associations appeared to be emerging quickly throughout the study. The other case appeared to be the "least successful" where strong relationship formation and identity building were not evident to the researchers initially. As a result of these "opposing" cases, I wanted to be able to compare, contrast and analyze the differing experiences of the co-investigative pairings themselves and between the groups. To better understand the co-investigative pairings, let us next look at who our volunteer co-investigators are and how they were recruited before placed into paired groups.

Participants and Recruitment

The participant population for this study comprised two distinct groups: *pre-service teachers* enrolled in the Bachelor of Education Kindergarten/Elementary program and *undergraduate science majors* enrolled in a Bachelor of Science program (such as physics, statistics, microbiology, etc.).

Recruitment for ISL in general, let alone a 10-week-long research study, can be challenging for already busy university students. As a result, targeted recruitment efforts were made towards specific populations who may be interested in participating. Professors were emailed from the “teaching elementary science” and “science communications” courses of the University to ask them to recommend pre-service teachers and undergraduate science majors they have taught or are currently teaching who may be interested in this type of program. Interested students then reached out to our research team by email. From these efforts, 4 pre-service teachers and 5 undergraduate science majors were recruited to participate in the study. Background information on all nine participants can be found in Table 1 below.

Participants were paired into teams (called “pairings”) of two and one team of three randomly, as follows (with pre-service teachers first; followed by the undergraduate science majors): pairing 1 (Jenny and Sam); pairing 2 (Anika and Mia); pairing 3 (Shirley and Wendy); and pairing 4 (Virginie, Celeste and Rachel). Pairing 1 (Jenny and Sam) and pairing 2 (Anika and Mia) took part in the case studies which make up the data set of this study.

Getting preservice teachers and undergraduate science majors together to learn collaboratively in this study context was purposeful, as undergraduate science majors have general science knowledge and know how to perform science investigations, while preservice teachers know how to teach and interact with youth. As a result, both parties theoretically have the tools and resources (capital) in the form of previous experiences with science and teaching, to work together to co-perform science investigations with youth in an afterschool club and perhaps build meaningful relationships in the process.

Fourteen elementary-aged youth participants were recruited by the elementary school’s science teacher to participate. Written parental permission to join the afterschool science club was obtained from each youth volunteer. For maximum transparency, it was explained to parents that this club was a part of a research study, but that no data would be collected from the youth themselves. To maximize the comfort of our youth participants, they chose which other youth they wanted to group up with, making 3 groups of 4 youths and 1 group of 3. These groups were then assigned a co-investigative pair to conduct their science investigations based on similar interests, obtained from the elementary science teacher before the beginning of the study.

Table 1: Participant Background Information.

Group	**Pseudonym**	**University Major**	**Country of Origin**
Pre-service teachers	Anika[a]	Elementary Education	Sri Lanka (Canada)[c]
	Jenny[a]	Elementary Education	Canada
	Virginie	Elementary Education	France
	Shirley	Biochemistry; Minor in Education[b]	Sri Lanka (Canada)[c]
Undergraduate science majors	Mia[a]	Biology	United States
	Sam[a]	Physics	United States
	Celeste	Microbiology and Immunology	Canada
	Wendy	Statistics	South Korea
	Rachel	Biochemistry	United States

[a] Participant took place in the 2 case studies upon which this thesis is based; [b] Participant had completed multiple credits in education and therefore was treated as a pre-service teacher for this study; [c] While these participants grew up in Canada, their parents were recent immigrants with significant cultural ties to their country of origin, perhaps providing them with a unique experience/insights.

Research Timeline

Our study was to happen over a ten-week period including 2 preparatory meetings for the co-investigators, followed by 8 weeks of programming. Each week one 2-hour meeting took place, either at the university (weeks 1 and 2) or at the afterschool science club located in the elementary school of the youth (weeks 3-10).

1) *Week 1*: a meet and greet with the participants was held to get to know them, introduce them to each other and explain the purpose of the study.
2) *Week 2*: 2-hour preparatory workshops on how to facilitate "youth-led inquiry" and productive questioning including discourse moves such as pressing, probing, and re-voicing student ideas. This workshop had the goal of providing tools for the co-investigators on how to position the youth at the forefront of the investigations.
3) *Week 3*: introductory meeting of the science club at the elementary school. Icebreaker games were played, and groups formed, with the youth and the paired co-investigators. Groups begun brainstorming ideas for investigations. *Interview 1* with individual co-investigators "timeline interview" took place this week.
4) *Week 4*: brainstorming and preparation for investigations, including making material lists and researching information.
5) *Week 5*: investigations begin.
6) *Week 6 until week 9*: continue investigations and document learning in a chosen creative way (comic book, short videos, journals, poster, presentation, etc)
7) *Week 10*: a party to showcase student work including parents. *Interview 2* was intended to take place this week.

Unfortunately, Covid-19 lockdown occurred after week 5, causing us to cut our study short (see figure 2). Therefore, interview 2 took place after week 6 instead of after week 10 as originally planned. Additionally, the interview was changed from in-person to an online interview to accommodate social distancing.

Youth-led Inquiry Investigations

The term “youth-led” refers to the type of learning found in the Ambitious Science Teaching (AST) framework developed by Windschitl et al (2020). In AST, teachers ask the students to be the ones to make sense of scientific phenomena through engaging with science and engineering practices and requires teachers to use students’ experiences and ideas as resources for learning. This occurs through teachers facilitating discussions in which students are required to collaboratively reason and develop understandings of science concepts (Windschitl & Stroupe, 2017). This model of teaching and learning is in direct contrast with the typical model of science teaching where the teacher stands at the front of the class and delivers science concepts and knowledge to the students. As a result, youth-led opportunities for learning offer youth opportunities to mobilize their funds of knowledge and supports new ways of learning and knowing (Tan et al., 2012). This model of youth-led teaching and learning is currently being taught at the University to the pre-service teachers in their teaching science methods courses. It is also the basis of the “reform-minded” teaching practices that pre-service teachers are expected to use and embody in their teacher preparation courses (Luehmann, 2007).

In this study, we upheld the AST framework by encouraging our co-investigators to ask the youth productive questions to guide their learning and to help the youth to research and answer their inquiry investigations as a team. During the training workshops, the undergraduate science majors and pre-service teachers were taught about facilitating AST-style youth-led investigations and given examples on how to ask productive questions to guide the youth’s inquiry. University co-investigators understood that their role in this afterschool science club was not to "teach" the youth science, but instead to learn alongside them using the AST framework and to allow the youth to drive the inquiry investigations. The youth chosen and youth-led investigations in this study looked like investigations on: what it would take to grow tomatoes on Mars, what types of air pollution were present in the school, how therapy animals work, and how to design bridges to be more accessible for all types of bodies and users.

Role of the Researcher

Before detailing the data construction methods, the role of the researcher must first be examined. My interest in working with preservice teachers and undergraduate science majors has evolved through my own practice as a high school science teacher. I have worked firsthand with students with negative attitudes toward science as a result of their elementary teachers' science teaching – infrequent and focused solely on the textbook. This was compounded by my work with elementary preservice teachers during my undergraduate teaching degree, where I would often hear "Oh I could never do that," as a response to hearing I was a science teacher, which led me to want to work with engaging preservice teachers in science communities. Additionally, I have personally collaborated with undergraduate science majors, through my job as a pedagogical consultant for university ISL initiatives. There I experienced undergraduate (and graduate) science majors' resistance to learning evidence-based teaching techniques, such as inquiry-based learning, to improve their practice. It was through these roles that I grew to want to support both groups to help them come together to learn from each other in informal, low-pressure ways, so that they may both better support youth's science engagement and learning.

While the above are generalizations about the types of science education issues I have experienced, I am aware that every situation is different, and each person's beliefs and identities are deeply their own and are a result of their individual previous experiences. Thus, I view research from an interpretivist point of view, where one's reality is deeply subjective and grounded strongly in experience. Additionally, I approach research from an interactionalist social theoretic tradition where my research looks at how social structures play out on the individual. As this is a very micro point of view, it can help to inform decisions made on a greater scale to such as educational policy or models for ISL efforts.

Finally, it is important to note that my experience as an anglophone, white, Canadian-born female researcher is not going to be the same, or perhaps even similar, to many of my participant's backgrounds or experiences. As a result, my research approach must emphasize the co-investigators' own experiences, as told in the way in which they wish to be expressed and not simply through the lens of the researcher. To ensure this, I did not simply "collect the data" from the co-investigators, but instead, we *co-constructed* it together (Kvale, 1996). Co-construction refers to the collaborative and dynamic nature of knowledge formation, where individuals engage in dialogues and interactions to construct shared meaning (Kvale, 1996). This aligns nicely with Lave and Wegner's sociocultural theory of learning, from our study's theoretical framework, where learning is a fundamentally social process and is inseparable from identity formation (Lave & Wenger, 1991). Here, therefore, data is not only co-constructed through our interactions with the co-investigators, which fundamentally shapes the type of data we will create, but it also shapes the identities of the participants and ourselves. In science identity and education research, the application of this cooperative approach to data construction allows researchers to explore how individuals actively participate in shaping their own science identities through interactions with educators, peers, and their learning environment, including the researcher (Akkerman & Bakker, 2011; Calabrese Barton, & Tan, 2019). The researchers cannot remove themselves completely from the data we co-generate, as we must recognize that we had significant influence in its creation which will be reflected in the type of data we construct as well as in how we approach data analysis and discussion. To stay true to this view of data generation, I used semi-structured techniques, such as interviews and video diaries, as they have defined structure but leave room for the participants to reflect freely in *conversations* with the researchers.

Data Construction

Data was co-constructed through multiple sources of information, namely semi-structured interviews and video diaries. The data is qualitative in nature, as opposed to quantitative, as a result of relying on in-depth descriptions of "richly textured experiences and reflections about those experiences" (Jackson et al., 2007, p. 22). In qualitative research, triangulation of findings is often achieved through using multiple data sources and methods (Denzin & Lincoln, 2000; Kincheloe & Berry, 2004). Yin's "Case Study Research: Design and methods" (2003, p. 75), suggests case studies use six types of data collection methods: archival records, documents, direct observations, interviews, participant observations, and physical artifacts. However, as identity work is so deeply personal in nature and flexible over time, I decided to focus on two data co-construction methods where the data is generated directly from the participants themselves: semi-structured interviews and video diaries.

Semi-Structured Interviews

In science identity research, the data construction methods most often used are interviews and ethnographies (Danielsson et al., 2023). Semi-structured interviews are often chosen as they allow for "discovery, exploration, and meaning making so that intricacy and nuance are not overlooked in the investigation" (Magaldi & Berler, 2020, p. 2825). These interviews offer researchers the flexibility to explore complex, multifaceted topics by combining open-ended questions with a predetermined structure in the form of an interview protocol, or question guide (Fylan, 2005; Magaldi & Berler, 2020). The researcher is allowed freedom to follow "topical trajectories" as the interview unfolds; providing the flexibility to create opportunities for the participant to comfortably share their personal histories, experiences, and thoughts, as they are not constrained to a rigorous structure but free to follow the natural conversation as it emerges (Fylan, 2005).

Semi-structured interviews are a valuable methodological tool in the realm of science identity and science education research as they offer a flexible approach to delve into the complex and nuanced aspects of science identity and learning. For instance, Calabrese Barton and Tan (2018) highlight their utility in exploring the formation of science identities, through their use of these interviews to elicit rich narratives about individuals' experiences and perceptions of their science identities, offering valuable insights into how these identities are formed and influenced over time. Semi-structured interviews are particularly valuable for shedding light on contextual insights, such as gender and cultural factors, as demonstrated by Carlone and Johnson (2007) in their work on the complexities of underrepresentation in the sciences. Furthermore, semi-structured interviews are adaptable to diverse participant populations, making them a crucial method for research involving marginalized individuals, as Miles et al. (2020) demonstrated in their work with the invalidated identities of Black doctoral students in university STEM programs. The semi-structured interview method of data construction offers us the flexibility needed to explore the multifaceted and context-dependent nature of science identity, thereby contributing to a richer understanding of this critical area in science education and equity. As a result, two 1-hour semi-structured interviews were conducted to co-construct the data – one in-person timeline life history interview and one online interview – both of which were video recorded with informed consent.

Interview 1: Timeline Interview

The first interview was a timeline life history interview (Adriansen, 2012). In this type of interview, participants generate chronological timelines using their life events and indicate their significance visually (Berends, 2011). The joint timeline and semi-structured interview style allowed for participants to freely elicit rich narratives about their experiences and provided opportunities for decision-making and deeper reflection via timeline creation (Berends, 2011). Timeline interviews have been shown to provide the opportunity for both the researcher and the interviewee to do "joint work" where the interviewee is also hunting to complete missing elements from the timeline; allowing for perhaps more of the story to be told than in non-timeline style interviews (Adriansen, 2012, p. 50). For example, in building timelines from kindergarten to university (present time) on memorable science experiences, if there are no events from grade five until grade 10, the interviewee will search their mind to find stories to fill that gap as they can visually see the hole without the researcher needing to prompt them. This method is particularly effective for building more complete histories because memory recall is improved when there is structure to build ideas around (Baddeley, 2013). Additionally, memories are interconnected; triggering a memory about one experience can prompt the memory of another, leading you down a "retrieval path" to find more sought-after information (Reisberg, 2016, p. 209). To continue the example above, thinking of your fifth-grade teacher might make you remember they were good friends with your seventh-grade teacher who loved turtles, allowing you to then recall a unit you really connected with on marine science in grade eight and so on. One study on identity found timelines helpful to access more "layers of experience" (Bagnoli, 2009) and another study on educational trajectories found timelines helped participants build a sense of ownership over their shared stories (I. A. Nelson, 2010). This is important as sharing these intimate details of your life experiences is difficult and it is important that participants feel a sense of control in this process to not feel overexposed and withdraw consent.

Finally, take-home timelines where participants generate their life history visuals on their own time in their own space, as opposed to timelines created in person with the researcher, have been seen to “help participants retrieve, organize and express complex ideas, thus potentially increasing the accuracy and richness of their narratives” (Bremner, 2020, p. 11). However, due to time constraints or preference to collaborate with the researcher to develop their timeline with real-time interaction, take-home timelines are not always appropriate (Bremner, 2020). The interviews and timeline generation for this study were conducted in person as I wanted to be able to talk through each experience the participants noted in real-time. Additionally, as this was already a time intensive project for the participants, I did not want to assign them more work to complete at home which they would then need to discuss with us during an interview afterwards; it was better to do it all at once together. The goal of the interview was for participants to timeline their memorable science experiences so as to learn about their experiences with science (which have enabled/hindered their accumulation of science capital), how they position themselves in relation to science throughout their lives (science identities), and their motivations for engaging in this ISL experience. I asked participants questions surrounding each of those goal topics. A full list of our interview questions can be found in Appendix B. Additionally, participants were asked to timeline their science experiences from kindergarten until present throughout the length of the interview as the experiences were discussed. Timelines were introduced to the participants, and they were given the freedom to depict them as they wished using blank sheets of paper and various coloured markers (Adriansen, 2012).

Interview 2: Online Interviews

The second interview was a simple semi-structured interview and was conducted online via Microsoft Teams video call. As this round of interviews took place during the COVID-19 pandemic lockdown, using digitally mediated communication tools was the only viable option to continue our interview data generation (Gray et al., 2020). Online interviews cannot be considered inferior to in-person methods as not only is digital communication increasing in both accessibility and familiarity, but it is also omni-present today, resulting in little perceived difference between the two methods (Maulana, 2022). Our participants were all very familiar with the use of online videoconferencing. Additionally, there are also benefits to conducting an interview online. Studies have found that participants have decreased anxiety and are more comfortable during online interviews in their own private space as opposed to the forced intimacy of being face-to-face with the researcher in person, often in an unfamiliar location to them (Seitz, 2016; Sipes et al., 2022; Wahl-Jorgensen, 2021). Gray et al. (2020) suggest that being in their own home and at physical distance from the researcher may even make the participants feel more comfortable to discuss personal and sensitive topics. One downside to the online interviews is that while the participant gets to choose their own location for the interview, the location may have distractions, a lack of privacy or poor internet connection (Gray et al., 2020). To mitigate this, I ensured participants felt comfortable discussing all topics in the environment they chose, and laughed off distractions with them until they were over – such as younger siblings coming into the room. We were, after all, in the middle of a pandemic and some expectations needed to be relaxed.

The goal of the second interview was to gain a better understanding of their experience with their co-investigative pair and with the youth, to learn about how they reflect on the partnership, to explore their learnings about science and the self, and to see how they figure the experience into their science aspirations (science identity trajectories). As a result, questions asked focused on those topics (see Appendix C for interview protocol). Participants used their timelines created from the previous interview (interview 1) to help situate themselves and reflect on their current and past science experiences throughout the interview. Additionally, participants were asked to position the co-investigations on their timelines and to relate them to their past experiences. This involved discussing whether it was a positive or a negative experience and reflecting on its similarity or difference to their past science experiences. Having their timelines present during interview 2 allowed for participants to reflect how they experienced science in the past and to then discuss with more examples ready (from the timeline) about how they felt about science then and now (their science identities).

Semi-Structured Video Diaries

Our final data construction method was video diaries (Noyes, 2004). Video diaries allow participants the private opportunity to share stories about their lives in monologue format on camera (Noyes, 2004, 2009). As a result, this method has been used in previous work to capture identity performances and to investigate students' identity constitution (Buchwald et al., 2009; Danielsson & Berge, 2020; A. J. Gonsalves et al., 2021; Holliday, 2004). Previous work found that video diaries allow for the capture of data which would 'not otherwise be obtained" (Buchwald et al., 2009, p. 12) as participants have the freedom to discuss anything they wish without researcher interruption. The lack of opportunity for the researcher to probe participants for more information has been hailed as a benefit as participants are able to present more authentic stories, have more control over the data generation and the method does not rely on the researcher-participant rapport (Cooley et al., 2014). Others believe the inability to ask for elaboration to be a limitation (Buchwald et al., 2009) as there is a lack of conversational support which some, especially second-language speakers, may find difficult to navigate (Danielsson & Berge, 2020). While some studies using video diaries have participants talk freely on a subject or theme of the researchers choosing (e.g. Noyes, 2004), others add more structure to the entries by providing open-ended questions for participants to answer, called "semi-structured video diaries" (Cooley et al., 2014). The use of questions helps to relax participants as it makes the task of video entries less open and daunting, encourages greater depth to participant responses and allows the researcher to direct the discussion to avenues of interest (Cooley et al., 2014). I utilized semi-structured video diaries to help direct and support our participants in the creation of their entries. Following Danielsson and Berge (2020), video diaries were implemented as a complementary data generation method, as they produce important data to inform semi-structured interviews. Both the use of this method in identity research and its ability to add to the richness of subsequent interview data makes the video diary method ideal for our study.

Previous work set up video diary rooms and video cameras for participants to film their diaries, or handed out video cameras (Buchwald et al., 2009; Cooley et al., 2014; Danielsson & Berge, 2020; Noyes, 2004, 2009, etc). More recent use of video diaries, including our own work, makes use of participants' smartphones (e.g. A. J. Gonsalves et al., 2021) or iPads (Larkin & Jorgensen, 2016) to film the video diaries in a location of their choosing. All our participants had their own smartphones and were familiar with how to film themselves. Participants created 2 video diaries throughout the study, one at the beginning of the outreach and one in the middle of the study. The goal of the first video diary was to have participants reflect on their first day of the outreach including their experience meeting the youth, working with their partner, and something that they learned. The goal of the second video diary was to discuss their thoughts and feelings about doing youth-led science inquiry with their co-investigator. The full question sets used for video diary 1 and video diary 2 can be found in Appendix D: Video Diary Questions. A third diary was planned, however due to the COVID-19 lockdown, the project had to be cut short, therefore removing the possibility of a third diary.

The overall purpose of the video diaries was to give the opportunity for participants to discuss what they thought was important and relevant to their experience after reflecting upon it. Rather than guide their answers with too many directed questions, questions were left open-ended to allow space for what they believed to be relevant to arise. Data from the video diaries was used to inform the second semi-structured interview questions. The interview and video diary data were all transcribed verbatim and sent to participants for review to ensure the accuracy of wording and ideas before analysis.

Data Analysis

In this section, I will describe the data analysis procedures employed in the study. I followed a two-step approach, first employing Saldaña's (2015) coding manual to perform open coding and in vivo coding on the raw transcription data. Subsequently, I implemented Braun and Clarke's (2006) thematic analysis technique to identify and interpret key themes within the coded data.

Saldaña's (2015) coding approach provides a systematic framework for coding the data as it is useful for organizing and categorizing data to identify emerging patterns and themes. These steps included familiarization with the data, and then *open coding* and *in vivo coding*. Open coding is the process of identifying concepts and themes in the data and labelling them. In vivo coding involves labelling identified codes using participants' own words. Using both open coding and in vivo coding help to minimize researcher bias as the coded data remains truer to participants own language instead of proscribing the researcher's own words/ideas to the data. Next, another round of *focused coding* was performed to refine the data to codes which were most relevant for the research questions. Multiple coders analyzed the data and compared results to ensure reliability of codes and emerging patterns. For a more detailed explanation of the coding process, please refer to Appendix E: Coding Methodology.

After coding the data, Braun and Clarke's (2006) thematic analysis technique was used. This method is used to identify and interpret patterns and themes in qualitative data sets. The following steps were followed:

1. *Data Organization*: Coded data from the previous step were collated and organized into a manageable dataset. This involved reviewing the codes and organizing them. As there were

multiple groups and participant backgrounds, the data was grouped and organized three different ways for analysis:

a. *individually by co-investigator*. This allowed us to see any insights on the individual person scale.
b. *into the pairings*. This was used for side-by-side comparison to see the insights and learnings between the co-investigators.
c. *into faculty groups* (pre-service teacher or undergraduate science major). This grouping allowed us to see if there were any collective experiences across the two research populations.

2. *Generating Initial Themes:* Initial themes were generated by identifying patterns and connections between codes. We considered the frequency and salience of each code to determine its relevance in forming themes.
3. *Reviewing Themes:* The generated themes were reviewed to ensure they accurately represented the coded data. This process involved checking for coherence and consistency within each theme.
4. *Defining and Naming Themes:* Each theme was carefully defined and named to reflect the content it represented. This step aimed to make the themes more descriptive and meaningful.
5. *Data Interpretation:* Themes were interpreted in the context of the study's research questions and objectives. This involved a deeper analysis of the relationships between themes and their implications for each research question. Themes were then compared and discussed between researchers for inter-researcher reliability checks to validate our thematic interpretations and resolve any discrepancies. This also served as another opportunity to unmask any unknown biases and unknowing invention/ignoring of themes.

6. *Final Report:* The results of the thematic analysis were integrated into a final report, with quotations from the coded data to support the identified themes. This report can be found in the "results" sections of this thesis.

The combined use of coding and thematic analysis provided a robust and structured approach to analyzing the qualitative data from the interview and video diary transcripts (Braun & Clarke, 2006; Saldaña, 2015). This process allowed us to explore the intricacies of participants' science experiences and the development of their science identities. The identified themes will be discussed in the subsequent chapters, providing valuable insights into the research questions.

Summary

This study created an afterschool science club for elementary-aged youth. Pre-service teacher and undergraduate science major volunteers, the participants in this study, attended two workshops to learn about youth-led inquiry and the AST framework. Co-investigative pairs, each with one pre-service teacher and undergraduate science major, were placed into groups with 3-4 youth to perform youth-led science investigations in the afterschool club. The science club was supposed to run for ten weeks but got cut short due to the covid-19 lockdown, stopping at week five. Data was co-constructed with the pre-service teachers and undergraduate science majors in the form of 2 semi-structured interviews (a time lime interview and an online interview) and 2 semi-structured video diaries. The overall purpose of the interviews and video diaries was to have the co-investigative pairs reflect on their previous experiences and orientations towards science, their experiences in the pairings and their aspirations for science in their future careers. Interviews and video diaries were recorded and transcribed verbatim. Data was then analyzed using Saldaña's (2015) coding manual using open coding and in vivo coding, and then thematically analyzed using Braun and Clarke's (2006) thematic analysis techniques. The results of this analysis were organized into reports, which will be discussed in the results section of the following three chapters.

Results and Discussion One: Science Capital Building Experiences

The following chapter will explore the prominent themes found from the analysis of the data co-constructed with the co-investigators. First, I will thematically describe the previous science experiences of the pre-service teachers, followed by a discussion of how they relate science to their identities. Then, I will explore the previous science experiences of the undergraduate science majors, followed by how they relate science to their identities. These experiences and perspectives of our co-investigators are of significance as they signal the types of science capital each individual has to use and exchange for recognition as a "certain kind of person" in science (Gee, 2000). The findings have been summarized into distinct themes based on how they addressed the following research question: *What kinds of science capital-forming experiences and perspectives are preservice teachers and undergraduate science majors bringing with them to co-perform youth-led ISL?* The presentation of the thematic results will be followed by a discussion to explore in greater depth the results and emergent themes in relation to the theoretical framework upon which this study is built and to situate the results within previous literature.

The data presented in the following chapter will reference tables A, B, C, and D. These tables serve to present examples of raw data excerpts from each co-investigator, as well as demonstrate the thematic coding I attached to each excerpt during thematic analysis. Throughout the results sections to follow, I will reference the data found in each row of these tables using the "code" value found in the rightmost column of the table. For example, (A1) will refer to table A, row 1, where the rightmost value is code 'A1' for ease of finding the correct value.

Table A. Anika's Science Experience Categories and Themes with Representative Data Samples.

Broad Category	Broad theme	Sample Code (sub-theme)	Example of utterance categorized in sub-theme	Code
Early Science Experiences	Family and friends	Not smart in science	They thought I was smart in science, but I wasn't smart. I was just like asking my questions like during lunchtime.	**A1**
		Friends disinterested	No really [science interested], they're more into business.	**A2**
	Positive experiences	Liked applied science	in secondary three, we had the option to continue the regular science or to a science plus, like the science plus it involved more like hands on experience, and the other one was the only theory. So I joined that and I really liked it because we're learning the theory and we're applying it. Whereas the other class we were just learning the theories.	**A3**
	Negative experiences	Language barrier to access science	It was hard because like, because I had, I was in French, and like, since I was the first child I didn't have anyone to speak French with.	**A4**
		Too much theory	I didn't like science at all before because it was, the teacher was doing everything like in elementary. Like us, we're just like taking notes in our notebooks.	**A5**
		Forget science; disinterested	learn for the exam and then I'll forget it. So yeah, I will, I was always studying for the exam. Not for myself.	**A6**
	Missed opportunity to engage	Biology didn't go in depth enough	secondary four we had the option to choose like biology or chemistry. I chose, I chose biology but I felt like we didn't go in depth, but I really liked the teacher. [...]Because I thought we'd learn about humans, like human nature. But we only learned about the plants	**A7**
University Science Experiences	Learning about science	YouTube as learning resource	But I watch sciencey YouTube videos and I like watching like the potions	**A8**
		As useful for career	I watched videos to see how to teach science.	**A9**
		Not interest driven to engage	Like even here in university, like, I'm learning, I'm watching this video cuz I have to. So like, I don't do it like, by myself because I want to.	**A10**

Science Attitudes, Beliefs and Dispositions	What is a science person?	A natural curiousness	I think it's someone who like questions everything. Why is this happened? It's someone whose like, who questions a lot, and who wants to keep on doing research.	**A11**
	Self and science	Not curious	I think like scientists are more curious and I'm not that curious. Like even here in university, like, I'm learning I'm watching this video cuz I have to. So like, I don't do it like, by myself because I want to.	**A12**
		Science as just another subject	I thought science as being like an additional course or learning in school.	**A13**
Science Futures	Career ambitions	Engage students in hands-on learning	like yesterday we were doing an experiment with warms and like, you just need a mud and worms. And so I feel like you could do it, I don't know why they didn't. It might be a little expensive, like you'll have to put, but it's fine. Like you want students to learn. And to create like a meaningful learning experience, they need to engage and be active. So I'll definitely include experiments and make them to it, like in groups.	**A14**
		Foster youth's curiosity	I think it's important to be curious. I don't have it but like, because at least it makes you discover new things	**A15**

Table B. Jenny's Science Experience Categories and Themes with Representative Data Samples.

Broad Category	Broad theme	Sub Theme	Example of utterance categorized in sub-theme	Code
Early Science Experiences	Family and friends	Exploration investigations with brother	[my brother and I] would grab the dish soap from under the same room and laundry detergent, and we would just like make a contraption of some sort and just watch it, like react to each other. But I think that wasn't really a premise to do this was sort of just like, oh, we're just mixing stuff and feeling like a scientist without actually being like conducting research	**B1**
		Friends were not interested	I feel like my whole entourage we just didn't have a positive view of science in high school	**B2**
	Positive experiences	Impromptu science	we decided to take recycled boxes and we just made something out of it. I don't think we actually had like a big idea in min	**B3**
		Felt like a wizard	I did [feel like a scientist] because I felt like, I don't know, like a wizard or anything that you would associate with the type. I would mix potions together. Like, just because, and also since I was older, I took the lead. So I was like, Oh, you're my assistant, you know, and then my brother would help me. It was really fun.	**B4**
		Fun exploration with class	I remember me with a grapefruit and I don't like grapefruit usually, well actually I didn't like fruit in general, but because my eyes were closed, I was able to I didn't really smell much, but then we had to taste it as well. And we had to guess based on taste so like it was a project on the senses, but from tasting I actually really enjoyed it. So it made me like more open to fruits.	**B5**
		Enjoys hands-on science	from kindergarten to grade six. I've probably really enjoyed it because it was very activity based	**B6**
	Negative experiences	Avoided doing science in high school	in high school was very, like, okay, study for the test, you know, like, here's the terminology, everything for the final exam. And then like when we started doing lab experiments, most of my teachers were sort of, just explaining it and then she let us do whatever we wanted. So either like, my twin or me would not do the experiment at all	**B7**
		Disinterested in science	I did not like science. I thought it was boring. I thought it was a waste of time. I didn't understand why we were doing this. I sort of just showed up, listened to lectures and just	**B8**

			wanted to do well on the test. So I would just like study the notes, but like not actually but like not actually understanding the content.	
	Missed opportunity to engage	Sex education not in depth enough	they just talked about how reproduction works in like the simplest way where it's like, oh, you know, the sperm gets in the egg. We didn't dig deep enough into it. So like I didn't get to really... like that was one of the few things I was interested in. And then we didn't actually like explore in depth. So I feel like the opportunity was just missed, I guess for me as a student	**B9**
University Science Experiences	Learning about science	Learning science content	now that I'm in university, I'm doing the teaching science classes now. I'm learning all the like, the little things again, I'm like, how did I, I'm sure we cover this in high school, at least. And I'm like, I didn't know anything. It's kind of sad.	**B10**
		Embodied inquiry	I was always really engaged. And I would always ask questions because genuinely I wanted to know, and I feel like in that classroom, I just sort of like embodied this like inquiry, like, I just want to know everything. So I would always ask questions. And I always make like, a hypothesis, even though they're like, really out of nowhere.	**B11**
	Powerful recognition	Recognized by professor	I was really like, happy to hear that like someone actually sees like me as like a science learner I guess because I've always approached the classes at elementary students like I just genuinely because I don't know much about it.	**B12**
Science Attitudes, Beliefs and Dispositions	What is a science person?	A natural inquiry "thinker"	someone who's really fully immersed, and I guess, like, adopts like scientific process and like everyday investigations as they think about like, just like natural phenomenon	**B13**
	Self and science	Uses more effort to think "like a scientist"	where me I have to think of it and I'm like, okay, here's what I'm seeing, Let's make a claim. Let's back it up with evidence. Well, what I'm currently doing in class, like, because I'm trying to like, teach it in a classroom, obviously. But I think someone who's naturally a science person does it without thinking though.	**B14**
		Approaches science like a kid	I like to approach it as a kid myself. Like, even like in the teaching science class, we do a lot of experiments. I'm always like, I'm approaching this like, like, I'm not even pretending to be a student. I literally am a student in my head, because I'm learning new things every day. And I approach it with, like, with no prior knowledge of it whatsoever	**B15**
		Spark interest	I think if I had that teacher that would really like open my eyes about science, I would be way more into it. Just that one teacher, that's all.	**B16**

Science Futures	Career ambitions	Wants to embody inquiry in teaching career	I like the process of science, especially so like, Yes, we'll have a time for science, but like, I think I'm gonna keep using the processes, even if we're not in science, because I think getting kids to actually think about the problems that they are faced and to provide them with multiple solutions will help them like understand the content better, but also push their thinking even further, which hopefully will like it will also allow for critical literacy to come into place.	**B17**

Pre-service Teachers (Anika and Jenny): Experiences with Science

In this first section, I will present the previous experiences and perspectives our pre-service teachers, Jenny and Anika, brought with them to co-perform youth-led science investigations. First, I will describe their experiences with science in elementary and high school, their informal engagement with science and then their experiences with science in university. Afterwards, I will present how they discuss science in relation to their identities.

Pre-Service Teachers: School Experiences with Science

Anika's disinterest in science began as early as elementary school. As a first-generation Canadian student, she attended school in a language she did not yet understand and in a system that did not provide adequate support to immigrant parents so that they may in turn support their children's language learning. She described her science education as very textbook focused, and teacher centered (A5). Only once Anika reached high school did the second language instruction get easier, and science became more interesting as she was able to choose an applied stream where there were more laboratory experiences (A3). Despite having more fun performing the experiments, she described only really engaging in science learning to do well on the tests (A6). Her success in science class, however, did not leave her feeling accomplished. She reflected on her success negatively as she had to ask questions in order to achieve that success (A1). When Anika had the opportunity to choose a science course, she was left disappointed in the course material as in the biology option they only learned about plants, not humans (A7).

In contrast to Anika's experience, Jenny described her elementary science experience as "fun-driven" and an "activity mania" (B6). Jenny remembered elementary school science to be very hands-on and reflected positively on some of those experiences (B5). However, Jenny's engagement with science all but stopped once she entered high school. Her friends and sister no longer had an interest in science, and neither did Jenny (B2). Jenny described actively avoiding doing science: *I did not like science. I thought it was boring. I thought it was a waste of time.* (B8). Jenny described one moment when she was finally interested in science class, but the lack of detail left her disappointed (B9). Her experience with high school science left her feeling like there was a missed opportunity to actively engage her in science learning. Overall, Jenny reflected on her science experiences as lacking: *I feel like I didn't have that many like, like, meaningful experiences with science.*

Pre-Service Teachers: Informal Science Experiences

Anika was not able to recall engaging in any informal science throughout her childhood or schooling years apart from now, in university, watching science-oriented YouTube videos to learn how to teach science (A8). However, watching these videos, she admits, is only to improve her teaching (A9), not for her own interest: *I'm learning, I'm watching this video cuz I have to. So like, I don't do it, like, by myself because I want to.* (A10).

Jenny, on the other hand, shared numerous memories of engaging informally in science explorations and experiments with her siblings as a child. She and her younger brother would watch science-related TV and then do experiments in their home, stating that "*just like a wizard*" she would "*mix potions together*" (B4). She would role play being a wizard or a science teacher, without consciously realizing at the time it was science they were engaging in. To them it was simply having fun and experimenting: *we were just mixing stuff and feeling like a scientist (B1)*. Jenny claims that she did not believe her explorations with her brother counted as "*real science*", and she used many qualifiers to downplay the experiences, including "*we were doing science in the <u>simplest</u> form*," "*just <u>pretending</u> to be a science teacher*," "*<u>just</u> experimenting*," and "*we were <u>just</u> doing crafts*" (B3). Together, these statements suggest that Jenny does not recognize her experiences as science engagement.

Pre-Service Teachers: University Experiences with Science

Jenny joined our youth-led ISL program at a pivotal moment in her teaching education. Having recently completed her teaching elementary science methods courses, Jenny had a renewed sense of the importance of science, what science is, and how she wants to include science in her future classroom as an inquiry-based teacher: *I like the process of science, especially so like, yes, we'll have a time for science, but like, I think I'm gonna keep using the processes, even if we're not in science* (B17). Importantly, she was now re-learning high school science through her university science methods teaching courses (B10). This is of critical importance as she stated that science content knowledge was not something she possessed. On top of not knowing the content, Jenny was also, by her own admission, afraid of science: *I was terrified of the content.*

While Anika did not express the same fear as Jenny about the subject of science, she too was re-learning science in her university science methods courses as throughout her previous schooling she would learn for the exam and then forget the content (A6). Anika viewed science as just another one of the courses she had to take in elementary and high school (A12). She didn’t have any friends interested in science either (A2). Now, through her engagement in her teaching science methods courses, her views on science were beginning to transform. She now knows that science is everywhere; *I understood the importance of science. And I told myself that I need to start learning. So that's when I started watching YouTube videos.* But even with this renewed sense of understanding, Anika did not have her interest in science and claimed to be only learning science because she knew she had to (A10).

Pre-Service Teachers: Summary of Science Capital Building Experiences

Jenny came to our ISL experience with limited formal experience with science. Her brief engagement with informal science, in the form of explorations and investigations with her siblings, is her main source of science capital coupled with the learnings from her university teaching science methods courses. Jenny, as a result, values informal engagement with science. Anika, on the other hand, had little engagement with informal science and limited engagement with formal science in school which left her frustrated, mainly due to the teacher-centered practices and communication difficulties. Anika, as well, had recently completed her teaching science methods course, and so she had an abundance of science educational theory knowledge to use during this experience, but little experience putting theory to practice. These findings align with previous literature which motivates pre-service teachers engaging in ISL contexts as an opportunity to put theory to practice (Borgerding & Caniglia, 2017; Macdonald, 2010; Marttinen et al., 2020; Rahm et al., 2016).

Pre-service Teachers: Science and the Self

To better understand how the pre-service teachers saw themselves in relation to science, I asked them to describe both "what a science person is" and "if they saw themselves as a science person". Their responses allowed me to see how they positioned themselves in relation to science, otherwise known as their "science identities". I will now describe their responses to those questions, so that we may understand the perspectives they brought with them to co-perform the youth-led inquiry investigations.

Jenny: A Strong Science Learner

Jenny described a "science person" as: *someone who's really fully immersed and adopts scientific process and like everyday investigations as they think about like, just like natural phenomenon that just occurs* (B13). Jenny, then, described herself as <u>not</u> a science person, but instead as a "strong science learner," since taking her teaching elementary science methods course. Throughout the course she was very engaged and approached the science learning genuinely: she embodied inquiry (B11). Here, Jenny appeared to be describing herself in the same definition as a science person, however, she further explained that she must actively think of the process of inquiry in order to do it (B14). She emphasized the difference between her and a science person is: *I think someone who's naturally a science person does it without thinking though.* Jenny believed she was not a science person as a result, because although she was now adopting scientific processes throughout her teaching and learning, she was actively working to do so (B14, B15). A science person, according to her, would do it naturally. Jenny believes that if she simply had one teacher spark her interest, she would have been a science person (B16). Furthermore, Jenny was very happy that she was recognized by her university professor as a science learner (B12). The recognition from her professor seemed to excite her and it was what encouraged her to participate in this ISL project.

Anika: Not a Science Person

Anika described a science person as someone who is curious, and in opposition to herself, saying *a scientist is some who questions everything* (A11) and *I think, like, scientists are more curious and I'm not that curious* (A12). Not only did Anika describe herself as not having an interest in science, but stated she was also not curious enough to learn more outside of what her classes require. Despite her previous experiences with science, Anika did believe that science engagement was possible in elementary classrooms (A14) and wants to one day foster and encourage her students' curiosity (A15).

While both Jenny and Anika expressed an interest in engaging in the ISL project of this study to gain more teaching experience and to develop skills to engage youth in science, Anika had the unique goal of developing her communication skills. Anika described herself as a naturally shy person who struggled with communication. In elementary school, she struggled to get help from her parents who did not speak the language of instruction (A4), and in university, she struggled with talking to and interacting with others. Anika viewed this ISL opportunity as a chance to work on her personal goal of opening up and talking more with others.

Pre-Service Teachers: Discussion

I will now discuss the science capital-building experiences and perspectives of the pre-service teachers, Anika and Jenny, in relation to the theoretical frameworks and previous literature. I will discuss their science capital to leverage followed by a discussion of their teacher capital to use and exchange during the context of this study.

Limited but Significant: Science Capital

Both Jenny and Anika stated having limited science content knowledge, limited friends and family in science, and limited engagement with science and in science contexts until present. These findings are congruent with Avraamidou's (2013) study, which discussed that pre-service teachers often leave their teaching programs with insufficient science content knowledge to feel confident teaching science. Similarly, both Jenny and Anika were apprehensive of the science content portion of this experience. These limited experiences with science signal that they had few opportunities to accrue *recognizable* forms of science capital. As a result, they now have limited *recognizable* forms of science capital to use to support their engagement in science and to exchange for more science capital (Black & Hernandez-Martinez, 2016). Jenny was able to position some of her science experiences as recognizable forms of science engagement, and therefore she was able to share these experiences with me. Anika, on the other hand, had very few science experiences to share. This suggests not that she had no engagement with science, but instead that she was unable to translate it into *recognizable* forms. That is, that the habitus (socially constructed dispositions, attitudes, and behaviors) of science Anika possessed does not value the engagement with science she has experienced to date. As a result, the social construction of what science is and who can do science has marginalized her forms of science capital and has not supported her engagement with science (Avraamidou, 2022).

A Rich Well: Teacher Capital

It remains important to note that through this afterschool science club, Jenny and Anika are entering a field where they may not have a lot of experience, but they do have a lot of amassed teacher capital (Hargreaves & Fullan, 2015). Gained from their university education courses, Anika and Jenny can use and exchange their teaching capital for recognition in this ISL context. This will, therefore, affect how they operate and position themselves within the field. Additionally, both Jenny and Anika came to this experience actively trying to accumulate more science (teaching) capital and are required to mobilize their teacher capital to support this endeavour (Varelas et al., 2015). This affords the preservice teachers a sense of agency in our ISL context (Adams & Gupta, 2017) and positions them as useful and valued members of our community of practice as they are needed to help support the undergraduate science majors in facilitating the youth.

Undergraduate Science Majors (Sam and Mia): Experiences with Science

In this next section, I will present the previous science capital-building experiences and perspectives our undergraduate science majors, Sam and Mia, brought with them to co-perform youth-led science investigations. First, I will describe their formal and informal experiences with science from early elementary until present. Afterwards, I will present how they discuss science in relation to their identities.

Table C. Mia's Science Experience Categories and Themes with Representative Data Samples.

Broad Category	**Broad theme**	**Sample Code (sub-theme)**	**Example of utterance categorized in sub-theme**	**Code**
Early Science Experiences	Family and friends	Parents in science	my mom works as a lab technician [...] and my dad works in, IT, he's a director managing data of like clinical trials	C1
		Supportive friends in science	I did have my friends in the classes like these classes. Um so it was it was also kind of like, you know I wasn't doing this alone	C2
		Mentors	we had mentors and parent volunteers to come in and they spent a lot of time with us, like everyone put in all that effort with it.	C3
		Parents encouraged science participation	I just picked the science stream because my mom always kept like science books, both mom and dad kept science in the household.	C4
	Positive experiences	Robotics club	I was part of the first robotics team at my high school. Though, I actually didn't do science for that one. I was just surrounded by science all the time	C5
		Science engagement as useful	it's very memorable because it took all four years of my high school experience. I used it for my college essays, like I still reference it sometimes in resumes because	C6
		Science communication	I did a lot of gathering of press releases and trying to communicate like, Oh, this is what our robot does and it has this, this and this and it was all towards like, judges that came to the pit into like the pit area or judges that were set up in this different room. And then we would talk like we would, we would give spiels about, you know, how, what attracted me towards entrepreneurship or with giving back to community and stuff like that. So, that took a lot of my time.	C7
		Exciting and engaging	So what we got to do is we got to essentially run gel electrophoresis and sequence DNA and then analyze the DNA. It's really cool. I loved it so much.	C8
		Science all around growing up	Mom always kept like, Encyclopedia books, kids encyclopedia books, and inside the house, the ones with illustrations. I remember it was like Illustrated Encyclopedia of chemistry or Illustrated Encyclopedia biology. And like, yeah, those were things that we read in house now that like, it wasn't something that I kind of can retain now, it's not like a story or novel. I read it just, yeah, we used to pick them up, open the page and just start reading.	C9

		Supportive teacher and multidisciplinary science engagement	she just really encouraged me not only in research, but to just look things up. Like I used to tie things a lot to pop culture. I was very into Dr Who at the time, so I used to tie those things in and she like she didn't like take off points or whatever. She wasn't very like, "Oh, you didn't mention this this or that," she was very encouraging in like how I make connections with pop culture, with literature, with all the other stuff that might not have been strictly research science	C10
		Feeling very official	But what they did is that we were in a lab type like high school science classroom where you had benches in the back and stuff like that. So it felt very official as like a middle schooler. And then, like, we didn't, I didn't know we were doing the cows heart. I didn't even think we're doing dissection because I felt Oh, wait, we're middle schoolers. They're not gonna make us do that. Right. [...] then suddenly there was a cows heart in front of me and I started making the incision.	C11
		ISL volunteering	that's what I did over the summer. I knew nothing of the field. Like she works with like, whole body like, not kinesiology but like, muscle and stuff. [...] she needed help just as like someone to hold the machine like parts of the machine together. So I got to go which was fun because I want to get out like explore more. And also I got to actually be in a lab technically	C12
	Mental health	ISL programming as helpful	I signed up for [ISL program] and I was just like, you like just, this is like three hours out of your schedule of just doing something you want to do, instead of like, struggling through everything else. So I started in that and then I got out of my situation and you know, I started doing other stuff, started talking to more people. And then I continued doing [ISL program] volunteering.	C13
University Science Experiences	Learning about science	Found enjoyment in science	I found my own like, enjoyment in molecular biology. I remember watching. It was, I think a Harvard animation they had online of what goes on in the cell. I just remember thinking that it looks so like smooth. And like kind of as if every molecule was sentient in which I know isn't the case because obviously but at the same time, it just looks weird and cool. And I kind of tried to embrace like, just how baffled but also intrigued I was by it. And yeah, that's what led me on to molecular bio in university.	C14
Science Attitudes,	What is a science person?	Comfortable in science	someone who feels comfortable in science because like the reason that for a second, I was doubting [being a science person] in freshman year, was because I no longer felt very comfortable in science.	C15

Beliefs and Dispositions		Comfort in Science doesn’t need to look one way	We're however you might define that as, like, it could be you're comfortable with the research aspect or you're comfortable with just science facts that you learn. Or if you're comfortable with the questions, just lots and lots and lots of questions. Maybe you're comfortable with outside with like, nature and ecology and stuff like that, or, you know, stuff like that.	C16
	Self and science	A science person	I never really thought of myself as not a science person	C17
		A multidisciplinary person	I'm a science person, but I also like learning about history and pop culture and culture in general. And I know that's, that's not something that I explored us fully a science but it's still something that kind of influences all of this.	C18
		Science as almost non-optional for her	I think I thought everyone else thought that I would go towards the sciences. So I did. And I mean, it's not so much like I was forced against my will. I did like going into science, but by that point in my life, I'd already been like, all my other experiences has shaped me shaped this environment that I was in that going into a different kind of like, going to English or history wasn't an option. It was could be a hobby, but maybe not an option. So I guess that and then yeah.	C19
Science Futures	Career ambitions	Science communication	I have changed my goal into more Science communications now I'm actually applying to jobs now. So now it's just you know science outreach events, science writing stuff like that even though I don't have that much of a portfolio.	C20

Table D. Sam's Science Experience Categories and Themes with Representative Data Samples.

Broad Category	**Broad theme**	**Sample Code (sub-theme)**	**Example of utterance categorized in sub-theme**	**Code**
Early Science Experiences	Family and friends	Non-science parents	parents are all in broadcast journalism, not science	**D1**
		Elementary science friends	a lot of my friends are very sciency. But I think because they also didn't know where they were heading, and now they know where they are in their life. It's like, Oh, we were all moving in that direction	**D2**
		Informal science debates with (current) friends	like what we would watch like a movie my friends. I'd be like, Oh, how does the movie passengers like the sci fi movie make sense? like is that what is there a flaw with it or something that. much more like analytical and like picking apart like the science of stuff in the, how many holes are in a straw? Well, if you look at the topography, if you like were spread out one of them. It's one hole right in the middle. So if you hit with a T shirt, it's three holes.	**D4**
		Informal exploration with friends	my friends, we lived in like a very like wooded area so we like, it was exploration like we'd wander around the woods	**D5**
	Positive experiences	Science TV	I was interested in um, Cyberchase. It's kind of a more of a math based thing or maybe even computer science but for children for it was on PBS broadcasts	**D6**
		Science at friends house	I was young and this was like my first like, big project, I think, like very hands on and I it was outside of school that we did it. I worked on a group so we had over to a friend's house. I think that that was a fun thing because I didn't normally, science projects before that were like in class or that kind of thing. So I liked the "this is a school project that was outside of school" with friends.	**D7**
		Hands-on engaging science project	a big one in high school was in my physics class. We did a mousetrap car. [...] that was similarly a hands on project with a group outside of school. We got to work together and like collab. We had a very interesting group of people who, basically, my friend Jasmine, did, we there were three trials that he had to do there was distance, stopping at 10 meters, exactly, and then going up a ramp. And like, we kind of each took one on our own, but we were still doing it together. But one of us was really leading each one like figuring how to do. I did the distance one, it went the farthest in the class. But Jasmine did the ramp thing and I remember us, Zack and I, had no idea what to like, we were really stuck on it. And she figured it	**D8**

			out and it was great and Zack did the stopping one. And so that one was really cool because it was very, I don't know, concrete.	
		High stakes science	We got an A on it. Because part of the part of the also interesting part was the grading was 50% was based off of the performance of it. That was kind of fun. It made it real.	**D9**
		Science museum as fun and inviting	I remember going to the Museum of Science in Boston, which is a very nice Museum of Science in this area that was like a big like, because they, that museum was very fun oriented.	**D10**
		Cool to attend MIT science day	I also did this thing with my friend in like, seventh grade, where we went to MIT for like, a day. And like they had young, we were a little young for it, I think, I think is probably more high school oriented. But they had like, little micro lecture type things. And that was cool just because it was MIT in Cambridge. And so that was, that was just with me and my friend and yeah, that was cool.	**D12**
	Negatives experiences	All positive experiences	I should think of bad ones...	**D13**
University Science Experiences	Learning about science learning about communication	Almost failed out	I think that if I had failed that class, I probably wouldn't be in physics. I may have stayed in science, but I think I would have like done something different. But it was a wake up call.	**D14**
		Peers as bad communicators	because we've just grouped together, they're my friends. And they were all the worst writers I've ever seen.	**D15**
	Feelings of belonging	Friends more science person than him	I think that most of my friends are more science people than me. Especially in physics. I was the like most like not awkward? extroverted? Is probably the best way.	**D16**
		Not an arts person either	[There was] this weird separation between how they thought and how I thought. It was good that we were brought together, but it was also like, very isolating, because I was like not thinking like them. They use very big words and jargon that I'd never heard before. And they, they all had book recommendations when you literally mentioned anything to them. They'd be like, "oh, have you read this one?" I was like, "No, I have not read this one specific book from this one specific author that all of you seem to have read.	**D17**

Science Attitudes, Beliefs and Dispositions	What is a science person?	To the point thinkers	I think they're a little bit more to the point. And then a little bit less of this like deep thinking type stuff. Like so the conversations I had with the humanities peoples were very like philosophical like, that kind of stuff. And then, but in like the physics lounge in my undergrad, it was always like, how do you define the difference between a soup salad or sandwich? What is the reality of...	**D18**
	Self and science	A non-science science person	I'm comparing myself to other physicists. And it's like, compared to them, I'm clearly. I like, I guess we're, there's a very big spectrum of science person, not science person. And physics is probably all the way on the end of science person. And because I'm, like, on the non science person side of physics, I feel like that.	**D19**
		Full invested in science	thinking I was going to be writer, a UN interpreter or something like that, was much later and so that, there was a point where I decided that not only was I a science person, but I am fully invested in science. It wasn't just an interest in science. It was a, that's the path I'm going down.	**D20**
		Friends don't understand value of ISL programming	most of my friends in physics don't get that, don't get like I think that this is another one of those things where it's like I'm doing this because I'm less of a science person than them. Because they don't see the value in it. And I think that that's a mistake.	**D21**
Science Futures	Career ambitions	Moving towards societal science career	I think because I have this like science outreach stuff, this science communication stuff, this background in my family of like that kind things, it would be wasteful for me to be one of the academia focused researchers in a lab type thing, and not trying to be more public.	**D22**
		Science communication	I think I'm embracing a part of the science side, that I think a lot of scientists neglect	**D23**

Mia: Previous Science Experiences

Mia grew up in a household where science was all around her. Her parents worked in science-related fields (C1), her friends enjoyed science (C2), she had adult mentors in her science pursuits (C3), science encyclopedias for kids filled the shelves to read (C9), and science TV shows were watched. Mia stated science felt like a natural, expected career path for her, and she was able to find her *own enjoyment in molecular biology* (C14). She described having a good teacher in high school who encouraged her interest in science and supported her desire to relate science with pop culture and literature, deep interests of hers (C10).

Mia was a member of her high school's robotics club for four years where she worked as a marketing consultant. However, when discussing her role in the club, she felt she didn't do science, but was always surrounded by science (C5). Despite stating she did not "*do science*" in that experience, her role was essentially a science communication liaison for the robotics club (C7). Mia reflects on the experience as being very useful to her as she was able to use it on her resume and in her college essays (C6). Mia reflected positively on the science classes she took in high school, as opportunities in which she felt official and important. She felt official when getting to dissect a real cow's heart at a lab bench (C11), and important when she took part in DNA sequencing of duckweed colonies for a local university's genome project. Getting to sequence DNA was very exciting and engaging for her (C8).

Upon entering university, Mia struggled with her academics and needed a lifeline to hold on to. She found one through engaging in ISL programs where she could volunteer with youth and feel like she was making a difference (C12, C13). As a result, Mia came to our ISL program with extensive prior experience working with youth in ISL contexts.

Sam: Previous Science Experiences

Sam also had a multitude of positive science experiences both formally and informally. In his youth, Sam recalled watching science TV (D6), going to the local science museum (D10), doing science explorations with friends in the woods (D5) and attending mini lectures at a local university (D12). Sam struggled to think of any bad experiences he had with science at all (D13). He remembered fondly engaging in hands-on projects in and out of school (D7, D8). His excitement and enjoyment of high-stakes science challenges in school is evident in his rich descriptions of the task, even years later (D9).

Sam's parents work in broadcast journalism (D1), which he believed influenced him to think of himself as a "*social and friendly*" guy who "*gets along with everyone*". These qualities have been to his benefit, through his enjoyment of participating in theatre in high school, but also to, his surprise, they set him apart from his university physics peers (D7). Because of his extroverted nature, Sam felt he did not fit in with his peers: *I'm comparing myself to other physicists. And it's like, compared to them, [...] I guess we're, there's a very big spectrum of science person, not science person. And physics is probably all the way on the end of science person. And because I'm, like, on the non-science person side of physics, I feel like that.* (D19)

Sam felt he did not totally belong with "arts people" either, finding their jargon and way of thinking hard to understand (D17), saying: *[There was] this weird separation between how they thought and how I thought.* As a result, Sam was struggling to find his place in science. Even with his science friends, with whom he regularly engaged in science debates (D4), he felt he did not quite fit in (D16). As he reflected on his future in science, Sam believed he was moving towards a "*societal branch of science*" with an emphasis on communicating science effectively, something which many of his peers do not understand: *I think I'm embracing a part of the science side, that I think a lot of scientists neglect* (D23). He was surprised at how his peers struggled to communicate science (D15) and he wanted to communicate science better because "*someone has to do this,"* and they need to be able to do a good job. He felt that his peers don't see the value in taking part in education-related experiences, such as the context of this study: *Because they don't see the value in it. And I think that that's a mistake.* (D21). As few people in his field shared this interest, Sam believed it would be wasteful of him not to go into a science career that is more public-facing, such as a science communication type career (D22).

Undergraduate Science Majors: Summary of Previous Science Experiences

The undergraduate science majors, Mia and Sam, describe numerous positive, formal and informal experiences with science from early childhood, all the way up until the present, and discuss science as being all around them throughout their lives. Overall, Sam and Mia both present their interest in science as developing naturally over time and encouraged by their parents' approval of their academic success in science (C4, C19). Since beginning university, Mia had extensive experiences in ISL contexts, while Sam mainly engaged in science academically within the physics domain.

Undergraduate Science Majors: Science and the Self

To understand how the perspectives about science the undergraduate science majors, Sam and Mia, brought with them to co-perform youth-led science inquiry investigations, I asked them to describe both "what a science person is" and "if they saw themselves as a science person". I will now describe their responses to those questions, to demonstrate how they positioned themselves in relation to science, otherwise known as their "science identities".

Mia: A Multifaceted Science Person

Mia described her enjoyment and engagement with science as multi-faceted and interdisciplinary, which carries over into how she sees herself in relation to science: *I'm a science person, but I also like learning about history and pop culture and culture in general. And I know that's, that's not something that I explored fully in science but it's still something that kind of influences all of this* (C18). Mia described herself as a science person, but also as a person who enjoys other things, all influencing each other. Mia defined a science person as *someone who is comfortable in science* (C15) but went on to expand into a more inclusive definition where being comfortable in science could be with science facts, with asking questions, being outside in nature, and more (C16). For Mia, being a science person is not necessarily related to academic success. When she experienced academic struggle in freshman year, she questioned whether she was a science person, but ultimately found new avenues to explore science and re-gained her comfort in science through ISL programming with youth. Despite her struggles, she explained she had never thought of herself as not being a science person (C17). Mia's career goals account for her interest in ISL programming, and she wanted to find work in science communication after graduation (C20).

Sam: A Non-Science Science Person

Sam was able to recall the moment where his interest in science became less of a hobby and instead a career direction he invested himself in: *It wasn't just an interest in science. It was a, that's the path I'm going down* (D20). Like Mia, Sam also experienced academic struggle in freshman year. When he failed 2 midterms, he thought he was going to drop out of physics altogether and went through a "*roller coaster of emotions*" (D14). Up until that moment, science for Sam had not only been something fun and interest-driven he engaged in, but it had also been a way of life, a way of thinking and being. Although he ultimately passed the course, it affected how he saw himself as a science person during that time.

Sam described knowing he was indeed still a science person when he began working with arts students through an idea exchange program at the university. He described it as isolating because of the marked difference in the way they thought compared to science people and himself (D17). As a result, he defined what a science person is in relation to that experience, and defined science people as: *a little bit more to the point. And then a little bit less of this like deep thinking type stuff* (D18). Similar to Mia, Sam described his feeling like a science person as wavering over time. Unlike Mia, however, Sam felt that how much of a science person he is depends on who he is interacting with, where he felt very clearly like a science person around arts people, and less of a science person with his physics friends and peers due to his social nature.

Undergraduate Science Majors: Discussion

I will now discuss the science capital-building experiences and perspectives of the undergraduate science majors, Mia and Sam, in relation to the theoretical frameworks and previous literature. I will begin with a discussion of each of their science capital to use and exchange throughout the context of this study, followed by a discussion of their teacher capital. These are of importance as the perceived value of their science capital, combined with their perspectives, affects their subsequent positioning in our study's community of practice, discussed further in the following chapter: Results and Discussion Two: Recognition of Expertise.

Science Capital

It is important to note that chief among the science capital forming experiences present in both undergraduate science majors, Sam and Mia, are the *recognizable* forms of science capital which fit within the types of science and science experiences valued by society and academia. As a result, both Sam and Mia have had numerous opportunities to exchange their science capital for recognition as a certain kind of person in science and to support their continued engagement in science, leading to the development of positive science identities (Black and Hernandez, 2016). These experiences stand in strong contrast to the pre-service teacher's experiences. For example, both Mia and Sam were able to recount numerous informal science engagement experiences and identified them as *being science.* Whereas Anika could not recall any informal science experiences and Jenny did not count her informal experiences as being "real science". The interactions between the undergraduate science majors' recognized science capital, habitus and science identities strongly affect how they will position themselves in our community of practice and how they will interact with the youth. That is, their science identities will mediate their perception of the value of not only their science capital but will also influence the types of science they perceive as valid and worthwhile (Gonsalves et al., 2021).

Sam: An Abundance of Specific Capital to Leverage

Sam joined our ISL context with a lot of formal and informal science experiences, but limited experience applying his science content knowledge and skills, his science capital, to informal science contexts with youth, the field of this study. Sam was, however, used to mobilizing his science capital in grade school and university physics contexts, fields in which he understood well the doxa. Despite this wealth of science capital, he stated feeling like he never really belonged with his physics major peers, nor with arts students. Similarly, Gonsalves et al (2021) discussed how the perceived value of science majors' science capital influences their science identity and subsequently their reasons for engaging in ISL programming. We see this change in perceived value in Sam when he discussed failing two midterms and how if he had failed the course entirely, he likely would have dropped out of physics altogether. Additionally, in how he felt more like a science person with "arts people" than "science people", as he felt he was more recognizable as a science person in those contexts. That is, he felt his science capital had more exchange value for recognition as a certain type of science person with arts people than it did with his physics peers. As a result, Sam was actively searching for his place within science where he felt comfortable with his peers. In other words, he was searching for science others who did not fit the "typical science mold" or for those who do not operate within the expected habitus of science he typically expected from his peers.

Carlone et al (2014) suggest that the more overlap between one's science identity work and the "celebrated subject positions," the easier and less threatening it is to perform science identity work (p.37). For Sam, the celebrated subject position of a person in physics, as academically successful and a bad communicator, does not align with how he views himself as a science person, as someone who is out-going, who almost failed a course and is an excellent science communicator. His identity work has not aligned with this "celebrated subject position" and as a result it threatens his science identity; making him question his belonging in physics and subsequently labelling himself as a "non-science" science person.

Mia: Wide Range of Science Capital to Leverage

Mia came to our community of practice with a multitude of experiences engaging youth in ISL, along with a wealth of other science capital both formal and informal. Previous work also found that undergraduate science majors often have a wealth of science cultural capital as a result of their continual engagement in various science contexts (McPherson, 2014). Science capital, however, was found in a recent study to not be as strong of an indicator of continued persistence in science as science identity was; therefore, making science capital most useful when it can be used and exchanged for recognition (Godec et al., 2024). Gonsalves et al (2021) discussed the benefit of science majors being able to see the use and exchange value of their science capital, as allowing for the facilitation of seeing themselves as science people with imagined science futures. When Mia encountered "hard work" at the beginning of her academic career, she *used* her science capital to support her continued engagement in sciences via a new context: ISL contexts. Encountering struggle was not a deterrent to science for Mia, as she had already had many opportunities in her life to be recognized as an insider to science and to author herself as a science person (Gonsalves et al, 2021). Additionally, through engagement in ISL programming with youth, Mia was able to *exchange* her science capital for recognition (Cavalcante & Gonsalves, 2021) as a science person who engages youth in ISL and who is moving towards a science career communicating science with others.

Finally, Mia explained she grew up in a science-research-oriented family culture, and as a result, she appears to be struggling to break away from the mentality of "research as the only path of value in science", as she moves toward a non-research-oriented career. As a result, Mia projects, and subsequently internally values, a research-oriented type science habitus, which affects her engagement, perception, and interactions within the fields of science (Archer et al., 2015; Bourdieu, 1986).

Sam and Mia: Teacher Capital

Sam discussed noticing a big difference in his ability to accessibly and effectively communicate science compared to his peers and motivated outreach as an opportunity to learn more about education and science communication. Previous work supports these findings on the motivations for engaging in ISL contexts as opportunities to learn about education (Gutstein et al., 2006) and improve science communication skills (Pickering et al., 2004). This sentiment was also discussed by Medina et al. (2014) who found that the science content knowledge and science literacy was significantly improved in undergraduates who engaged in ISL contexts like Sam does, compared to those who didn't, like many of Sam's physics peers. I argue that this skill Sam noticed and subsequently valued in himself, is a form of teacher capital (Hargreaves &

Fullan, 2015). Here, Sam is actively trying to accumulate more (science) teacher capital through engaging in this ISL experience.

Mia, on the other hand, expressed having a lot of experience performing ISL with youth. Additionally, she spoke to many experiences, such as working as a communication liaison for her robotics club, in which she was required to develop science communication skills for varied contexts. Hargreaves & Fullan (2012) discuss how the adaptability of scientists *is* a form of teacher capital. As a result, Mia is coming to this experience with a wealth of amassed teacher capital, along with science capital, which she has experience exchanging for more capital, and using to support her engagement in ISL contexts.

Summary

The pre-service teachers, Jenny and Anika, come to this experience with limited engagement in science. Their lack of recognizable experiences with science to share may in part be due to the habitus of science held by society. They bring with them a hesitancy to engage with science. Jenny and Anika both, however, have a wealth of teacher capital and are eager to use and exchange this capital in this new context. The undergraduate science majors, Sam and Mia, recounted many science experiences and had positive orientations toward science. For Sam, this recognizable science capital coupled with his science identity of a non-science science person, left him searching for his place in science outside of the typical physics identity "celebrated" by society (Carlone et al., 2014). Conversely, Mia was struggling to break out of the highly valued research science orientations, despite her continued engagement in ISL contexts. Both Sam and Mia bring teacher capital in the form of science communication. Mia, however, has an added wealth of experience in ISL programming, which has further supported her accumulation of capital and recognition as someone who engages in ISL contexts.

Results and Discussion Two: Mutual (Mis)Recognition

The following chapter will explore the prominent themes found from the analysis of the data co-constructed with the co-investigators as a result of their experiences within their pairings. I will describe the pre-service teachers' and undergraduate science majors' experiences in their pairings as they relate to their abilities to recognize and value their partners, and their own, skills and expertise (or not). The findings have been summarized into distinct themes based on how they addressed the following research question: *Are undergraduate science majors and preservice teachers able to recognize each other's expertise while co-performing youth-led ISL?* The presentation of the thematic results will be followed by a discussion to explore the emergent themes in relation to the theoretical framework and to situate the results within previous literature.

The data presented in the following chapter will reference tables E and F. These tables serve to present examples of raw data excerpts from each co-investigator, as well as to demonstrate the thematic coding I attached to each excerpt during thematic analysis. Throughout the results sections to follow, I will reference the data found in each row of these tables using the "code" value found in the rightmost column of the table. For example, (E1) will refer to table E, row 1, where the rightmost value is code 'E1' for ease of finding the correct value.

Table E. Recognition Categories and Themes with Representative Data Samples for Co-Investigators Sam and Jenny.

Broad Category	Broad Theme	Sample Code (sub-theme)	Example of Utterance Categorized in Sub-theme	Code
Position in Science Club	Self as a novice	Unsure about science	I feel really confident as a whole... but then, like, it's more about science content than I'm like, a bit wobbly. Like where I'm not really sure. (Jenny)	E1
			I think she made it very clear that she was unfamiliar with a lot of the topics and but then again she wasn't trying to be that wasn't what she was doing that wasn't her role that wasn't what she was aspiring to be. (Sam)	E2
		Unsure about leading the youth	She knows what she's supposed to be doing. I don't. Like she's read the textbook that has like this is how you talk to kids. (Sam)	E3
			so far, he seems to be really happy that we're working together because he said that he's terrified about how we're going to do it. (Jenny)	E4
Partner Recognition	Partner as a support	Guiding the youth	And so I would see her do it. Almost, like to me, it's super obvious, but to them, they're like, "Oh, yeah, like, what a perfectly worded question", and they wouldn't see it. You know how sometimes you see, like, a politician avoid a question? It's like I saw her do it, but they didn't see her do it. And I was like, how do you do that? (Sam)	E5
		Education expert	I think that's I think it's really cool just to see like how practiced they are. (Sam)	E6
		Very knowledgeable	She sits there and points out the calendar and the classroom layout and the all the all the different little initiatives of that school. She like, a lot, like a lot of things where it's like, I have never thought about that. There's a lot of thought and energy going into how these teachers are educating the students (Sam)	E7
			I'm happy with Sam because he knows so much. And like he was just talking to the kids on Tuesday, and I was like, fascinated because I'm like, one how did I not know any of this. And two I can't believe someone knows this much about science (Jenny)	E8
			But the fact that he knew so much, and he, he just like, he really knew a lot you could tell this is his passion. (Jenny)	E8
	Valuing partners skills	Opening up new Avenues of investigation	And then Sam was really great at mentioning key concepts within that would sort of open up this a new world of things that we can investigate. So let's say like, like the particulate matter thing [...] I had no idea that like, we can we can investigate like how air pollution.. Well, air pollution as a whole by looking at particulate matter. I had no idea. So Sam was really good at shining light on to those things. (Jenny)	E10
		Explaining science using accessible language	Sam, he sort of knew the answer right away. So he would explain it in in a really accessible way for fifth and sixth graders. So I really enjoyed that so I think that, yeah, he really was a support for me. (Jenny)	E11
			So then Sam was also really good at at, let's say, they've stumbled upon a resource that wasn't as accessible for students, he was really good at like, turning that language into really kid friendly language. So like, I noticed, he was talking a lot with one of the students who was doing like, what air pollution is, as a whole, just to understand it better and he was explaining, like, what it is and like, how it how it came to be and like what causes it he was really explaining in such like, a really accessible way for students. (Jenny)	E12
		Able to engage youth in science	So like, having him I sort of saw it as a buffer because like, one, he was great with kids. So like, that was really reassuring, too. (Jenny)	E13
		Youth-centered pedagogy	I learned so much from the education students in just that hour and a half with them about basically what they do about what education and what the new modern education theory is all about, kind of trying to stop the teacher oriented and make it more like collaborative group oriented and so that was that was really just right off the bat learning kind of thing. (Sam)	E14

		Able to elicit youth's ideas:	orienting the conversation with these kids, because that's what Jenny was really doing. She was very good at like, the other day when we were doing the brain mapping activity, it was like, they would ask a question like, what's smog? And I could answer that in good detail and bring to their level and all that stuff. But then it's like now we're just talking about smog for 10 minutes. And she is, Jenny was one that was able to be like, all right, like, like redirecting and focusing on like, what what we're doing, and like, so there's, there's a technique in that, like, the questions the way you ask questions, and try to elicit their own curiosity. And there's like, it's an art basically. (Sam)	E15
		Facilitating youth led inquiry investigations	I think I would've struggled leading the youths through their activities and structuring their progress and then also keeping the tension low or whatever I think that I don't know how she's doing it but like, making the sure the kids feel more heard or whatever and that kind of thing. I may have over looked that kind of stuff just cause I wouldn't have been thinking about it. (Sam)	E16
Self-Recognition	Valuing one's own skills to support their partner	Science expert to refer to	So that was kind of the dynamic where she was leading it but I was like filling in the information for her so she doesn't have to like research. What do teachers do, they make their plan before the education the lesson plan, because Jenny didn't have a lesson plan to refer to, so she referred to me. (Sam)	E17
		Accessible science communication	She was like "I would have to be googling something in real time that you were giving really solid accessible answers to on a whim or whatever that expression is, immediately." I didn't even mean to (Sam)	E18
		Content knowledge	she would have had to google and would've given great answers too after a twenty second google search. I think that's where she was impressed because it kept it moving and I think that was probably the way I was the most helpful (Sam)	E19
		Education knowledge	Like I told him that we have a bunch of resources in education as to ideas of how to conduct experiments with kids. I'm happy that I can help him in that way because I feel like he's been helping me a lot. (Jenny)	E20
		Able to guide the youth	Sam was someone who was I was paired with and he knows a lot about science. I think he kind of noticed him taking over and I sort of more like asked a lot of productive questions where he felt trapped to giving the answer when I didn't want to give the answer because I wanted them to find their own answer. (Jenny)	E21
		Pedagogical skills	Sam mentioned this, he said that, like, "I really like how you're able to, like, keep things organized and like, help the kids out more in that way. Well, I just sort of helped them in the science content". That's what he said. And I think I have to agree, but I would elaborate more. And so in that, like, I sort of just geared their thinking as much as possible. I tried my best to keep them on track. Because I did want this to be like their process and them doing their own thing, which I think at the end of day, they did explore on their own as they were doing the research (Jenny)	E22
	Valuing one's own skills to support the youth	Science expert	I was kind of acting as there like in house science person where they would mention an idea and I would list off some bullet points of like what that might entail. So they would be like so what about if we looked at just plants and that kind of thing, and I would be like well we can look at the medicinal uses of plants we can look at how they grow... (Sam)	E23
		Organizational skills	I was also doing the most of the writing because, something I found funny is that they found my handwriting nice, which I've never heard in my life. So I was like, "Oh, cool." But, um, well, I wanted to, like I said, I wanted to sort of be a facilitator, like and keep everything organized. So that's why I took that role. (Jenny)	E24
		Inquiry-based teaching skills	Everything I'm learning in my science teaching science two is going to be really handy for applying this into context, I guess. So like, specifically right now learning is like inquiry based learning, which turns out great because I think that inquiry based learning can really be used in this context because students are really exploring something based on their interests and the best way to explore is by actually questioning and investigating it, so I feel like I can actually use my productive questions and to help students like uncover new things about the phenomenon that they're interested in. (Jenny)	E25

Table F. Recognition Categories and Themes with Representative Data Samples for Co-Investigators Mia and Anika

Broad Category	Broad Theme	Sample Code (sub-theme)	Example of Utterance Categorized in Sub-theme	Code
Position in Science Club	Self as a novice	No previous experience	I don't have any experience other than stage and like volunteering, like working with kids I think this is a great opportunity for me to like gain experience working, asking questions and all. (Anika)	F1
		Overwhelmed	I felt a bit like overwhelmed because I didn't know like how to guide and, and I didn't know what type of questions to ask either. (Anika)	F2
	Equal co-investigators	Different perspectives	It all comes down to a matter of what perspective and you can bring. Like, for me and Anika, during the conversation, she brought more of an education perspective, and I brought more of the scientific research perspective. But, you know, we both had an idea of how we want this to go together. (Mia)	F3
	Expert	Have done this many times before	Every time I kind of do some kind of outreach, I get a bit nervous going in, but once I'm there, I just kind of go with the flow and see what happens, because there's nothing to be done. There's only so much you can plan for this stuff and most of it can come down to like the types of interactions that you have with other students with the audience, in this case, students. I've volunteered for science symposiums, tabling activities, festivals, and workshops and a bunch of other things.... (Mia)	F4
Partner Recognition	Valuing of partner's science skills and expertise	How to interact with the youth	So on the first day, I didn't know really how to, like, ask questions and all, which was very challenging. But, like, I improved on the second meeting, because on the first I was mostly like observing the children's and how Mia was asking, and it's only on the second that I found that I improved. So the first day was a bit hard for me. (Anika)	F5
		Science content knowledge	She knew about the other topics, but I, like half of what the students are saying I didn't even know, but she knew. And that really helped me because she was she was able to guide. She had a lot of knowledge on science aspects. (Anika)	F6
		Ability to classify science ideas	I think she knows everything about science. And she like, like she she was, she was fine with students like doing like, a bunch of science ideas. But, so, yeah, and like she was able to manage, and like classify those ideas, which I was not able to. So yeah, in that note, I learned how to do that. (Anika)	F7
	Valuing of partner's pedagogical skills and expertise	Productive questioning skills	My partner is Mia and I really learning a lot from her. Sometimes I have a hard time to guide the students through their ideas, and I feel like she does a great job by asking productive questions and I feel like I'm really weak in asking productive questions, but I always try my best. So, she always has a bunch of question to ask them and help them think further. (Anika)	F8
		Engaging the youth	She was really strong and she knew, like, how to approach the kids. I was really like noticing, like, how, like, what type of questions she asked, so that I could like learn and, like make that happen on the second meeting (Anika)	F9
		Guiding the youth in inquiry investigations	It was really like observing and listening to Mia. Like how she, she was interacting with the kids. So, like I learned by observing her really. I also know that like, when she'll ask the questions, and like, what type of questions she'll ask them. So yeah, it was like, yeah, listening to her really helped me. (Anika)	F10
		guiding conversations with the youth	I think it helped me, having a different like discipline [as a partner] because, like, she brought in more aspects of how to guide the conversations, of how to talk in a group with, with the students. (Mia)	F11

	Role model	Engage the youth	And I really had a hard time like asking questions, like to childrens and I think this was a great opportunity for me. Cuz I saw how Mia was asking. And then I started jumping in, I started asking questions. So I think it was, I think it's, it's good, I wouldn't change anything. (Anika)	F12
		Engage partner	Like she, she didn't only do it everything by herself. Like, even if she'll, she'll try to, like engage me into it. Like, she'll pass me the marker and asked me to write it like if it's on my side. And yeah, and also like, after we'll, like once it's done, we'll be talking to each other and you know, and she'll tell me like, Oh, these you could ask such questions. And also on the second meeting she did say that I improved, which I was really happy, like asking questions and all. (Anika)	F13
	Valuing paired ISL programming	Writing on the paper/organizing student ideas	I think it was me and Anika for the most part that were actually writing because we don't want this to be kind of like, we want to figure out the same thing of it, because we, at least I know, I kind of figured that, you know, this is going to be a lot like the kids are very curious. So the web is going to be big. So I'm trying to like I'm trying to like maneuver the web so that it doesn't like blow off the table. (Mia)	F14
		Organizing the sessions together	I think for Anika and I work well together with this group of kids. We discuss right before and after about our general game plan. For example, this last week was for research. So, we knew we were going to give each child a specific focus (Mia)	F15
		Splitting the group up for discussions	And I like to think that we worked off each other well. So, for example, while I was answering maybe general questions that were thrown at us from the group, she was able to talk individually for a few minutes with the kids. And of course, maybe vice versa, like this dynamic was a bit fluid. So, the conversations were very productive and the whole group as we kind of, you know, compensated for each other and stuff like that. (Mia)	F16
		Helping when stuck with the youth	And those are very nice, like, because you can like make eye contact or, like made eye contact with Anika, you know, just like, you ask questions like, do you have a question right off question, something like that. And yeah, it helps to be able to bounce off, that bounce off each other when it comes to like, the guiding kind of questions or the ideas and stuff like that. (Mia)	F17
		Youth-centered	I feel the same, it's because it's, if it's one person doing the guiding feels very, it can feel very heavy handed, at least in my mind, that's how I go. But with two people there, it becomes more open, I think, because we can bounce off each other when it comes to ideas or, you know, ways we suggest, you know which thing to focus on the same time, it means that there are two people to be, like, that's just gonna be open with instead of one person that there might be some I feel like a bit more, you know, as kind of, I don't say authority figure, but kind of like, you know, someone other than students, students of this one person, but the two people become sort of a team kind of thing. (Mia)	F18
		More one-on-one time with youth	it's really it's useful throughout the experience like it's, it's like I said, like if it's one person like, one person who's obviously like, different in the group as in like, I'm the university students came in with all the researchers so obviously is a little different than students. Or, you know, part of the school in and you have the kind of group dynamic, like having two and two help, or two and three. Yes, three students like that helps kind of balance it out. And you get, you know, you have for the students, it's twice with the amount of people who you can bounce ideas off of the people who can help draw on stations or help focus some ideas, stuff like that (Mia)	F19
Self-Recognition	Capable to lead youth in science investigations	Research science	And I also did a few research beforehand, because like, I didn't really know about bridge that much. So and that helped the end that helped also, like observing Mia and doing a little research on like disabled people and bridges. The research was mainly for my own, like knowledge, because I didn't know like, about bridges, like, because I want to know what type of bridges there were. Like, you know, like arched and all. So yeah, it was mainly for myself to know more about the topic because if I don't know about bridge, I can't really ask them questions either. Like, it won't balance. So I had to have some knowledge. So that's why I did some research. Because I felt like they knew more than I did. (Anika)	F20

	A science person	Ah, I think she does. Because after the meeting, she said that, like I was able to ask questions like, like good questions. So I think she does [think of me as a science person]. It pushes me to like include her, like to work hard and all. Because I want her, I want her to think that way, like, throughout the project, so for sure. (Anika)	F20
Developing pedagogical skills	How to connect student ideas	like more like the questions we asked and being like, okay, like, Here you go, you're looking at this question. And then you were talking about this. So like trying to find this connection between the different rabbit holes I guess that they went down and trying to get towards, towards you know, what I need Be Kind of like scientific please field that, again, it's kind of helped us. (Mia)	F21
	Need to work on facilitation skills	But if I were to talk about like personal professional goals, I guess it would be more experience with the facilitation skills, maybe organizational skills. (Mia)	F22
		I think to be a bit more guiding. it, it's hard because like, it's supposed to be youth-led. Like, if you just keep on, keep on saying that in my mind, like, they have to, you know, see where their ideas and their minds take them and then from there (Mia)	F23
	Led the youth to choose a certain idea	I mean, we suggested it. And the thing is like, they were very excited about any one of them. So when we were asking them, like, you know, what, which one do you think we could do something for or like, create something for? And I think that yeah, I think we all worked towards the bridges (Mia)	F24

Pairing 1: Jenny and Sam

In this first section, I will present the experiences of the co-investigative pairing 1, Jenny and Sam, as they pertain to their abilities to recognize the skills and expertise of their partner and self-recognize their own skills and expertise throughout the co-investigations.

A Mutual Exchange of Competence and Recognition

Both Jenny and Sam came to this experience with little experience engaging youth in science investigations, especially youth-led investigations. Neither Sam nor Jenny came to the experience feeling prepared to handle the task on their own (E1, E3), and they shared this vulnerability with their partner, positioning themselves as novices in performing science investigations with youth (E2, E4). Jenny and Sam both expressed feeling supported by their partner's presence, specifically mentioning how they felt impressed by the other's knowledge and expertise (E5 to E9). Furthermore, they were able to mention specific skills their partner had which were particularly useful during the inquiry investigations with the youth. Jenny recognized Sam's valuable abilities to: open up new avenues of investigation (E10), explain science in accessible ways (E11, E12), and his ability to engage youth in science investigations (E13). Sam recognized Jenny's valuable youth-centred pedagogical skills (E14), experience eliciting youth's ideas (E15), and ability to facilitate youth-led inquiry investigations (E16). Both Sam and Jenny found value in the other's skill, knowledge, and expertise throughout the inquiry investigations with the youth. Sam also illustrated that the support from his partner was crucial for the success of the project: "*I wouldn't trust half the science students I know to do that alone [...] yeah, you definitely need that support from an education student (Sam, 2-502)*".

Importantly, each co-investigator in the pairing also felt that they themselves brought skills to the experience in support of the other co-investigators and the youth. Sam recognized he brought skills to support his partner in the form of being a science expert for Jenny to refer to (E17), communicating science effectively to the youth and with Jenny (E18) and that he possessed a wealth of science content knowledge the group tapped into frequently (E19). Sam felt that he supported the youth as well through his acting as their in-house science expert (E23). Jenny was also able to recognize her own expertise in supporting Sam through the youth-led science investigations through her ability to: share educational resources with Sam on how to conduct investigations with youth (E20), how to guide the youth and other pedagogical skills such as organizational skills and how to keep the youth on track (E22). Jenny recognized her expertise in organization and inquiry-based teaching pedagogical skills benefitted the youth as well (E24, E25).

To summarize, both Sam and Jenny felt that their skills and expertise had value in the partnership and were able to recognize the other's value as well. They were, therefore, able to have a mutual exchange of competence and recognition to help and support their partner through the inquiry co-investigations with the youth.

Pairing 2: Anika and Mia

In this next section, I will present the experiences of the second co-investigative pairing, Anika and Mia, as they pertain to their abilities to recognize the skills and expertise of their partner and self-recognize their own skills and expertise, throughout the co-investigations. I present first Anika's experiences in the partnerships, followed by Mia's experiences in the subsequent section.

Anika: Recognizing the Science Educator in Mia

Anika came to this ISL experience without any previous experience in ISL programming or in engaging youth in science (F1). She did not know how to interact with the youth or her co-investigator on the first day of the program, and it left her feeling overwhelmed (F2). However, she gained confidence in her abilities at the second meeting of the science club, as during the first meeting, she was able to learn how to interact with the youth by observing her partner engaging the youth (F5). Anika learned how to guide the youth in youth-led inquiry investigations by watching and learning from her partner Mia's example. She was able to recognize her partner's science skills and expertise and remarked on her impressive science content knowledge (F6) and her ability to classify science ideas (F7).

Interestingly, the qualities which Anika recognized the most in Mia were not science major-related skills, but her science pedagogical skills and expertise. She valued Mia's ability to ask productive questions (F8), engage the youth (F9), and to facilitate the youth in inquiry investigations (F10). Mia acted as a source of support during the ISL programming and served as a role model for the type of science educator Anika wanted to be. Observing Mia asking questions, made Anika more confident to join in and ask questions too (F12). Additionally, Anika felt supported by Mia in engaging the youth as Mia was sure to actively include and engage Anika (F13). Anika took particular notice of Mia's competence and skill as a science educator, rather than simply as a "science person". This is consistent as she not only has already admitted to not being interested in science herself, but also because her interests do include learning how to become a better educator. She valued Mia's ability to model how to be a teacher who engages youth in science and learned from her how to engage youth in science conversations, which was the reason she came to the ISL program in the first place.

Anika was also able to recognize her own skills she brought to the co-investigations with the youth, stating she was able to research science she didn't know between club sessions, both for the youth's benefit and for her own (F20). Additionally, she felt recognized by Mia as able to ask good questions and as a science person (F21). Furthermore, she wanted Mia to see her as a science person, so she worked hard through the co-investigations to be recognized as such.

Mia: Recognizing a Productive Partnership

While Sam, Jenny, and Anika came to the project wary of teaching science to the youth, Mia came full of confidence, despite some initial nerves on the first day. Mia already had a lot of ISL programming experience, and she knew what it should look like and how to interact with the youth. She positioned herself as a seasoned member of the ISL programming community (F4). Mia's extensive previous involvement in similar ISL programming gave her a sense of ease and comfort that the other co-investigators did not have. Despite their different backgrounds, Mia saw Anika and herself having the same role in the co-investigations with the youth – to cooperatively guide the youth. This is in great contrast to how Jenny and Sam quickly differentiated their roles into their fields of expertise. Mia, however, positioned Anika as an equal who brought a different perspective than her own (F3).

When questioned about the benefits of having Anika as her partner, Mia did not elaborate on Anika's unique educational perspective and discuss her skills and expertise, like Sam did for Jenny. Instead, Mia outlined the organizational and support benefits of having a partner to perform ISL programming, including having help to organize student ideas (F14), organize the sessions together (F15), help to split up the group for discussions (F16), and help when stuck with youth ideas (F17). Mia also saw the partnership as being beneficial for the youth as it made the co-investigations more youth-centred (F18) and allowed for more one-on-one time with the youth (F19). Only once did Mia mention Anika's skill as an educator, on how to guide the conversations with the youth, saying that her different perspective allowed Anika to bring in more aspects on how to guide the youth in inquiry investigations (F11). Essentially, while Mia did see some benefit of having an education student, Anika, as a partner, it was not Mia's focus as the benefit of the partnership as it was for Jenny and Sam's partnership. Mia was not, therefore, able to recognize her partner's expertise to the same extent that the others were able to. She was, however, able to recognize Anika as a member of a productive partnership in guiding youth-led investigations.

Mia was able to recognize herself as bringing pedagogical skills, such as how to connect student ideas (F21), but recognized she needed to work on how to facilitate youth-led inquiry (F22). She gave an example from during the investigations on how she led the youth to choose a topic which was something they could "*create something for*" (F24). This shows that Mia was impressing her views on what counts as a valid scientific inquiry on the youth, something which the other co-investigative groups did not do. Mia did reflect on it, however, and recognized her role was to support the youth in *youth-led* investigations (F23). Mia's tensions between letting the youth run the investigations and trying to make the investigations look like a certain kind of science are evident throughout her description of the co-investigations. Mia struggled with her idea of what science is, and what science looks like in this ISL programming context.

Discussion

I will now discuss the experiences of the co-investigative pairings as they pertain to their abilities to recognize the skills and expertise of their partner, in relation to the theoretical frameworks and previous literature. This recognition is of vital importance, as recognition from others, and from the self, constitutes identity work, influencing science identity development, and continued engagement in science (Carlone & Johnson, 2007). The results on self-recognition will be discussed in the following chapter (Results and Discussion Three: Identities in Science), as the self-recognition and the coming identity results cannot be discussed without the other, they are mutually constitutive. Before the discussion on partner recognition, I will first discuss how each partner positioned themselves within our community of practice, as a direct result of their previous science capital-forming experiences and perspectives of science.

Positioning in the Community of Practice

Jenny and Anika, our pre-service teachers, positioned themselves, as novices in this study's community of practice, the youth-led afterschool science club. This comes as a result of their limited experiences with science learning leaving them unaware of the "doxa" (rules and regulations) of interacting in formal science environments, such as in academic science research contexts, and in informal science contexts, such as the "field" of this study (Bourdieu, 1986). Novices in a community of practice position themselves on the periphery of a community to learn from their coparticipants the skills and knowledge necessary to gain further access to the sociocultural practices of the community (Lave & Wenger, 1991). How they will learn, what they will do and how they will view themselves in this science club will be affected by how they situate themselves within this field, as novices (Lave & Wenger, 1991).

Despite Sam's continued engagement in science and amassed science capital, Sam, too, was not aware of the doxa of interacting in this type of informal science space. Sam did not have any previous experiences in youth-led ISL contexts either. As a result, Sam also positioned himself as a novice in our community of practice. He knew he did not know how to guide the youth through inquiry investigations and stated that he had a lot to learn.

Mia, on the other hand, is unique in the pairings in that she positioned herself as an expert member in our community of practice due to her continued engagement in ISL programming contexts. Mia had a wealth of science capital which she was comfortable using and exchanging in varied science contexts, both formally and informally. Her previous experiences, too, will shape how Mia will learn, what she will do and how she will view her participation in this science club (Lave & Wenger, 1991).

Pairing 1: Jenny and Sam

I will now discuss the exchange of recognition experienced by Jenny and Sam in relation to the theoretical framework and the previous literature.

A Mutual Exchange of Recognition. Jenny came to the co-investigations positioning herself as strong at facilitating the youth in learning situations, but weak in science content knowledge. Her co-investigative partner, Sam, positioned himself as strong in science content knowledge and in need of support for guiding the youth, the opposite of Jenny. As a result of this reciprocal skill set, each partner was able to use their capital to support their participation in the community of practice and exchanged their capital for recognition from their partner. Sam received recognition from Jenny as a science person capable of communicating science in an accessible way and Jenny received recognition as a capable educator who is also a strong science learner. Additionally, they were each able to exchange their capital for more science and teacher capital, such as how to guide the youth in science investigations, something which both partners learned from each other. Similarly, Fogg-Rogers et al. (2017) also found that paired engineering ISL with youth allowed for the partners to learn from the expertise of the other. Additionally, the study found that the partnerships yielded improved confidence and perceived self-efficacy in the preservice teachers. In our study, both Sam, the undergraduate science major, and Jenny, the pre-service teacher, felt confident and capable of motivating youth in youth-led science investigations as a direct result of the support received from their partner.

Jenny and Sam's mutual recognition was made possible due to both partners being novices in this ISL context and learning the doxa of the field together, as opposed to one partner prescribing rules to the space the other would have had to follow in order to receive recognition. Jenny's science capital was amassed within an elementary science educational framework and therefore the ways in which she performed science and her views on who can participate in science, were very accepting of novices and learners. This in turn made Sam and his expertise recognizable to her. Sam, as previously discussed, was actively searching for science others outside of the expected and celebrated science attitudes and dispositions he had been encultured to value (Carlone et al, 2014): where science people, especially those in physics, are seen as academically successful, bad communicators and not very social. As a result, Sam was able to recognize Jenny not as a science person, but as an enthusiastic learner in the science context; an identity to which she is proud to receive recognition.

Additionally, Sam and Jenny became good friends throughout this experience and spoke highly of each other, each discussing how impressed they were with the other's expertise. This signals that they were able to become "meaningful scientific others" to each other within this ISL context (Carlone & Johnson, 2007). This is significant because when science capital is exchanged for recognition from significant science others in the field, it can aid in the formation and development of science identities, a vital component of continued engagement in science (Gonsalves et al., 2021). Another reason this partnership was so successful was because the partners were working *together* to engage the youth. This is reflective of Cook and Buck's (2014) study where the pre-service teacher partners found working to design projects *with* their scientist partners as an essential aspect for their movement into the community of practice, as there was mutual benefit. Both Jenny and Sam felt they mutually benefitted from the partnership, allowing for mutual sharing of competence and recognition.

Pairing 2: Anika and Mia

I will now discuss the exchange of recognition experienced by Anika and Mia in relation to the theoretical framework and the previous literature.

Recognition of Teacher Capital. Anika came to this experience desiring to be recognized as a valid member of a team, which we understood through her overall motivation for participating in this ISL project: to learn to communicate more with others. Additionally, Anika wanted to be recognized as capable of motivating the youth in science learning. As previously discussed, much of Anika's *science* capital was unrecognizable. Mia did not, therefore recognize Anika's science capital, but was able to recognize Anika as a valued member of a science facilitator team and this recognition was hugely impactful to Anika. Here, Mia recognized Anika's *teacher* capital, as someone who is helpful at guiding the youth, and Anika recognized Mia's *teacher* capital, through her skills as a science educator. There was a mutual exchange of teacher capital for recognition from both Anika and Mia.

Misrecognition of Science Capital. In addition to Anika's science capital being unrecognizable, this pairing exhibited a case of misrecognition of science capital (Avraamidou & Schwartz, 2021). Mia's extensive experience in ISL contexts resulted in familiarity with the rules and regulations (doxa) of these types of ISL spaces. Mia has been encultured to value research science above other forms of science and was, therefore, not fully able to recognize the science the youth participated in as "real science" nor to recognize the science skills and expertise of Anika in this context. Gonsalves et al. (2013) discussed how out-of-school time engagement with science allowed for limited engagement with what counts as "real science" and suggested that the refiguring of the concept of science to more expansive views takes time. This suggests that the short time frame of this study was insufficient to deconstruct Mia's encultured views on what counts as science (as research-oriented) and beliefs on who is allowed to participate in science, nor was it enough time to re-construct her views on science to be more inclusive of the science the youth performed in this study.

The science capital Anika displayed, including her dispositions, attitudes, and behaviours related to science acquired through her upbringing and experiences, were not recognizable to the types of science capital Mia's science identity projected and valued. The undergraduate science major, Mia, was looking for her pre-service teacher peer, Anika, to outwardly show the types of science, including the doxa of academic science, Mia was used to seeing in her university courses and research laboratories. Anika did not perform science in these ways for a variety of reasons, including that she has not been encultured in science in the same ways, through not pursuing science degrees, and had learned science through a very different lens: a teaching lens. This has, therefore, rendered Anika's skills and expertise related to science unrecognizable to Mia, and rendered Mia's skills and expertise related to science mostly unrecognizable to Anika as well. While Anika was able to see Mia had a lot of science content knowledge, her skills relating to science were not recognizable to Anika. Anika recognized instead Mia's *teacher* capital, in the form of asking questions to the youth and guiding the youth; (science) teacher capital which Anika has been encultured to value.

These results reflect Thompson & Jensen-Ryan's (2018) work, which discussed recognition as a reflection of what you expected to see and what cultural capital the other is performing. Their study found that students are often misrecognized by faculty members due to outwardly showing cultural capital that goes against the habitus of science the faculty expected to see. Avraamidou and Schwartz (2021) discussed misrecognition and described clearly that it is important to conduct explorations of how certain people are not recognized in science, due to the politics of recognition, and how it plays out in the formation of physics identities and engagement with science, citing this exploration as the first step understanding the underrepresentation of women in physics. The findings of this study contribute towards this goal.

While not explicitly stated, these results do also reflect the findings of Shanahan and Bechtel (2020) who found that pre-service teachers are being positioned as "lesser than" in terms of expertise. It reflects as well Cook and Buck's (2014) work where educational expertise is positioned as inferior to the "real work" of scientists. Mia's conflict around what counts as science, however, did not affect Anika's perception of the experience, as Anika was able to recognize Mia's teacher capital and successfully exchanged her own teacher capital for recognition as a good partner in science co-investigations from Mia, something that was all but inconceivable to her before her participation in the study.

Conversely to the other coinvestigators, Mia came to this ISL experience positioning herself as a seasoned member of this community of practice. She was able to use her science capital and teacher capital to support her engagement in this ISL context and to exchange her teacher capital for recognition from Anika as someone who communicates science effectively, and who engages youth in science investigations. While this does support her continued engagement in ISL contexts, it was not new for Mia to receive recognition as this type of person. Additionally, Anika is a new member of the community of practice and only engaging in the community peripherally, as opposed to the more central membership of Mia in these ISL communities. This, coupled with both Mia and Anika's misrecognition of each other's skills and expertise, made Anika's recognition of Mia's skills and expertise as a (science) teacher unrecognizable to Mia. That is, it did not affect how Mia reflected on herself as someone who engages in science communication and in ISL contexts.

Summary

Jenny and Sam came to their co-investigative pairings positioning themselves as novices in this ISL context. Jenny's science habitus valued learning and she was therefore able to recognize Sam's science skills and expertise. Additionally, Jenny was able to exchange her own teacher capital for science capital and recognition as a science learner. Sam was actively looking outside of his expected science habitus, and was, therefore, able to recognize Jenny as a strong science learner. Sam was also able to exchange his own science capital for both teacher capital, on how to guide the youth, and for recognition from Jenny as a science person capable of communicating science in an accessible way.

Anika and Mia, on the other hand, were not able to recognize each other's science capital due to opposing habitus of science and subsequent misrecognition of each other's science capital. Mia uniquely positioned herself as an expert in this community of practice, compared to Anika's novice status. This led to Anika being able to exchange her teacher capital for recognition as someone who is a useful co-investigator and capable of guiding the youth in science investigations, further reinforcing her membership in this community of practice. Mia, on the other hand, did not receive such a benefit from Anika's recognition. Mia's struggle over what counts as "real science" created tensions and left her unable to recognize Anika's and the youth's engagement in science throughout these co-investigations as legitimate science participation.

Results and Discussion Three: Identities in Science

The following chapter will explore the themes found from the analysis of the data describing the pre-service teachers' and undergraduate science majors' experiences in their pairings as they relate to their science identities. The findings have been summarized into distinct themes based on how they addressed the following research question: *What are the science identity impacts of preservice teachers and undergraduate science majors engaging in youth-led ISL?* The presentation of the thematic results will be followed by a discussion exploring the emergent themes in relation to the theoretical framework and situating the results within previous literature.

The data presented in the following chapter will reference table G: Science identity impacts with representative data samples for all co-investigators. This table serves to present examples of raw data excerpts from each co-investigator, as well as to demonstrate the thematic coding I attached to each excerpt during thematic analysis. Throughout the results sections to follow, I will reference the data found in each row of this table using the "code" value found in the rightmost column of the table. For example, (G1) will refer to table G, row 1, where the rightmost value is code 'G1' for ease of finding the correct value.

Table G. Science Identity Impacts with Representative Data Samples for All Co-Investigators.

Co-investigator	Broad Category	Broad theme	Sub-Theme	Example of Utterance Categorized in Sub-Theme	Code
Anika	Expanding Identity	Gain	Experience guiding youth in science learning	I don’t know for the science students, but for the education students I think it's a nice way to, because like I don't have any experience other than stage and, like, volunteering, like, working with kids I think this is a great opportunity for me to, like, gain experience and, like, working, asking questions and all. (Anika)	G1
			Experience with youth	For education students especially, this is a great opportunity. Because, like, I don't really work with children apart from the field experience, and this is a great option for me to practice every, like, everything we've learned in class (Anika)	G2
		Science identity	Wanted partner to see her as one	It pushes me to like include her, like to work hard and all. Because I want her, I want her to think that way, like, throughout the project, so for sure. (Anika)	G3
			Partner recognition	Ah, I think she does. Because after the meeting, she said that, like, I was able to ask questions like, like, good questions. So, I think she does [think of me as a science person] (Anika).	G4
			Expanded definition	Like to that I will add that it's someone who like who executes. Like who doesn't really, who doesn't only think about science, but actually like, works on it and like builds something. (Anika)	G5
		Expanded science futures	Teacher who can engage youth in enjoyable science	I think science is a fun topic. And also, having them plan their science like project is even more interesting for them. So I'll definitely incorporate that into my classroom, like having them execute everything. And yeah, so like having them, like physically be engaged with the project. Yeah, like I won't be the teacher standing in front and doing the experiment, where they'll be taking notes. I think that's not helpful for them. (Anika)	G6
Sam	Expanding Identity	Gain	Experience/ knowledge peers don’t understand or value	I just want to say that there’s this idea in my, within like the science students I’ve met that, like, teaching isn’t as valuable, that education isn’t the, like, the best pursuit. That of course you can become a science teacher but the people that become science teachers are like failed scientists, like people that didn’t perform well. And I think doing this kind of thing, with specifically children, being like, you are teaching science not because you’re bad at science but because you want to make someone better at science. And that kind of thing, and just kind of changing that mentality was so important (Sam)	G7
			Pedagogical skills	I obviously did learn so much from Laurie and I think some of the, like, the science students that are a little bit more haughty in their science knowledge would, like, benefit a lot more from having like, “this is how you teach children. This is how youths learn, this is how you got to work with them”. You can’t just ramble off a dozen equations and expect them to follow along because most people can’t do that. (Sam)	G8
		Science identity	Expanded view of science as multidisciplinary	I think it highlighted a lot of overlap that, between different science subjects and stuff like that. Working with the kids and trying to find those compromises and stuff. Because you don’t often see, I’ve known this was like an issue and that kind of thing, but in sciences you’re in a chemistry building, you’re in a physics building that kind of thing. You don’t see a lot of that like cooperation and or like a group of people from different backgrounds working together. But that’s a common critique of the sciences. And so I’ve seen these kids who are so broad in their science interests that they had their own little like meeting of the minds. You couldn’t pin them down to one science but each one of them was bringing	G9

				something different and so that was interesting to see that cooperation collaboration between different fields of science. Not just inside their own heads but amongst each other. (Sam)	
			A science person in all contexts	After our first interview when you asked that I was like, well I don't know, because compared to some of my science friends I feel like I'm less so, because I'm doing these science outreach programs and I took the science communications courses, I'm like less [of a science person].[...] but then through talking to Laurie and the kids, it was I'm like comparing myself to the far end of the spectrum and that doesn't mean I'm not still very much on that side of the spectrum kind of thing. (Sam)	G10
		Expanded science futures	Use of science communication skills	This was an opportunity for me to not only use the science communication skills that I thought were interesting but also to, like, work with children in a way that I didn't think I ever would. I also was never one to be like "oh I want to be a physics teacher", still probably not going to. But now I also would love to do more of these kinds of things. (Sam)	G11
Jenny	Supported Identity	Gain	Recognition as a learner	Honestly, no. Just straight up, no. I don't think so. Okay, I think they would describe Sam, but not me. I think they would describe me as someone who likes to learn though, because I think I brought my enthusiasm to the table. (Jenny)	G12
		Science identity	Science learner her teacher secret weapon	I used to think I wouldn't be capable of teaching science because I'm not very good at it. And I always used to view myself as a student of science, like a, like a elementary student themselves. But I realized that that's actually like a gift. Like to actually see yourself as a student. It's like, you can actually really put yourself in their shoes and you can actually join the students in the process of learning. So I feel like that could be like, kind of like my secret weapon or something for a teacher.. it'd be. I feel like it'd be fun because they would see a teacher that's really enthusiastic, excited to learn about the thing, because they're also learning about the thing with the students. (Jenny)	G13
		Science futures	Now comfortable learning alongside her students	I think the one thing I have to change is maybe just doing a bit more research prior to embarking on the investigation, just so that I can have like a bit more of that repertoire that that students might need, may need if they have questions. But I think it's okay to just go in and learn along with the student. (Jenny)	G14
Mia	Identity in conflict	Gain	New perspective	Because it makes you, it makes you better. Like as a science student, because you have it gives you a new perspective. Of Like, what? How your research is going to look to everything else. Like, it's important to do the research and all that other stuff, but also to communicate it effectively. (Mia)	G15
		Resist	Open-ended-ness of youth-led inquiry	I like it a lot. I like the, like, I like it when its there for ideas that we can be exploring. But I think it's not something that we've done like, it needs to be done in this kind of like week by week kind of project structure. There needs to be some kind of guiding like, or, yeah, the Code of Conduct there's like, we need to be there to have this you know, as an open towards like, one thing to focus on, because you've led up to that inquiry based learning There we go. Yeah. It, it opens up the door to a lot of different things to explore. And it's so cool. But at the same time, like, if you're working on a schedule, that means that you have to take something and kind of stick with it. Because then if you take one, then that'll open up more doors in that specific area and then pick another thing and it opens up more doors. Like it's great. (Mia)	G16
		Science identity	Non-research-oriented science person	you can be a science person, you can be very into like the science behind things and not be a scientist. I guess a scientist is more like, going through with the scientific methods actually try and answer a question that goes towards more research. (Mia)	G17
		Science futures	Science communication	I want to do something with science outreach, find something like I did writing for you. And I do want to try and get back into writing. But outreach is always like, I have a lot of experiences and like experience	G18

		I can put on my resume and that people can see that it's something like I can demonstrate and show that that I do well or relatively well or at least, you know, trying, again show how like my methodology when it comes to connecting students and who might come into the event. (Mia)	
	ISL contexts as reinforcing her societal view of science	Little bit context thing. I mean, it's something that I have been thinking about since I started University is just like, you know, how does this research fit in the social setting? Or like, how, how is it influenced by the time around us? One of the things like I know I've said before, it science is not a monolith. It's not just the big, kind of like, inescapable thing in the sky that stands alone. It's always affected by the society or surrounds the field, and the people who are in the fields. And then this [study's ISL programming] experience, you see this happening from like, the youth, like the people who are going to be most affected because they have to grow up in a world where about the science that affects them? like whatever happens in that field effect will affect them the longest as they have to grow up with it. (Mia)	G19

The Landscape of Becoming

In the following four sections, I will present the results surrounding the science identity impacts of engaging in this paired ISL experience. The data is organized around 3 emergent themes: expanding identity (Anika and Sam), supported identity (Jenny), and identity in conflict (Mia). As a reminder, following Avraamidou (2020), identity is not a fixed construct but instead a continual and intersectional "landscape of becoming" where recognition and emotions are core features. That is, where previous experiences and perspectives, coupled with recognition from the self and from others, all interplay as the individual processes what they *mean* to them, giving further meaning to the "process of becoming". As a result, this chapter's results and subsequent discussion will take into account the previous two chapters as we open a window into the science identity landscapes of our co-investigators.

Expanding Identity: Anika

Anika positioned participating in this ISL experience as an opportunity for her to gain confidence interacting with others, and also to gain valuable experience with youth and with using educational theory and skills learned in her university courses (G1). She viewed it as an opportunity to practice everything she's been learning (G2). As a result, Anika found value in this learning experience as it made her a better educator. While she did not see herself as a science person, she wanted Mia to see her as one (G3). This made her work hard and study to prepare for the group meetings (G4). Anika was trying out being a "science person" during the youth-led investigations to see how it felt, and to see if she could be recognized as such. She even went a step further and added to her definition of what a science person is:

> *I will add that it's someone who, like, who executes. Like who doesn't really, who doesn't only think about science, but actually like, works on it and like builds something. (G5)*

Anika is expanding her views on what science is and who can participate in science. While she did not explicitly say she was a science person now, her newly expanded definition is one in which someone who is working towards understanding and learning how to teach science, like herself, could conceivably fit. Anika also expressed wanting to follow a similar model to the youth-led investigations in her future classroom:

> *I think science is a fun topic. And also, having them plan their science like project is even more interesting for them. So I'll definitely incorporate that into my classroom, like having them execute everything. And yeah, so like having them, like physically be engaged with the project. Yeah, like I won't be the teacher standing in front and doing the experiment, where they'll be taking notes. I think that's not helpful for them. (G6)*

Anika uses positive words to describe science for the youth, including "fun" and "interesting". This is a dramatic difference from how she previously described science. She is learning about how to be the type of science educator she wants to be from Mia: one who engages youth in fun science learning.

Expanding Identity: Sam

Sam came to this opportunity knowing that it was an experience that his physics peers would not understand; it was far outside of the usual learning experiences for physics students. Sam feels it is important to change the mentality many science students have that educational pursuits are not of value (G7). He feels that participating in these types of ISL opportunities with youth is one method to combat those beliefs. After participating in the experience, Sam positioned himself as having learned a lot about education in ways that his peers could benefit from, such as learning how to teach youth and communicate science accessibly (G8). He now sees the value of educational theory in ways which he didn't before this experience, thanks to Jenny. Additionally, Sam positions ISL programming with youth as an opportunity to use his science communication skills in meaningful ways, which he would like to continue to do in his future science career (G9).

As a result of his interactions with Jenny and with the youth, the experience has helped Sam to expand his view of science in new, multidisciplinary ways: *I think it highlighted a lot of overlap between different science subjects and stuff like that.* Through working with the youth, he saw that science often stands alone in university, all separated into different buildings on campus (G9). He saw the youth as existing in a multidisciplinary plane of science he hadn't seen before:

> *You couldn't pin them down to one science but each one of them was bringing something different and so that was interesting to see that cooperation, collaboration between different fields of science. Not just inside their own heads but amongst each other. (Sam, Int2, 804)*

This redefinition of science fits more accordingly with Sam's view of himself as a "non-science, science person" or as a science person with diverse interests and skills. Here, Sam is expanding his science identity to fit the ways he sees himself, as a certain type of person who engages in science, a multidisciplinary science person. Sam states that he is indeed still a science person, despite his continued work in avenues less appreciated by other science people (G10); this engagement no longer makes his science identity waver. As a result of his engagement in this ISL experience, Sam has expanded his view of what counts as science and what people who engage in science can do.

Supported Identity: Jenny

Jenny positioned herself as a "strong science learner", not a science person, upon entering this experience. She received lots of recognition as a "science learner" from Sam and her professor who recommended her for this project, but most importantly from herself. When asked if she thought the youth would think of her as a science person, Jenny responded with a resounding *no*. However, she followed up with: *I think they would describe me as someone who likes to learn though, because I think I brought my enthusiasm to the table.* (G12). Jenny maintains she is not a science person and does not think she will be recognized as such. Interestingly, however, she does believe she would be recognized by others as an enthusiastic learner of science. Jenny has a positive view of herself as a science learner and in how that relates to her future teaching career. She sees herself as capable of teaching science and feels that positioning herself as a learner is her "secret weapon" as a teacher, it makes her better at her job (G13). Jenny went from being very wary of the subject of science to feeling capable of facilitating youth-led science investigations in her future teaching career: *I think it's okay to just go in and learn along with the students* (G14). Jenny's experience co-investigating youth-led science investigations supported her identity development as a "strong science learner" and has allowed her to gain confidence in her role as a teacher capable of engaging youth in science learning.

Identity in Conflict: Mia

Mia positioned this experience as one of the many ISL programming experiences she has engaged in. She found these types of experiences to bring about new perspectives valuable for science majors to engage with to learn to communicate their science more effectively. This study's ISL context, however, was new to her in that it was designed to be youth-led, and her role was to co-investigate with the youth and her partner, not to be the bringer of knowledge. As discussed above, Mia found letting the youth guide the process to be difficult but understood the importance of it. She found letting the investigations be so open-ended, with many avenues of investigation at once, particularly challenging and resisted letting the youth guide the process (G16). Mia struggled with what she believes science and scientific inquiry to be, and what she is seeing occur in this informal science context. She further shows this struggle when she adds to her definition of a science person:

> *you can be a science person, you can be very into, like, the science behind things and not be a scientist. I guess a scientist is more, like, going through with the scientific methods and actually try to answer a question that goes towards more research* (G17).

Mia's comment demonstrates that she views there to be two different realms of science, an academic one and a more informal one, a view in which you can only be a scientist if you are formally trying to answer research questions. Again, the struggle is evident in the fact that her definition appears to align with the idea that the youth were being scientists in their investigations, but, as above, Mia described the youth as leading very open-ended investigations without ever really focusing on one thing. As a result, she viewed her role to focus the youth's investigations to more concrete questions. Mia's struggle with what science inquiry "should" look like creates tensions within her interactions with the youth.

Mia's definition of a science person and a scientist does, however, align with how she described a science person at the beginning of this experience: as multifaceted and engaged in both informal and formal science. Mia maintains that she is not a scientist, despite being a molecular biology major in university, perhaps because she wishes to pursue a non-research-oriented science communications career. Again, this illustrates Mia's inner conflict with what science is, and what science should look like, especially in regard to being "official", i.e. being a "scientist". This also is reflected in her previous experiences in high school, where Mia felt the most official and important in science when she was working at a laboratory bench or doing high-level DNA sequencing. While Mia is in some ways struggling to place and understand the type of science that takes place in these ISL contexts, she still hails the experiences as integral to giving perspective on science as influenced by time and its place in society (G19). Mia finds ISL experiences to be empowering and future-oriented as she can directly see this multidisciplinary science acted out by the youth and can imagine its future impacts.

Discussion

In this next section, I will discuss the science identity impacts of the paired pre-service teachers and undergraduate science majors engaging in youth-led science investigations, in relation to the previous literature and theoretical frameworks. Broadly, these impacts have been categorized into 3 themes: supported identity (Jenny), expanded identity (Sam and Anika) and identity in conflict (Mia), and rely heavily on the results and discussions of the previous two chapters: previous science capital building experiences and perspectives, and mutual (mis)recognition.

Supported Identity: Jenny

As previously seen in Douglass' (2023) study, interactions with science others in ISL contexts can be exhilarating and empowering for pre-service teachers. Jenny, most especially, had a renewed sense of purpose in relation to science, her future career and herself after her interactions with Sam. What she once viewed as a deficit, being a novice in science, was transformed into a positive; being a science learner is now her "secret weapon" as a teacher, as she described it. The low-stakes practice environment afforded by our science club allowed Jenny the opportunity to try out her identity as a science learner in the ISL teaching context (Luehmann, 2007). Throughout this experience, Jenny was actively trying to exchange her teacher capital in the form of her embodying the process of inquiry, and her resources on how youth learn, for recognition as a strong science learner. The recognition she received, from her partner, from the youth, and from herself, functioned as identity development opportunities and allowed her to understand, interpret, and recognize herself as a "certain kind of teacher" (Luehmann, 2007). This opportunity for Jenny to engage in reform-minded science teaching, as an inquiry-based teacher, was impactful for her as it came with many opportunities to engage in reflection and self-recognition, as well as to receive recognition from a valued science other, Sam. Engaging with her partner in this ISL context, therefore, powerfully impacted Jenny's beliefs about herself and her ability to engage youth in science. These findings align with previous studies that found that engaging in ISL contexts can be transformative for pre-service teachers as it can lead to a marked change in how they see themselves as learners and teachers (Rahm et al., 2016) and can support the development of "reform-minded science teaching identities" (Avraamidou, 2014).

Expanded Identity: Sam

At the beginning of this experience, Sam discussed how his science identity fluctuated over time depending on the context. This is reflective of how the value of science capital can fluctuate depending on the field in which it is used and exchanged (DeWitt et al., 2016). Different fields prescribe unique rules (doxa) regarding exchange and use value, shaping the recognition and utilization of science capital within those spaces. Interestingly, Sam felt most like a science person when he was able to use and exchange his science capital for recognition as a science person from arts people, and less like a science person when using his capital with his physics peers. This is because Sam does not fit within his encultured view of science and the expected image of a physics major. Throughout engaging in discussions and science learning with Jenny and the youth, however, Sam was able to exchange his science capital for a new kind of capital for him: teacher capital. Sam had never been in an ISL field like this, and so he referred to Jenny for support and as a source for learning about science education and how to guide the youth. He was then able to use that accrued capital to support his participation in the

ISL context by engaging the youth more effectively. Most importantly, he was able to exchange this capital for *self*-recognition as a science person who engages youth in informal science investigations. This self-recognition was important as it was a science context in which he knew his peers did not value, but also in a science context in which he felt like he belonged as a science person himself. As a result, Sam was able to expand his definition of what being a science person is and what science can look like. Sam was impressed at the multidisciplinary science the youth performed, as it looked nothing like the science field he knew so well, with "different" sciences being contained in their respective buildings and courses on campus. This experience provided Sam, the science major, with opportunities to experience different ways of doing science and of being a person who does science. It allowed for different avenues of being a person who does science to emerge, similar to what was found to occur with pre-service teachers in previous literature (Adams & Gupta, 2017b; Luehmann, 2007; Rahm et al., 2016).

Expanded Identity: Anika

Throughout this experience, Anika exchanged her recognition from Mia as a competent partner and the recognition from herself as a teacher who can engage youth in science learning, into identity work, allowing her to render possible a new science future for herself as an educator. Anika was trying out being an educator who can motivate science learning *and* enjoyment in science (Harlow, 2012); a newly emerging pedagogical imaginary for herself (Adams & Gupta, 2017). Anika learned about how to be a science educator from Mia and used this gained teacher capital to support her engagement in ISL contexts. That is, the gained teacher capital allowed Anika to be able to imagine the new role she would like to fill as a future teacher: one who engages youth in enjoyable science learning (Adams & Gupta, 2017). Avraamidou (2015) found that through informal learning-to-teach science experiences, pre-service teachers were able to develop positive orientations towards science and science teaching. Anika reflected this when she discussed science learning for her future students as “fun” and “interesting”, demonstrating she had gained positive orientations towards what learning science can be as a result of her participation in this experience. Experiencing success at facilitating the youth in enjoyable science learning through this project, was integral for Anika being able to see herself as *able* to successfully motivate enjoyable science learning in her future classroom (Harlow, 2012).

Identity in Conflict: Mia

Throughout her life, Mia experienced many positive opportunities to be seen, recognized and supported as an insider to science (Carlone & Johnson, 2007). She positioned science as a natural choice for her but subscribed to the belief that being a scientist requires elements of discipline and hard work, echoing the sentiments of the undergraduate science majors in previous studies who also believed that success in elite science fields is due to hard work and motivation (Cech & Blair-Loy, 2010; Gonsalves et al., 2021). Just like Gonsalves et al (2021), I see these two narratives, that science is a “natural choice” and takes “hard work”, as sitting in conflict with one another. Gonsalves et al (2021) discussed that science capital accrued by science majors only prepared them for “one way” of being a scientist – as difficult, hardworking, and isolated – which can cause conflict in those with insufficient science capital (2021, p. 31). While Mia has sufficient science capital, her inability to view herself as a scientist, as she is not pursuing a research-oriented career with her molecular biology degree, signals her internal struggle with breaking away from the expected dispositions, attitudes, and behaviours related to engagement in science that she has been encultured to value. Mia further highlighted this inner conflict in her definition of a science person, which was more open-ended and congruent with a haphazard engagement with science, as opposed to a scientist’s rigorous and focused work. Additionally, while the recognition of her partner was not impactful to Mia, what was impactful was the youth-led component of the science investigations. Mia struggled to place the kind of science she saw performed by the youth and what she believes counts as “real science”. Engaging in ISL contexts has put Mia in a state of “disequilibrium” (Spector et al., 2020) and challenged her in her beliefs about science and science learning (Clarke-Vivier & Bard, 2016). While this, according to previous literature, has hailed to be an opportunity for reflection on one’s own place and practice in science (Clarke-Vivier & Bard, 2016), Mia did not have enough time to reflect upon and experience this disequilibrium due to the project being cut short. Again, as Gonsalves et al. (2013) previously discussed, re-figuring the world of what can be “real science” takes time and requires more consistent engagement in the context which challenges your beliefs, such as the context within youth-led inquiry investigations for Mia.

Summary

The paired model of youth-led science inquiry co-investigations, allowed for science identity work, in the form of recognition work, to be performed by our pre-service teachers and undergraduate science majors. These identity impacts came in the form of; *supporting* budding science identities in Jenny as a science learner, *expanding* science identities in Anika as a capable science educator and in Sam through expanding his idea of what counts as science and who can participate in science, and in *creating conflict* in established science identities in Mia, who viewed the science the youth performed as in opposition to the “real science” of scientists.

Conclusion

In this chapter, I will provide a summary of my research beginning with an overview of the study's objectives. I will briefly summarize the literature to which this work joins the conversation and then review the main findings of this study and address its implications. Finally, I will outline the limitations and possible future research directions on this topic.

Objective

Undergraduate science majors are participating in ISL programming contexts with little pedagogical support (Renaud et al., 2006) and pre-service teachers are leaving their teacher preparation courses with little confidence in their ability to teach science (Avraamidou, 2013). A paired ISL model was developed to help support each other's learning using their reciprocal skills sets following Fogg-Roger et al.'s (2017) study on paired engineering ISL programming with youth. The overall aim was to support undergraduate science majors and pre-service teachers in their participation in ISL contexts with youth and to support their development of positive science identities. This study's goal was to fill the gap in undergraduate and pre-service teacher research surrounding paired ISL and to discuss the identity impacts surrounding these partnerships through a thorough examination of the previous experiences they bring to co-perform youth-led ISL, their ability to recognize each other's (and their own) expertise, and the science identity impacts of the partnerships.

Literature Review

Previous work on pre-service teachers engaging in ISL contexts motivated it as a way for pre-service teachers to put theory to practice and to supplement gaps in teacher education university programs (Macdonald, 2010; Marttinen et al., 2020). Importantly, ISL contexts have been found to profoundly impact pre-service teachers' identities by fostering increased self-efficacy in science teaching and facilitating ontological shifts in their perceived teaching roles (Avraamidou, 2015; Douglass, 2023; Luehmann, 2007; Rahm et al., 2016). Recognition work within ISL contexts supports transformative identity development, encouraging positive orientations towards science teaching and supporting the development of “reform-minded teaching identities (Adams & Gupta, 2017b).

Undergraduate science majors are participating in ISL programs to gain skills for future careers, help students, explore teaching interests, and increase their scientific knowledge (Carpenter, 2015; Fogg-Rogers et al., 2017). Although the benefits of engaging in ISL are well-documented, the identity impacts on undergraduates are not well-researched (Carpenter, 2015; Ferreira, 2007). Evidence suggests that engaging in ISL contexts can bring about changes in attitudes and beliefs about science, shaping their perspectives on teaching science (Cavalcante & Gonsalves, 2021), allowing for different avenues of being a scientist (Gonsalves et al., 2021) and impacting professional identities, influencing career trajectories (Laursen et al., 2012).

Fogg-Rogers et al. (2017) paired pre-service teachers and engineering students leading to enhanced confidence and science self-efficacy for pre-service teachers. However, challenges in recognizing pre-service teacher expertise were observed in some similar partnership models (Cook & Buck, 2014; Shanahan & Bechtel, 2020). This study aimed to address these issues by placing pre-service teachers and science majors in an afterschool science club, to level out the power imbalance, and sought to explore the identity impacts of such pairings, filling the gap in the literature.

Review of Findings

Pre-service teachers and undergraduate science majors brought with them a wealth of science and teacher capital resources to co-perform youth-led science investigations. Jenny and Anika, the pre-service teacher co-investigators, had fewer previous experiences with science but had a wealth of newfound learning and feelings of agency surrounding science from their recently completed university teaching elementary science methods courses. Their undergraduate science major counterparts, Sam and Mia, brought with them a multitude of diverse previous science experiences and positive orientations toward science. Mia, uniquely, had extensive previous experience in ISL contexts.

One pre-service teacher and undergraduate science major pairing, Jenny and Sam, was able to share in a mutual exchange of competence and recognition, each able to see and value the other's expertise and hail it as integral to supporting them throughout the co-investigations. The other pairing, Mia and Anika, misrecognized each other's expertise due to socially engrained dispositions of what counts as science. Despite this, they were able to share in recognizing each other's teacher capital, leaving Mia feeling supported by the organizational skills of Anika. Anika, Mia's pre-service teacher partner, was able to recognize the science educator in Mia and felt very supported in her pedagogical development as a result.

The identity impacts of these parings were organized into three categories: supported identity (Jenny), expanding identity (Anika and Sam), and identity in conflict (Mia). Jenny's identity as a strong science learner was renegotiated into a positive which subsequently well supported her identity, through her learning alongside Sam throughout this experience. Sam's definitions of what science is and what a science person can be were expanded to better include himself as a diverse person in sciences, after learning about educational theory with Jenny. Anika's identity expanded from not at all being a science person, to being an educator who can successfully engage youth in enjoyable science learning as a result of the positive teacher capital recognition and support she received from Mia throughout their partnership. Finally, Mia entered a state of disequilibrium as a result of the new types of science she experienced from the youth-led investigations being in conflict with the type of research-oriented sciences she valued from scientists. Overall, this project and its paired model of ISL with youth led to transformative changes in the science identities of pre-service teachers and undergraduate science majors.

Implications: The Importance of Support and Suggestions for Change

After having experienced the positive science identity impacts on the undergraduate science majors and pre-service teachers as a result of their participation in this paired model of ISL with youth, I call upon future university-community partnerships to model their ISL programming similarly. Bringing together the different perspectives of undergraduate science majors and pre-service teachers encourages not only reciprocal learning but also a mutual exchange of recognition, vital for their continued engagement in ISL contexts. The undergraduate science majors were able to mentor the pre-service teachers in the science content, while the preservice teachers supported the science majors' pedagogical learning. Having peers and mentors in their collective areas of learning can lead to opportunities for recognition of their skills and expertise, constituting identity work, and subsequently supporting their development of positive science identities. Importantly, the science majors in this study had strong science identities *and* were able to identify mentors and friends who supported them throughout their science engagement journeys, while the pre-service teachers were unable to identify such influences. Future work should focus on the relationship-building aspect of this model. I suggest including more structured reflection and discussion time between partners to debrief and discuss their learnings after each session as one way to support their relationship development.

Finally, I suggest this model of paired ISL engagement with youth be an opportunity to dismantle the prevalent notion amongst scientists and undergraduate science majors that education is “lesser than” the work of scientists as discussed by Sam (Cook & Buck, 2014; Shanahan & Bechtel, 2020). Sam hailed this experience as eye-opening to himself, in terms of both pedagogical skills and educational theory. This model has not only the ability to introduce undergraduate science majors to new perspectives on education, but it also affords the opportunity for pre-service teachers to experience agency in science learning. Here, pre-service teachers are positioned as also being sources of support for science majors throughout the experience, not only being the ones with something to learn. This, along with relationship building over time, can help to disrupt the imbalance of power felt in previous research (Cook & Buck, 2014; Shanahan & Bechtel, 2020).

Situating the Research and Future Work

This study joins the literature conversations surrounding science capital and science identity of undergraduate science majors, pre-service teachers and paired ISL programming with youth. It aims to fill the gap discussed in the literature surrounding paired undergraduate science majors and pre-service teachers co-performing youth-led science investigations. Additionally, it joins the small body of research discussing science capital and science identity frameworks of undergraduate science majors engaging in ISL contexts and the larger body of work on pre-service teachers engaging in ISL contexts.

This work serves to start the discussion on the interplay between science capital and teacher capital in the development of science identities in paired ISL contexts. My research demonstrates that pairing pre-service teachers and undergraduate science majors to co-perform ISL with youth can help support both parties in their science identity development and open new avenues of being a science person, in addition to new ways of thinking about science. Future university-community partnerships might consider the benefits of modelling their ISL programming with youth after this study's framework to help support both undergraduate science majors and pre-service teachers in their future practices. My insights around recognition and (mis) recognition highlight the importance of engaging these groups in joint work for longer periods of time to allow for relationship building in the community of practice, and to provide many opportunities for discussions and (self)reflection. Future work might consider engaging the pre-service teachers and undergraduate science majors in workshops about capital (such as the science capital teaching approach) with partners, to emphasize the science capital of youth, but also to aid in the recognition of the important forms of capital that their co-investigators bring to the pairing. The findings of this study could be used as a stepping stone in designing future teacher and scientist preparation courses at the university level, that allow for collaboration and cooperation, vital components attributed to this study's success.

Limitations

The methodological limitations of this research project are essential to consider when interpreting its findings. First and foremost, researchers inevitably bring their own biases and perspectives to the research process, which can influence data collection and analysis (Johnson, 1997). Our continuous presence throughout the co-investigations, interviews and analysis, cannot be ignored as a potential source of bias. To maximize transparency, some of my potential sources of bias come from my point of view as a cis-gendered, white, middle-class Canadian female who experienced success in science education. These factors influence how I approach this research study, the data co-generation, and analyses. To help reduce these areas of bias, I, the researcher, have ensured to analyze the data separately and then come together with my research team to review and consolidate ideas and discuss inconsistencies. Additionally, the co-investigator participants reviewed the researcher's interpretations to ensure that their original meanings were maintained.

Secondly, the COVID-19 lockdown unexpectedly curtailed this research project during Week 5, disrupting the intended timeline. Had the experience reached its full conclusion, it might have yielded more comprehensive insights into the impacts on the co-investigators and their reflections. As previously discussed, more time may have allowed for less misrecognition. Unfortunately, the early conclusion of the science club resulted in incomplete data collection, specifically with the missing intended third video diary and the inability of participants to witness the full fruition of their investigative projects with the youth. Regardless of the incomplete data set, however, the co-investigator participants still had important insights on their experiences to share and their stories are worth telling.

Finally, the limitation of a small sample size prevents generalizations from being drawn from the findings (Schreier, 2018). The experiences and sentiments shared by the participants are unique to them, and, by extension, to this particular case study. However, this data can serve as a rich resource for characterizing the participants' experiences and can inform future ISL endeavours, offering valuable insights into the complexities of paired learning in youth-led science inquiry experiences.

Summary

Following the work of Fogg Rogers et al. (2017) on paired engineering ISL with youth, this work aimed to explore the paired pre-service teacher and undergraduate science major model of youth-led science investigations. Pre-service teachers brought with them little science capital, but a wealth of teacher capital, while undergraduate science majors brought the opposite. These reciprocal skill sets allowed for mutual recognition of expertise and shared learning. It also allowed for discussion of socially engrained views and dispositions hindering the recognition of the pre-service teacher's expertise from the undergraduate science majors, a phenomenon which has been previously seen in the literature (Cook & Buck, 2014; Shanahan & Bechtel, 2020).

Regardless, transformational change was observed in all participants, leading to science identities which were supported, expanded or in-conflict in light of this experience. This work addressed the gap in the literature of paired pre-service teachers and undergraduate science majors in ISL contexts and adds to the small body of work on science identity and undergraduate science majors. This work also serves to begin the conversation on the identity impacts of the paired ISL model with youth. Future work should explore this paired model over a longer time frame and explore the interplay between recognition and feelings of belonging as identity work as a result of these mentoring relationships, an identified gap in the literature.

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Appendices

Appendix A: Benefits of Engaging in ISL Programming

Table 1: Benefits of pre-service teachers engaging in ISL programming.

Category	PST Benefits of ISL...	Literature
Science Related Attitudes and Experiences	Positive future-thinking	(Douglass, 2023)
	Positive feelings about science (& less content dread)	(Douglass, 2023; Spector et al., 2020)
	Increased science and science teaching self-efficacy	(Douglass, 2023; Fogg-Rogers et al., 2017; Harlow, 2012; Kang & Martin, 2018)
	Felt excitement and enjoyment	(Douglass, 2023; Harlow, 2012)
	Develop a sense of ownership with science (teaching)	(Tembrevilla & Milner-Bolotin, 2019)
	Felt rewarded by the experience	(Fogg-Rogers et al., 2017; Kang & Martin, 2018)
	Feeling of agency and empowerment	(Adams & Gupta, 2017; Tembrevilla & Milner-Bolotin, 2019)
	Increased interest and skill level in science (STEM)	(Petillo, 2016; Spector et al., 2020)
	Enhance confidence in science and science teaching	(Borgerding & Caniglia, 2017; Fogg-Rogers et al., 2017; Kang & Martin, 2018; Spector et al., 2020; Tembrevilla & Milner-Bolotin, 2019) (Kang & Martin, 2018)
	Engage with applications of STEM content	(Douglass, 2023)
	Develop reform-minded understandings of: the Nature of Science, what science is, what can be considered as science, understandings of scientists and their work, and the objectives of science education.	(Avraamidou, 2015; Rahm et al., 2016) (Avraamidou, 2015)
Identity Work	Expanded identities related to their future teaching	(Douglass, 2023)
	Foster more positive beliefs about their role as a teacher	(Kang & Martin, 2018)
	Develop more positive attitudes towards inclusive classrooms	(Kang & Martin, 2018)
	Deepen understanding of role of a teacher and future practice	(Kang & Martin, 2018)
	Gained awareness to their responsibilities to diverse learners	(Adams & Gupta, 2017)
	Allowed for new pedagogical imaginaries (imagine selves) to emerge	(Adams & Gupta, 2017)
	Development of reform-minded science teacher identities	(Adams & Gupta, 2017)
	Seeing STEM as relevant and worthwhile	(Petillo, 2016)
	ISL challenged beliefs about science teaching and learning	(Clarke-Vivier & Bard, 2016)
	Reflect on one's own practice and position as a teacher	(Borgerding & Caniglia, 2017; Kang & Martin, 2018; Rahm et al., 2016; Scharfenberg & Bogner, 2019)
	Develop positive attitudes towards teaching diverse learners	(Kang & Martin, 2018)
Informal Science Learning	Learn about the value of ISL and its role in supporting science inquiry	(Avraamidou, 2015; Dani et al., 2018)
	Gain confidence in ISL spaces	(Kreuzer & Dreesmann, 2017)
	Try out teaching and science knowledge	(Adams & Gupta, 2017)
	Learn how to use the affordances of ISL spaces	(Adams & Gupta, 2017)
	multidimensional, future-oriented experience	(Petillo, 2016)
	ISL settings as effective approach to science teaching and learning	(Avraamidou, 2015)
	ISL engages students in deep thinking	(Harlow, 2012)

	Learn about different types of informal science providers that exist	(Harlow, 2012)
	Presents an opportunity to see the relevance in what they are learning	(Cone, 2012)
	Provides safe opportunity to display science competence, exercise agency and assume central role in inquiry-based teaching	(Luehmann, 2007)
	ISL as increasing access to increased access to learning and science resources, increased student learning, and increased student motivation	(Luehmann & Markowitz, 2007)
Pedagogical Growth	Create educational resources	(Borgerding & Caniglia, 2017; Kreuzer & Dreesmann, 2017; Tembrevilla & Milner-Bolotin, 2019)
	Develop science communication skills	(Borgerding & Caniglia, 2017; Kang & Martin, 2018; Tembrevilla & Milner-Bolotin, 2019)
	Practice inquiry-based skills and activities	(Dani et al., 2018; Douglass, 2023; Tembrevilla & Milner-Bolotin, 2019)
	Develop appreciation for student centered pedagogy	(Dani et al., 2018; Macdonald, 2010; Rahm et al., 2016; Scharfenberg & Bogner, 2019; Wallace, 2013)
	Transfer knowledge (theory) to practice	(Macdonald, 2010; Rahm et al., 2016; Scharfenberg & Bogner, 2019)
	Develop science teaching skills (such as how to select examples, working with diverse learners, now to use technology in teaching, etc)	(Dani et al., 2018; Kang & Martin, 2018; Kreuzer & Dreesmann, 2017; Tembrevilla & Milner-Bolotin, 2019)
	Experience teaching science	(Borgerding & Caniglia, 2017; Dani et al., 2018)
	Improve and optimize time management skills	(Kreuzer & Dreesmann, 2017)
	Explore topics across grade levels	(Borgerding & Caniglia, 2017)
	Explore one's own teaching preferences	(Borgerding & Caniglia, 2017)
	Gained ability to improvise, reflect and respond real time	(Adams & Gupta, 2017; Dani et al., 2018)
	Utilize identities and intellectual affordances visitors brought	(Adams & Gupta, 2017)
	Use objects to encourage learning	(Adams & Gupta, 2017)
	How to quickly assess and use prior knowledge and experiences	(Adams & Gupta, 2017; Wallace, 2013)
	Develop cultural competence	(Burke, 2016)
	Reform minded science teaching practices, such as: letting students explore and figure it out for themselves, that student have ideas which can be built upon, using questions effectively	(Harlow, 2012; Wallace, 2013)
Learners	Learn about youth's science learning, ideas and reasoning	(Adams & Gupta, 2017; Dani et al., 2018; Harlow, 2012; Scharfenberg & Bogner, 2019)
	Develop positive attitudes towards teaching diverse learners	(Kang & Martin, 2018)
	Engage diverse learners in science learning	(Rahm et al., 2016) (Cone, 2012)
	Enhanced knowledge and understanding of diverse learners' capability and interests	(Clarke-Vivier & Bard, 2016; Cone, 2012; Kang & Martin, 2018; Wallace, 2013)
	Enhance relationships with the learners	(Luehmann & Markowitz, 2007)
	Surprised by youth's prior knowledge and abilities	(Clarke-Vivier & Bard, 2016)
Peers	Learn from peer's expertise	(Fogg-Rogers et al., 2017)
	Learn best practices from peers	(Tembrevilla & Milner-Bolotin, 2019)
Negatives	ISL was disequilibrating and uncomfortable initially	(Spector et al., 2020)

Table 2: Benefits of undergraduate science majors engaging in ISL programming.

Broad Area of Learning	Benefit	Literature
Science	Future career related skills or career knowledge advancement	(Anderson et al., 2015; Carpenter, 2015; Fogg-Rogers et al., 2017; Nelson et al., 2017)
	Scientific knowledge and skills	(Anderson et al., 2015; Bruce et al., 1997; Carpenter, 2015; Ferrara et al., 2017, 2017; Fogg-Rogers et al., 2017; Goebel et al., 2009; Harrison et al., 2013; Nelson et al., 2017; Pickering et al., 2004; Rao et al., 2007; Robinette & Noblet, 2009; Zardetto-Smith et al., 2006)
	Teaching skills	(Anderson et al., 2015; Bruce et al., 1997; Ferreira, 2007; Fitzallen & Brown, 2017; Grant et al., 2015; Gutstein et al., 2006; Rao et al., 2007)
	Learn about research	(Rao et al., 2007)
	Science related skills	(Anderson et al., 2015; Bruce et al., 1997; Carpenter, 2015; Ferrara et al., 2017; Ferreira, 2007; Fitzallen & Brown, 2017; Fogg-Rogers et al., 2017; Grant et al., 2015; Gutstein et al., 2006; Harrison et al., 2013; Lewis, 2011; Lewis et al., 2018; Nelson et al., 2017; Pickering et al., 2004; Robinette & Noblet, 2009)
Develop Mentoring Relationships	with students	(Grant et al., 2015)
	with faculty	(Carpenter, 2015);
	with graduates	(Frieze, 2005; Pluth et al., 2015);
	with pre-service teachers	(Fogg-Rogers et al., 2017);
	with teachers	(Ferreira, 2007; Goebel et al., 2009)
Beliefs, Attitudes, and Dispositions	Personal gains (i.e., rewarding, satisfying, etc.)	(Anderson et al., 2015; Carpenter, 2015; Grant et al., 2015; Nelson et al., 2017; Robinette & Noblet, 2009; Zardetto-Smith et al., 2006)
	Altered career choice	(Bruce et al., 1997; Ferrara et al., 2017; Ferreira, 2007; Gutstein et al., 2006; Harrison et al., 2013; Lewis et al., 2018; Nelson et al., 2017; Rao et al., 2007)
	Reflect on own learning	(Carpenter, 2015)
	Learn about education and diverse learners	(Carpenter, 2015; Ferreira, 2007; Fogg-Rogers et al., 2017; Goebel et al., 2009; Robinette & Noblet, 2009)
	More likely to get involved in other ISL programming opportunities	(Anderson et al., 2015; Fogg-Rogers et al., 2017; Grant et al., 2015; Nelson et al., 2017; Rao et al., 2007; Zardetto-Smith et al., 2006)

Appendix B: Interview Protocol – Life History Interview

1. Demographic info: Tell me about your childhood. Where did you grow up? What kind of school did you attend? What do your parents do? Siblings? Etc.

Previous science experiences

2. Please describe three memorable science experiences that you had in your childhood. Please draw these on the timeline! What were you doing and who was there? Science clubs/camps/museums? Science with family/friends (parents?) ? Any other activities outside of school related to other subjects? Negative or positive experiences.
3. Tell me about how you felt about science when you were in school (K-12)? Belonging? was it enjoyable? Hard? Stressful? Alienating?

Science identity

4. Some people think of themselves as a ‘science person’ or ‘not a science person’. How do you think of yourself and why? How would you describe what a ‘science person’ is? How have the experiences you described (on timeline) shaped how you see yourself as a science person (or not)? (capture science capital and intersection with identity) Recognition? PROBE if possible. (who was there, how were they influential?)
5. Was there a specific time when you knew you were or were not a science person? Where? What was happening? Who was there? (place on timeline)
6. What made you want to study science at university? Have any of the prior experiences (on timeline) influenced your decision? (capture science capital and use/exchange value) Have any of those prior experiences been useful during your program of study?
7. Has your interest in science changed over time? Can you put those on the timeline? What happened? Why? What made it more or less interesting for you?

Outreach

8. What motivated you to participate in this outreach project? What goals do you have for doing outreach? Is there anything you want to work on? (PROBE: skills, practices, other)
9. How confident do you feel doing science with youth? Is there anything that you are very excited or nervous about?
10. What is valuable about doing science outreach? For youth? For university students?

Future

11. How would you describe the kind of teacher/scientist that you would like to be? Science teacher? (is science included) What kind of support do you need to get there?

Appendix C: Interview Protocol – Online Interview

Science outreach experiences and working with youth

1. Can you describe a moment from your co-investigation that was memorable for you?
    a. What was working in that moment?
    b. Why do you think that worked well?
    c. Would you change anything in that activity?
    d. What did you take away from that moment?
2. Can you describe a moment from your co-investigation that stood out to you as challenging?
    a. What was working in that moment?
    b. Why do you think that did not work well?
    c. Would you change anything in that activity?
    d. What did you take away from that moment?
3. Now that you have had the experience of working with the youth, what are your thoughts about youth-directed inquiry?
    a. Was there anything that surprised you?
    b. How did it feel letting youth guide the inquiry process?
    c. Maybe probe from interview 1, probe if worry or learning
4. Can you describe the process by which your group came to decide on the topic you ultimately worked on? (Show concept maps)
    a. What was your role in this decision making?
    b. What was your partner's role?
    c. What were the youths' roles?
    d. How did you feel about these various roles? Was there anything in your interactions with your group that you struggled with?
5. Were there moments of tension where the group wanted to go one way, but you felt their ideas were not feasible, or not "scientific" enough?
    a. What did you do in that instance?
    b. How did you understand your role?

    *This question may reveal participants' epistemic orientations (e.g., what they think "counts" as science).
6. Did this project change anything about how you think about doing science overall?
7. Can you tell me about a time during the outreach when you felt having a partner was very helpful/useful? Or not?
    a. Did you feel supported by your partner?
    b. Do you think it would be easier or harder to do this on your own?
    c. Would you prefer to work with another science/education student or did you enjoy working with someone from another discipline?
8. Were there moments when you felt that you were able to implement some of your science communication or teacher training? If so, what was the situation?
9. Is there anything you would change about the outreach activities you did?
    a. What could we have done to better support you in your outreach planning/enactments?
    b. Is there anything **you** would have liked to have done differently (to support your co-investigator or the youth?)
10. What do you think the point of science outreach is? (with youth)
    a. In the first interview you said XYZ . Now that you have taught some science to youth, how do you reflect on your previous thoughts?
    b. What do you think youth should walk away from outreach.
    c. What is most important for them to learn at this level?
11. What do you think you would tell another science student about outreach? Would you encourage others to pursue outreach? Why?
    a. What would you tell another student to convince them to do outreach (or not)
    b. PROBE Is there something different or important about informal or out-of-school time science outreach?
    c. PROBE Is there something important about co-teaching with PSTs/USM?

Self as scientist

12. Do you think the youth you worked with would describe you as a science person? How so?
13. Do you think your partner would describe you as a science person?
14. Does this impact how you see yourself as a science person?
    i. Why or why not?
15. Did you feel "belonging" during the SORI project?
    a. When is it strongest?
    b. When does it diminish?
16. Do experience "belonging" in your current program?
    a. When is it strongest?
    b. When does it diminish?
17. Is there anything you would like to add to your timeline from this experience? Is there anything that you leveraged from your timeline or drew on from your timeline which helped you in this outreach experience?
    a. From the Sci Comms class? (if applicable)
18. At what stage in your education did you first become interested in communicating about/teaching science to youth ?
    a. Was there an initial event that you remember? Or from timeline?
19. Where do you see yourself in 5 years?
    a. How does science outreach figure into your career goals? (for USMs)
    b. How does science figure into your career goals? (for PSTs)
20. What do you think you will bring from this experience to graduate school/ profession as a scientist OR to your future elementary teaching?

Appendix D: Video Diary Questions

Video Diary #1

1. Please reflect on your first outreach experience. What worked and what didn't work?
2. How confident do you feel doing science outreach?
3. What was something that you learned from this experience?
4. What are your personal/professional goals for this outreach project?

Video Diary #2

1. What are your feelings about your groups' research project?
    a. Where there any surprises about topic choice?
    b. Do you have any concerns about the topic?
    c. How does it feel letting youth guide the process?
2. What are you learning from your partner?
3. What are you learning about working with youth?

Video Diary #3*

1. Please reflect on your entire experience learning about co-investigating with youth at PET. What was the most satisfying experience you had? What was the most frustrating experience you had?
2. If you were to do this again, what would you change?
3. What is the image you have of yourself as a (science person/science teacher)? Has this changed since engaging in this outreach program? If so, how, and what caused the change?
4. Would you recommend the outreach program to other science / education students? What advice would you have for them?

*Please note this video diary was planned but never completed due to covid-19 lockdown, and therefore the data from these diaries was never collected for this study

Appendix E: Coding Methodology

Following Saldaña's (2015) coding approach the following steps were undertaken:

1. *Familiarization with the Data:* First, we performed a thorough review of the transcribed interviews and video diaries. This helped me to become familiar with the data and gain an understanding of the participants' experiences. It was at this stage that we sent the transcripts to the co-investigators for review to ensure they expressed themselves as they wanted to, and that the data was transcribed accurately. Once approved, we then de-identified the data by replacing all names with the participant chosen pseudonyms for anonymity purposes.

2. *Open Coding:* Open coding is a process of identifying and labelling concepts, phrases, or themes in the data. Through this process, we generated initial codes that captured various aspects of science capital, feelings of belonging and science identity within the data. For example, if the participant described going to many science museums with family as very valuable to them, we might code this as "informal science learning – museums".

3. *In Vivo Coding:* In vivo coding involves identifying codes that are based on participants' own words or expressions. We highlighted phrases or terms used by participants to describe their experiences related to science and identity. For example, if the participant described their science museum trips as "really important for us as a family as it was our bonding time, I think we all found it deeply impactful for us and we reference them a lot even now." We might code this as "important for us as a family" and "deeply impactful".

4. *Focused Coding:* After generating a comprehensive list of open and in vivo codes, we focused on specific patterns and categories that emerged from the data. This process involved selecting and refining codes that were most relevant to the research questions. This looked like grouping codes together from a master list, and seeing which ones were similar and could be grouped together. For example, "family bonding time", "my brother and I did it together", "mom always loved that", and "family activities" might all be grouped together into a category called "family science experiences".

5. *Coding Consistency and Quality Control:* To ensure reliability, coding was conducted independently by multiple coders. Inter-coder reliability checks were performed to validate the coding process and resolve any discrepancies. This helped to reduce any potential sources of bias or blind spots one researcher might have and ensured that all possible codes were generated and included in our data set.