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The Science Identity of Informal Educators in a Professional Development Program

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Education

by

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ABSTRACT

The Science Identity of Informal Educators in a Professional Development Program

by

Jasmine Grace Evans

In an increasingly globalized world, the ability to engage with science meaningfully to make decisions on small and large scales is essential to be an informed citizen and to create a more equitable world. To engage with science, people need to develop a science identity. In this study, science identity, or feeling like a science person, includes the development of science knowledge (competence), ways of talking about and doing science (performance), an interest or other motivation to engage with science (investment), and recognition of oneself and/or by others as being a science person (recognition).

Informal science education institutions, like science museums, are places where learners can follow their curiosities and access science learning in distinctly different ways than they may have experienced in a classroom setting. Informal educators in such spaces play instrumental roles in facilitating these learning experiences and may impact the development of learners' science identities. While informal educators may influence the way learners develop a science identity (or sense of being a "science person"), informal educators themselves are not frequently the subject of science identity research, researchers choosing instead to focus on young learners in the space, such as students on a field trip visit. However, science identity development of the informal educators is equally important to understand because how an informal educator's sense of being a

science person develops will have a direct impact on how they interact with and facilitate the identity development of museum visitors. Thus, the changes that institutions wish to see in the visitor experience must begin with changes in the informal educators themselves.

I was interested to explore how informal educators developed a science identity while participating in a professional development program. I asked two major questions in this study:

(1.) How did informal educators' identities as science people change during participation in an informal science education professional development program?

(2.) How did informal educators create or aim to create opportunities for learners to be a science person?

In this qualitative study, I focused on four informal educators' experiences throughout a year-long professional development program at the interactive science museum where they were employed. I conducted five interviews throughout the year with each of the participants and collected written artifacts in the form of blog posts.

I found that participants' science identities did change over the course of the program, and, likewise, their facilitation practice changed over time. Participants ended the program with a more expansive and inclusive definition of science identity than they began the program with, and, as their definitions of "a science person" broadened, participants facilitated experiences with learners that were more inclusive and that increasingly prioritized making sufficient space for learners to lead their own explorations and be recognized as capable of engaging in science. Participants did display discrepancies between their individual definitions of science identity and how they chose

to incorporate science identity into facilitation; however, this was partially explained because participants largely drew a distinction between enacting a science identity as individuals and facilitating a learner's development of a science identity. They interpreted their role as an educator as necessitating a different approach to science identity than they might in other contexts. These findings support the value of investing in informal educators and offering them professional learning opportunities, which are much rarer for informal educators than for formal educators. If institutions can more effectively and meaningfully train their staff by creating opportunities to engage in professional learning, they can more easily achieve their goals and better serve their visitors. This study contributed to the gap in the literature for research on the science identity of informal educators, showing that in fact science identity of the individual educator does affect their facilitation with learners.

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Chapter I: Purpose

In an ever-increasingly interconnected world, science touches the lives of everyone. Whether considering the disproportionate impact of climate change on the world's most vulnerable communities or trying to make decisions about how to keep one's family safe during a global pandemic, making decisions requires science. Unfortunately, Western science as a field has historically been restricted to an elite, highly educated group of people, who are often seen as gatekeepers of information and knowledge. While access to scientific information has increased over time, this work is not complete, and science needs to become even more accessible to a wider audience (Bybee, 2010; National Science Foundation, Hamrick, 2019). For the general public to engage with science in a meaningful way, everyone needs to see themselves as capable of engaging with science.

Some educators aim to help more students pursue science, technology, engineering, and/or math (STEM) in higher education and STEM careers, with a particular focus on making STEM more equitable by increasing the diversity of STEM professionals, making these fields more representative of the general public (O'Brien et al., 2015). But this is not enough. For those students who do not have an interest in STEM careers and adults who do not have access to science in a formal education setting, seeing themselves as capable of engaging with science as it relates to their personal interests and concerns is still necessary for building a better-informed, more equitable society (Kim et al., 2012; Roth & Lee, 2004). Thus, it is important for people to have both positive feelings towards science and for them to feel capable of engaging with

science ideas and practices to the extent they need to in order to feel empowered in their lives.

In this study, someone who is capable of engaging in science as it relates to their individual lives and their communities is a science person. I use the term "science person" interchangeably with "science identity," as the primary framework of analysis for this study was derived from Carlone and Johnson (2007) who used the term "science identity" in their explanation of the concept. They broke this concept down into three components: competence, or science knowledge; performance, or ways of acting like a scientist; and recognition of being a science person, both by other people and of oneself. In this paper, all three of these elements are explored as essential aspects of a person's science identity, and thus essential parts of being a science person. In addition, I have added a fourth element to science identity, as it emerged from the data—investment, feeling positively towards or in some other way motivated to engage in the science learning process. Thus, if a person embodies all four elements of science identity, they are a science person.

The idea of a "science person" has been used in many contexts in previous research. The term has been used in the context of higher education as a tool to help researchers and educators attend to the issues of developing a science identity as it relates to increased retention in STEM majors and careers (Chen et al., 2021; Dou et al., 2019; Thompson & Jensen-Ryan, 2018). For example, Chen and colleagues (2021) used science person in this way and defined this term as a sense of belonging in science classrooms. In this way, the definition of science person used in my study closely resembles Chen and colleagues' definition. "Science person" has also been applied to research on classroom

teachers as it relates to their self-efficacy to impart science knowledge and practices to students (Mansfield & Woods-McConney, 2012).

One place people develop a sense of being a science person is in informal science spaces. Informal spaces allow learners to have greater agency in their learning than is typically found in formal education settings and, as such, offer different opportunities for engaging in science, supporting a wide range of learners (Bamberger & Tal, 2007). My research focuses on the experience of science educators (museum facilitators) in a hands-on science museum, the Museum of Physical Sciences (pseudonym). By meeting museum visitors where they are with respect to their personal interests, their educational background, etc., informal educators can provide experiences that help people have a more positive association with engaging in science. However, because we know that classroom teachers' sense of themselves as science people with strong science identities can influence how they engage students in science concepts (Avraamidou, 2014a), it would suggest that informal educators' (also referred to as "facilitators," "museum floor staff," or "explainers") sense of themselves as science people can influence how they will construct opportunities for others to engage in science and develop their own self-concepts as science people. Therefore, how an informal educator's sense of being a science person develops may have a direct impact on how they interact with and facilitate the identity development of museum visitors. Thus, the changes that institutions wish to see in the visitor experience must begin with changes in the informal educators themselves (Ash & Lombana, 2013).

Informal science education is significantly different from formal science education (e.g., less time to interact with learners, less accountability to content

standards, interactions with a wider range of learners). While some museums remain focused on science content transmission as their primary function (Jorro et al., 2017; Kamolpattana et al., 2015; Rennie & Williams, 2006), others have moved to consider a more holistic view of the learner's experience (Shaby et al., 2016; Tran, 2008). In many institutions, informal educators have moved from looking at the *what* of learning to the *how*, assessing the whole experience of learning that takes place in a science museum (Nyhof-Young, 1996; Shaby et al., 2016; Tran, 2007). More specifically, some institutions have shifted focus from content to practices, emphasizing the benefits of engaging learners in the work of scientists, such as making observations, conducting experiments, and modeling phenomena (Allen & Gutwill, 2009; Harlow & Skinner, 2019; Pattison et al., 2018). Part of engaging in the work of scientists may mean learners simply try something new or change their thinking in some way (Pattison & Dierking, 2012; Shehade & Stylianou-Lambert, 2020). This focus on science practices and engaging in different ways of thinking is true for the Museum of Physical Sciences.

Research on informal educators as science people is limited because most research on educators' science identities is centered on pre- or in-service teachers (e.g., Avraamidou, 2014a; Katz et al., 2011; Moore, 2008; Rivera Maulucci, 2013) and because research on science identity in informal education spaces tends to center on school-age children visiting the museum (e.g., Calabrese Barton et al., 2013; Carlone et al., 2015; Hughes et al., 2013; Pattison et al., 2018; Shaby & Vedder-Weiss, 2020). While there has been work on classroom teachers, it cannot be assumed that findings about science identity development as it relates to classroom teachers will apply to informal educators' sense of being science people because the backgrounds, experiences, and contextual

factors that constitute these two professions are markedly different. Reasons for limited research in informal education may include high turn-over rates of museum staff, part-time museum staff, and limited funding. These limitations make tracking changes in educators over time and drawing conclusions about their science identity development difficult.

Introduction to Study

The qualitative research conducted in this paper investigated informal educators' evolving identities as science people over the course of a year-long professional development program for informal science educators. This timeframe provided sufficient time to observe potential changes in identity. In this professional development program participants participated both in coursework to learn about theory related to informal science education and in facilitation on the floor of the museum, interacting with learners. In general, professional development programs for informal educators are rare (e.g., Kelton & Saraniero, 2018; Tran, Werner-Avidon, & Newton, 2013; Webb et al., 2012), so this work also provided an opportunity to see how educators may be impacted by participation in such a program.

This study aimed to 1. Describe how science identities changed during a professional development program, and 2. Describe how informal educators incorporated science identity into facilitation. These two facets of science identity enactment together provided insight into the impact a professional development program like this one can have on individual educators' science identities and how those changes in identity manifest in facilitation encounters with visitors.

Research Questions

As introduced above, I posed two sets of research questions:

1. How did informal educators' identities as science people change during participation in an informal science education professional development program?
    a. How did their conception of a science person change over the course of the program?
    b. How did recognition of themselves and by others as being a science person change over the course of the program?
    c. How did educators demonstrate different parts of being a science person?
2. How did informal educators create or aim to create opportunities for learners to be a science person?

To explore how informal educators developed as science people in the context of the Museum of Physical Sciences, this qualitative study, comprised primarily of interview data collected at multiple points throughout the program, looked at different facets of science identity. I broke the first research question down into three parts. First, I analyzed how educators defined "science person" in the general sense, as it related to the four core elements of science identity: competence, performance, investment, and recognition. Notably, recognition never came up in these general definitions, so only three of the elements of science identity were included in the analysis of this first sub-question. This analysis gave me a sense of what the term "science person" meant to participants and what they valued most in a science identity. Asking them to define "science person" gave me insight into who participants imagined belonged in science and possessed the capabilities to engage with science. Second, I analyzed how educators

placed themselves within their definitions, including whether other people in their lives had recognized them as science people. This dealt exclusively with the recognition aspect of science identity. Third, I looked at how educators demonstrated content knowledge (competence), ways of behaving like a scientist (performance), and investment in science (investment). This showed evidence of how participants embodied different aspects of science identity more objectively, apart from their self-descriptions included in the second sub-question. In the second research question, I wanted to bring in the informal education context of the study and discuss how science identity was meaningful in this type of setting. I analyzed how educators made space for learners to engage with all the elements of science identity through facilitation both in the museum and in other informal education settings over the course of this professional development program. The goal of the program was to train informal educators to better engage museum visitors in science, so I wanted to connect their personal embodiment of science identity to their facilitation and engaging learners in the development of a science identity.

Chapter II: Conceptual Framework & Literature Review

Conceptual Framework

The conceptual framework for this work includes Carlone and Johnson's (2007) framework of science identity as well as Falk and Dierking's (2000) Contextual Model of Learning. Carlone and Johnson's conception of science identity, consisting of competence, performance, and recognition, guided my analysis of informal educators' identity as science people. Falk and Dierking's framework provided the context in which identity development takes place by describing the defining features of learning in informal education settings and better contextualized the identity development learners may engage in with informal educators.

Science Identity

Informal educators are supposed to facilitate learning but are also expected to engage with learners in such a way that they are partners on equal footing with each other (Bailey, 2006; Bell et al., 2009; Pattison & Dierking, 2013; Pattison et al., 2018). In this way, because facilitation experiences are visitor-led and co-constructed between visitor and educator, informal educators play a kind of teacher role, but they may also be learners themselves (Bailey, 2006; Kelton & Saraniero, 2018; Tran et al., 2013). Striking this balance is a complex and possibly challenging part of being an informal educator, so analyzing their sense of being or becoming a science person requires a framework that encompasses both the science educator and science learner aspects of their role.

In studies on science identity (e.g., Carlone & Johnson, 2007; Rahm, 2008; Rodriguez, et al., 2019; Tan & Calabrese Barton, 2018), a key part of being a science person, researchers gained insight into the ways in which individuals can be supported to

think of themselves as having a science identity—having a place in the scientific community and being capable of engaging with science—thus leading to greater participation in everyday science. Researchers have found that supporting science identity formation can include providing many opportunities to take up an identity in low stakes situations, exposing individuals to role-models who are considered to already possess a science identity and who also look, talk, and act like those individuals, and offering positive emotional reinforcement in response to attempts to take up an identity (Carlone et al., 2015; Chapman & Feldman, 2017; Hughes et al., 2013; Johnson et al., 2011).

Unlike the research conducted in formal science education settings, in which researchers may be concerned with equity in terms of how many students pursue science in higher education and as a career, in informal education, the research goals are more open-ended. In informal education settings researchers and educators may want to see that a learner is merely engaged with and having a positive experience connected to science rather than that they are interested in pursuing STEM careers. Thus, in informal settings, increased access to science is a goal.

This study begins with the assumption that visitors to a science museum should gain experiences that give them more confidence and comfortability with science in their day-to-day lives. Therefore, developing a greater sense of themselves as science people in an informal space may be another pathway to increased science literacy for a broader range of people than relying solely on the pathways through formal education. Analyzing the ways in which individuals may develop a sense of being a science person in educator-visitor interactions provides opportunities to explore how that goal is being met.

Researchers may explore the ways individuals, both educators and museum visitors, perform being a science person in the ways they talk about themselves or science, or in the science practices they engage in, for example. Because informal educators may not have a background in science, they may not have a well-formed sense of being science people themselves; however, they can still work to develop a science identity, and incorporating science identity as part of being a science person into their view of facilitation can enrich their understanding of the work they can accomplish for both themselves and learners.

Core Qualities of Identity: Adding Investment

Researchers largely agree upon the characteristics of science identity, as well as of identity more generally. Identity is not a fixed entity, but rather is contextually and temporally dependent (Avraamidou, 2014a; Avraamidou, 2014b; Carlone & Johnson, 2007; Gee, 2000; Malone & Barabino, 2009; Shaby & Vedder-Weiss, 2020). Identity is formed in different moments based on the specific conditions present at a given time. At the same time, many scholars have acknowledged that identity formation happens on different timescales. Identity formation occurs in individual moments and interactions between people, but identity formation also occurs over longer periods of time. Therefore, while identities emerge as a result of practices engaged in under specific conditions at a given time, moments of identity formation are connected, so that moments add up to form longer-lasting habits (Carlone et al., 2015; Carlone & Johnson, 2007; Johnson et al., 2011; Tan & Calabrese Barton, 2018). Considering the many timescales involved in identity formation, people require multiple opportunities to vie for recognition as a member of an identity (Pattison et al., 2018). Because identity is

constructed in the moment, identity is also largely seen as practice-based, meaning observing people engaging in practices can provide insight into their identities. Practicing an identity can manifest in discourse and behavior, encompassing ways of being, particularly in relation to others (Archer et al., 2014; Brandt, 2008; Brown, 2004; Calabrese Barton et al., 2013; Carlone & Johnson, 2007; Chapman & Feldman, 2017; Jackson, 2017; Rahm, 2008). Thus, people who do science can also be thought of as having a science identity that is rooted in practices.

Additionally, emotion plays a crucial role in identity work, the ways in which people take on particular identities at various times through specific actions and relationships (Carlone et al., 2015; Rivera Maulucci, 2013). If people make positive associations when performing an identity, it not only makes them more likely to pursue experiences that match that identity in the future, but also gives them a stronger sense of self with respect to that identity. Positive emotions in the context of science identity formation may include "pride, ownership, and belonging" (Carlone et al., 2015, p. 1528). For those groups that have historically been discouraged from seeing themselves as science people, positive emotional reinforcement of identity work can be crucial because short-term, in-the-moment denials of a person's science identity work can have lasting effects on what kinds of people constitute the science field (Johnson et al., 2011). The role of emotion is particularly significant in the context of this paper because one of the primary roles of science museums is to produce a positive affect in its visitors (Shaby et al., 2016). Both educator and learner should come away from an experience in a science museum with positive feelings. Negative emotions such as fear and uncertainty are all but guaranteed in identity work; however, facilitators of identity work (e.g., teachers,

museum educators) should create conditions for the learner to engage with those emotions in a productive way to come to a place of better understanding of the self (Geijsel & Meijers, 2005). Geijsel and Meijers argued that, to facilitate identity work in the interest of learning, educators need to relate the content or activity to the learner in a way that makes it meaningful for them. In a science museum, this means tailoring a science experience to the individual in each encounter.

This idea of being emotionally invested in the science learning experience was incorporated into the analysis of this paper as a fourth component of science identity referred to as "investment." Anytime participants talked about taking ownership of science learning or having a personal interest in a science topic, this was seen as a part of practicing a science identity, an element that was not originally included in Carlone and Johnson's (2007) definition, which formed the basis of the analysis of this paper.

Science Identity Framework

As a derivative of Gee's (2000) identity framework, Carlone and Johnson (2007) presented a framework for science identity, proposing that it is made up of three elements: competence (the knowledge, skills, and understanding required to practice an identity), performance (practicing an identity and interacting with others in the community), and recognition (by the self and by others). This view of identity reinforced the practice-based nature of science identity as well as acknowledged the need for recognition by others to form an identity and make it valid. However, Carlone and Johnson further emphasized the recognition aspect, beyond what Gee's framework had done, by showing how social identities such as gender, race, and class play a role as well. They concluded:

> It is much easier to get recognized as a scientist if your ways of talking, looking, acting, and interacting align with historical and prototypical notions of scientist. This, of course, makes it more likely that members of the discipline will keep reproducing members who look, talk, act, think, and interact like they do. (Carlone & Johnson, 2007, p. 1207)

They argued that because recognition relies on other people seeing an individual, who may not look, talk, or act similarly to themselves, as capable of occupying the same identity they do, populations that have been minoritized and historically excluded from science have to look to the majority population, who has historically possessed a science identity, for validation. This contains the potential for the inequitable distribution of science identities that exists today. Informal educators in a science museum, then, are in a position to provide recognition in a meaningful way by making space for a diversity of ways of engaging with science. The competence component of this science identity framework was not directly addressed in the professional development program, which was practice-based rather than content-based. Moreover, the program taught the importance of facilitating science learning in an equitable manner, acknowledging everyone's sense of belonging in the museum space. For the purposes of this paper, I analyzed data using all three components of the Carlone and Johnson science identity framework plus investment, just knowing that of these, competence was not an explicit focus of the program.

Facilitating Science Identity Work for Others

While the work an informal educator does with a learner in a single interaction may not be enough to impart long-lasting identity transformations for either individual,

these experiences can contribute to the ongoing process of identity development of both parties (Carlone & Johnson, 2007; Johnson et al., 2011). Informal educators play a key role in providing the opportunities one needs to develop an identity to feel it has enough continuity to be considered part of an individual's identity over a sustained time period, but informal educators experience these opportunities as well when learners give them chances to be recognized as science people. As Johnson et al. (2011) found, even individuals who thought of themselves as science people and who held positions in science-based professions needed to be in settings that allowed them to practice and be recognized in that way to solidify that identity. Informal education settings such as science museums can play a critical role in increasing access to science identity for a broad range of people. How informal educators view what constitutes performing science and how they choose to create opportunities for positioning oneself as a science person directly affect how both they and learners access science identity (Moore, 2008). It follows that in studies on informal science education, educators' own views on and engagement in science identity work are important topics of exploration with significant implications for their own perception of self as well as how their sense of identity impacts their role as someone who may influence others' science identities.

Because informal educators are not only learners possibly attempting to take up a science identity but are also educators who are expected to support others' science identity work, an investigation of informal science educators' identity development needs to consider the social structures that constrain identity work. Informal educators work with a diverse audience with regards to age, knowledge levels, gender, race, ethnicity, socio-economic status, language, etc. For this very reason, science museums may be able

to counter inequities in science that are pervasive in formal education and society in general (Archer et al., 2014; Carlone, 2004; Hughes et al., 2013; Johnson et al., 2011; Moore, 2008; Rahm, 2008; Tan et al., 2013). To conduct research in an inclusive and equitable manner, researchers need to consider how identity:

> Is a layering of events of participation and reification by which our experience and social interpretation inform each other. As we encounter our effects on the world and develop our relations with others, these layers build upon each other to produce our identity. (Wenger, 1998, p. 151)

Researchers should recognize that as places where learners consistently engage with science, science museums offer numerous opportunities for participation that ultimately contribute to building a science identity, whether through building investment, through accumulation of knowledge, through practices, or through recognition from others of being a science person. Wenger also included in this definition of identity a special consideration of social structures as key components in developing an identity. Thus, in science, groups who have been historically marginalized require additional considerations in their science identity work pursuits, such as creating sufficient safe spaces for individuals to practice science and providing a greater number of opportunities for identity development.

Johnson and colleagues (2011) supported this view of identity work, arguing that rather than focusing on equipping individuals to combat the social structures they find themselves in, the field of science identity should work to create safe spaces for minoritized people, such as women and people of color, to practice science identity in ways they can be their full selves. Although the work of increasing science identity

equity centers the learner's experience, for the learner to have an equitable encounter, informal educators need to consider the ways they themselves perceive what constitutes a science person or doing science. Understanding how informal educators view science and science people gives insight into how they may view themselves and into the image of science they convey to learners, as an educator's sense of science identity will inevitably influence how they perform and recognize science with others (Geijels & Meijers, 2005). While social structures do place constraints on the identity work of groups who have been minoritized and marginalized, it is important to remember that gender, ethnicity, and other labels are not monolithic (Rahm, 2008). Individuals experience their assigned labels in different ways. Therefore, while being aware of the differences that may exist among populations, informal educators should not make assumptions about individuals based on these socially constructed labels, and, likewise, researchers should not make these types of assumptions about educators.

Contextual Model of Learning: Personal, Sociocultural, and Physical

Falk and Dierking's (2000) Contextual Model of Learning is rooted in constructivist and sociocultural theories, acknowledging learning occurs amidst many contexts, which can be largely categorized into personal, sociocultural, and physical. The work in this paper emphasized the sociocultural aspects of this framework based in sociocultural theory, as this theory allows researchers to look at all the influences each person has on the other in an interaction in the pursuit of learning. As Falk and Dierking commented, "Free-choice learning in general and museum learning in particular are commonly marked by some sort of socially facilitated learning" (Falk & Dierking, 2000, p. 46).

The sociocultural aspect of the Contextual Model of Learning fits well with studies done on informal educators and learners because they should be equal partners in learning and exploration, co-constructing an enjoyable and productive experience (Bailey, 2006; Bell et al., 2009; Pattison et al., 2018; Shaby et al., 2016; Shaby et al., 2019; Winstanley, 2018). When museum visitors interact with individuals outside their own social group, museum staff are the most likely and most influential source of that interaction (Falk & Dierking, 2000, p. 191). The role museum staff play in visitors' museum experiences cannot be understated. However, when considering the sociocultural context of museum learning, researchers must remember that museum "staff and volunteers are members of the community of learners themselves" (Falk & Dierking, 2000, p. 107). A sociocultural lens leads to interpretations about the socially mediated aspect of learning that is characteristic of and prevalent in science museums, which is an essential component of the museum experience because it "plays a critical role in personalizing the museum experience for visitors, facilitating their efforts to learn and find meaning" (Falk & Dierking, 2000, p. 109). The meaning making that occurs in interactions between museum staff and visitors goes both ways with the potential for all individuals involved to act as learners, and in the case of this study, engage in identity work as part of that learning.

While this paper will draw mainly on the sociocultural aspect of this framework, the other two aspects are the personal and the physical context. Focusing primarily on the interactions and learning that occur in museums and other free-choice education settings, Falk and Storksdiek (2005) described the personal context as not only the genetic history of a learner but their past knowledge, interests, and beliefs, which will directly impact

how they choose to spend their time in a museum. This aspect directly relates to the investment aspect of science identity in that one way to create buy-in to the learning experiences is for informal educators to leverage the learner's personal interests or background. The physical context of museum learning includes the following: "large-scale properties such as space, lighting, and climate as well as the smaller scale aspects such as the exhibitions and objects contained within" (Falk & Storksdiek, 2005). This aspect of the framework does not have much relevance for this study.

Falk and Storksdiek (2005) further defined the three contexts in this framework using 12 factors of learning:

Personal Context

1. Visit motivation and expectations
2. Prior knowledge
3. Prior experiences
4. Prior interests
5. Choice and control

Sociocultural Context

6. Within-group social mediation
7. Mediation by others outside the immediate social group

Physical Context

8. Advance organizers
9. Orientation to the physical space
10. Architecture and large-scale environment
11. Design and exposure to exhibits and programs

12. Subsequent reinforcing events and experiences outside the museum

One of the takeaways from The Contextual Model of Learning is that learning in informal contexts is complex with many considerations impacting it. The sociocultural context is the most relevant to the analysis of this paper, and added to the science identity framework, it allows for consideration of a more holistic view of identity work in the specific context of informal learning. Identity work was analyzed both in the activities educators engaged in during the professional development program and in the interactions between informal educators and learners on the museum floor.

Literature Review

The Role of an Informal Educator

Informal educators are distinct from formal educators (i.e., classroom teachers) in many ways. While a single definition of an informal educator is not used uniformly across all institutions and contexts, research on informal education has revealed some key roles informal educators fulfill for the learner, including acting as a bridge between a learner and the physical space, facilitating a learner-centered experience, and fostering a positive experience, both emotionally and socially. These roles are consistent with what is expected of educators at the Museum of Physical Sciences and align with some of the key elements in the Contextual Model of Learning (Falk & Dierking, 2000). Although many studies have been conducted on the various roles informal educators play in a museum setting, little has been done to explore how they can support identity work of learners and to explore the identity work of educators themselves.

Shifting from Content-Focused Museum Experiences to More Holistic Ones

While science museums as informal education settings have qualities that distinguish them from classroom teaching and learning, some institutions and informal educators still view their primary purpose as transmission of science content. Shaby and colleagues (2016) identified three crucial aspects to any facilitation interaction, including cognitive, affective, and social. The cognitive aspect is the idea that the educational role science museum is to convey science content to the public. While this idea is still prevalent among some more traditional science museums, interactive science centers, a newer model of science museums, often do not consider the cognitive component to be the most important (e.g., Allen & Gutwill, 2009; Davidsson & Jakobsson, 2009). Similarly, Rennie and Williams (2006) discussed communicating science to the public as part of informal educators' responsibility to serve their communities. Another component of more traditional facilitation is answering questions. In science museums today, one may find educators who facilitate only when approached by a visitor and then for only brief periods, long enough to address visitors' concerns or confusion (Kamolpattana et al., 2015). However, this kind of interaction does not lead to deeper or more complex exploration and learning.

The view of informal educators as providers of science content, while still pervasive among some institutions, is no longer the pervasive view everywhere, and some institutions and researchers are guiding informal educators to think beyond the traditional roles that center on knowledge transfer. For example, Davidsson and Jakobsson (2009) found that multiple educators from different science centers focused on content knowledge goals over other elements of learning such as the sociocultural aspect. Their study focused primarily on interactions with field trip groups, in which informal

educators viewed themselves as mediators of the learning process. The educators spoke of needing to communicate with the classroom teachers to ensure productive learning goals were being set and achieved and needing to differentiate facilitation based on the content knowledge of the learners. Informal educators said their facilitation depended mostly on two things: the circumstances of the visit and the expected learning outcomes. The researchers of this study found the effort to align with teachers' learning goals to be limiting from a sociocultural perspective because through this view, informal educators made a distinction between students who "take the visit seriously" and those who "are just playing" (Davidsson & Jakobsson, 2009, p. 136). In discussing their findings, researchers pointed out that "just playing" can be a great opportunity for learning and to engage further. When visitors play, they open themselves up to the potential benefits social learning provides in a space such as a science museum. Thus, Davidsson and Jakobsson gained insight into what educators valued in their role, and they uncovered areas for improvement and areas in which informal educators could expand their roles beyond helping students achieve the content goals determined by their formal educators.

Informal educators may be expected to assist visitors in gaining new content knowledge, but this responsibility has largely been overshadowed by roles deemed more important. Even the language informal educators tend to use to describe the work they do distances themselves from traditional teaching with words like "presenting," "facilitating," and "engaging" (Tran, 2008). Additionally, many institutions have started to value engagement in science skills over retention of science content. Researchers who have investigated facilitation in such institutions have described new models of facilitation beyond answering questions and transmitting content, such as those I describe

in the following three examples. Harlow and Skinner (2019), for example, described a model intended to engage visitors in science and engineering practices and identify three pathways an informal educator may follow to enhance the visitor learning experience, including optimizing the use of a science practice and extending to the use of a different science practice. Similarly, during a scaffolded, interactive family activity at a science museum, Allen and Gutwill (2009), the researchers of the study and the facilitators of the activity, prioritized engaging visitors in skills that may be applied in future contexts. Pattison and colleagues (2018) found that facilitation, which included balancing content-related goals with learners' own goals, increased stay time for visitors at a particular exhibit which led to, in part, an increased use of science practices, identifying this as a highly desirable outcome of informal education.

Knowing the Physical Space

A major role of informal educators discussed at length in the literature is as a bridge between the visitor and the physical space of the science museum, specifically the exhibits. Harlow and Skinner (2019) discussed the importance of educators in providing a richer learning experience than what visitors would encounter with access to only the exhibits. Hein (as cited in Winstanley, 2018) noted that educators serve a crucial role as a way for visitors to make personal connections to the museum experience and the learning that occurs therein. Informal educators, then, can be viewed as mediators of learning through the use of physical objects (Tran, 2008). Thus, educators can serve just as important a role in visitor learning as the exhibits themselves, putting the affordances for learning provided by informal educators on the same level of importance as the affordances for learning provided by the physical space (Davidsson & Jakobsson, 2009).

Bailey (2006) described informal educators as presenters of the space, which includes educators being knowledgeable about the exhibits themselves. Indeed, many studies have supported building a thorough knowledge base of exhibits in museum educators. Different exhibits provide different affordances for learning and engagement; thus, educators should be aware of the potential that is present in different areas of the physical space in which they work (Harlow & Skinner, 2019; Pattison et al., 2018).

Centering the Learner

Across numerous studies, researchers have stressed the importance of facilitation that is flexible and learner-centered. A one-size-fits-all model does not work in a museum setting, as educators should be making on-the-spot decisions about facilitation based on the specific learner and learning goals (Bell et al., 2009; Harlow & Skinner, 2019; Shaby et al., 2019). For example, educators need to take into account that each visitor may have a different level of knowledge about or experience with a particular science concept, so they will have to differentiate their facilitation based on this quality (Davidsson & Jakobsson, 2009). Additionally, many researchers have found that personal connection and relevancy to learning are important. For instance, educators may connect a science concept to a local, community issue or event, thus serving both the individual learner and their community as a whole (Porter & Garcia, 2018; Rennie & Williams, 2006). One purpose a science museum serves is to provide learning opportunities to a broad and diverse audience. In this way, museums may play a role in making science education more equitable and accessible to the general public (Kristinsdottir, 2017). Whether making a connection to a personal experience or to a community issue, making science relevant to the visitor's life helps visitors be more invested in their learning, which

enhances the overall experience (Shaby et al., 2016). In making these connections, informal educators should also make space for visitors to bring in their prior knowledge and experiences to an interaction, prioritizing visitor interests and goals over their own (Bailey, 2006; Bell et al., 2009; Pattison & Dierking, 2013; Porter & Garcia, 2018; Tran, 2007; Winstanley, 2018). Because visitor experiences, interests, motivations, and goals should be at the center of any interaction, informal educators may propose new goals or ideas to enrich the learning experience, but the visitor ultimately decides whether to pursue them (Pattison & Dierking, 2013). Thus, the relationship between an educator and a learner is a partnership (Bailey, 2006; Bell et al., 2009; Pattison et al., 2018). Educators are a resource for learning rather than the director or authority of it (Herz as cited in Winstanley, 2018; Pattison et al., 2018). Gutwill and colleagues (2015) explained that balance educators have to strike between being a resource, offering support to the visitor, and allowing the visitor to direct their own experience and exploration. This is an ongoing task for educators, as different learners will require different forms and degrees of support.

Attending to Emotional and Social Needs

Educators have to attend to needs of learners outside the content of a facilitation (e.g., their interests, knowledge, and learning goals)—learners need to feel the museum experience is enjoyable and comfortable. Because museum interactions tend to be brief, making the experience positive and memorable is all the more important (Tran, 2007). Thus, another balance educators have to be conscious of is between immediate enjoyment and learning goals (Shehade & Stylianou-Lambert, 2020; Winstanley, 2018). While guiding learners toward a goal establishes some structure for the interaction, educators

have to prioritize having an enjoyable experience for it to be beneficial because the emotional connections learners make to the space help make the experience more memorable (Winstanley, 2018). As mentioned earlier, Shaby and colleagues (2016) identified the importance of the cognitive component of an interaction, but equally, they discussed the affective component as essential to learning. Without the affective element of learning, without feeling like they had an overall positive experience, learners will not get the most out of their experience no matter how much an educator engages them in the cognitive, meaning science content and practices. Positive in this context does not necessarily mean feeling emotions of happiness or complete understanding but rather that the experience was productive and worthwhile. Educators also have to make the learner feel comfortable to take risks, ask questions, and try new things (Tlili et al., 2016). Porter and Garcia (2018) talked about this role of informal educators as "establishing brave spaces" (p. 293). Moreover, they recommended educators do this through modeling their own comfort in the space. Educators need to attend to museum visitors not just as learners but as persons who require emotional assurance and enjoyment. This attention to the whole experience of the visitor recognizes them as a person first.

In viewing learners as persons in the space, educators must also be aware of the social nature of educational interactions. Shaby and colleagues' (2016) third and final crucial component to a good interaction is the social one. Learning in a museum does not happen in isolation. In interactions between visitor and educator, educators talk *to* and *with* the learner, not *at* them (Porter & Garcia, 2018). Furthermore, many people come to a science museum in a group, typically families. As part of their facilitation, educators should take into account the social dynamics already at play before they approach a

learner (Pattison & Dierking, 2012; 2013). For example, educators should recognize that parents and guardians can be resources of knowledge about how to engage their children, as they have years of experience facilitating their children's learning (Pattison & Dierking, 2012). In a science museum, many social relationships exist simultaneously. Educators must not only be aware of how they will engage with and relate to a learner one-on-one but also how to do so with a group of learners.

Pattison and colleagues (2018) focused on the influential factors on visitor engagement and learning in their work. They showed facilitation increased visitor learning and experiences quantitatively, in terms of stay time at an exhibit, and qualitatively, in terms of satisfaction and mathematical reasoning. Informal educators co-constructed the focus and pathway of an interaction with the museum visitor, using a range of facilitation strategies. Through observation and surveys, researchers found educators' facilitation decisions depended on their evaluation of five attributes of the visitor or family: how well they could navigate the exhibit, if they explored the exhibit more deeply over time, their level of mathematical reasoning (as this was a primary focus of the exhibits), how much they took ownership of their experiences, and how well the adults and children within a group interacted with each other. While Pattison and colleagues found facilitation had a positive effect on visitor satisfaction and mathematical reasoning, they found it had a negative effect on intergenerational communication. Lastly, they found the exhibit was an important variable to determine impact of facilitation on learning outcomes and visitor engagement because among the three exhibits studied, some were better supported by the addition of facilitation than others. In studying the interactions between educators and visitors, researchers highlighted the ways

in which social dynamics influenced outcomes. They analyzed both how educators evaluated social situations among visitors at exhibits to determine a facilitation approach and how visitors responded to the social impact of facilitation on their learning and overall experience.

Overall, informal educators should conduct their interactions with visitors in such a way that their facilitation increases both the quantity and quality of learning (Pattison et al., 2018). This means not only do visitors spend longer at a particular exhibit, but this increased stay time leads to a better learning experience in which they may change their thinking, try something new, or engage in science practices. Pattison and colleagues (2018) summed up the role of informal educators by saying they must, "Prioritize participants' enjoyments, choice and control, social interactions, and life-long learning relevance and interests" (p. 4-5). All of these considerations contribute to the kind of holistic learning experience informal educators should strive towards in each visitor interaction.

Science Identity

Many studies exist on science identity and the idea of being a science person; however, these tend to focus on the identity development that occurs in formal education settings (e.g., Archer et al., 2010; Carlone & Johnson, 2007; Chapman & Feldman, 2017; Malone & Barabino, 2009; Rodriguez et al., 2019; Tan et al., 2013). When it does concern informal education settings, the participants of interest are students, typically taking part in an afterschool program or a school field trip in an informal space (e.g., Calabrese Barton et al., 2013; Carlone et al., 2015; Hughes et al., 2013; Shaby & Vedder-Weiss, 2020; Tan et al., 2013). Furthermore, researchers have used slightly different

definitions of science identity, as identity work research has been conducted in widely varying contexts, and none of these studies have used investment as part of their framework.

Competence, Performance, and Recognition

An often-used conception of science identity is derived from the work of Carlone and Johnson (2007) who defined science identity as being composed of three equal parts: competence, performance, and recognition. They conducted their research in formal (Carlone, 2004; Carlone & Johnson, 2007) and informal (Carlone et al., 2015) education settings. Chapman and Feldman (2017) used this framework in their analysis of historically marginalized high school students' science identities when students were given the opportunity to assist in research. They focused on the specific science practices, as derived from the Next Generation Science Standards (NGSS; NGSS Lead States, 2013), that students had the opportunity to engage in through the research experience, and how those actions influenced their sense of science identity. They found that performance, in comparison to competence and recognition, was the strongest aspect of students' sense of a science identity. This finding is promising for studies on science identity work in a science museum because performance is much more easily accessed in naturalistic observations between visitors and educators than competence. Chapman and Feldman also addressed the recognition aspect of the framework by looking at interactions between students and teachers and/or science experts to find confirmation or refutation of recognition of a science identity. Focusing on recognition would work well in a science museum because a science museum tends to be more socially interactive than

experiences in formal education, so the recognition element is even more prominently featured.

Rodriguez and colleagues (2019), using Carlone and Johnson's (2007) framework, explored the role of recognition in science identity further when studying the science identity formation of 17 Latina undergraduate science students. Using interview data, researchers explored participants' STEM interest, STEM experiences, self-recognition of possessing a STEM identity, and recognition from others. Participants also provided artifacts they felt reflected their STEM identity. In this work, researchers defined STEM identity as "the 'kind of person' who participates in STEM activities" (Rodriguez et al., 2019, p. 256). Participants identified "enthusiasm for learning disciplinary concepts, and an ability to innovate and think critically" as key attributes of being a STEM person (Rodriguez et al., 2019, p. 260). In addition, some students highlighted persistence in the face of challenges as a sign they were STEM people. Importantly, researchers found that while recognition of STEM identity from family was valuable, students sought recognition primarily from peers, and teachers or other experts in the science community. Because this work was conducted in the realm of formal education, the recognition from faculty members in particular was important to participants because many had aspirations of continuing on to graduate school and STEM careers, of which many viewed faculty as gatekeepers to those experiences. From their findings, researchers encouraged institutions of learning to create opportunities for low-stakes STEM experiences in an effort to increase recognition and thus increase the number of people who possess a positive science identity.

In the context of science museums, educators may be crucial to identity work because visitors may see them as experts in the space, so the recognition an educator grants to a learner can be particularly valuable in developing a science identity.

Addressing Inequities

As facilitators of science identity work, informal educators need to consider how best to support all people, with particular attention to the history of science as a field in which women, people of color, and individuals of low socioeconomic status have been largely excluded.

Burke and Navas (2021) studied the science identity work low-income students engaged in during an out-of-school science club. They collected pre- and post-survey data from 202 participants and focus group data from a subset consisting of 45 students. The club that served as the research context was designed to serve students ages 8-14. The definition of science person Burke and Navas used was a sense of belonging in science defined by three components: practices, agency, and positioning. They viewed these components as overlapping during identity work, for example, saying, "The perception of who I am in my given social context (positioning), may lead me to believe that I have a certain capability or capability to decide whether or not to participate (agency) in certain enactments (practices)" (Burke & Navas, 2021, p. 1430). They found that the emotional aspect involved in science learning experiences was impactful for participants. However, even though they enjoyed their science experiences in this informal setting, they hesitated to see themselves as science people because they viewed their experiences in the club and at school to be distinct, with formal science learning carrying more weight as the deciding factor of whether a student had the potential to be a

practitioner of science. For many students, not having a science identity associated with school prevented them from feeling like they truly belonged in science. Furthermore, the participants expressed enjoying science in the context of the club more than in the context of school, making the distinction between doing science and learning about science. Researchers concluded that informal education settings had the potential to improve a child's science identity and helped them feel more positively about science, but the next crucial step would be strengthening the connection between science identity in an informal setting and science identity in a formal setting, so that identity would not only be associated with certain, limited contexts.

Archer and colleagues (2014) spoke of science capital, which includes types of economic, cultural, and social capital as they are related to science, such as "science-related qualifications, knowledge/understanding, interest, literacy and social contacts" (p. 19). Science capital ultimately affects students' science aspirations, and a lack of science capital makes it harder for students to form and maintain science aspirations, a direct product of a sense of science identity. Archer and colleagues (2014), using the recognition component of Carlone and Johnson's (2007) identity framework, argued that due to other people's perceptions of the amount of science capital an individual possesses, individuals may be more or less supported by experts in or gatekeepers of a community of practice. They specifically focused on how masculinity factors into a person's science identity. After surveying and interviewing 85 10-14-year-old students, exploring topics such as self-concept, school experiences, teachers, aspirations, parental involvement, and images of scientists, researchers looked for discursive gendered performances and patterns of aspirations in and relationships with science. Researchers

found that science was typically seen as most suited to middle-class boys who were in good academic standing and seen as "good students" by teachers and other adults. These students behaved with an attitude and used cultural tools in ways that aligned with institutional practices, thus they were seen as a natural fit for science. Not only girls but working-class boys were dissuaded from taking up a science identity and science aspirations, seeing themselves as misaligned with the expected model of behavior in science. This work showed that science identity is heavily influenced by the social structures surrounding it, making it classed, racialized, and gendered. As a result, some individuals may feel more entitled to participation in science than others.

Similarly, Wade-Jaimes and colleagues (2021) explored three Black female middle school students' science identities in an afterschool STEM program. The researchers analyzed each participant's definition of science person through interviews and observed conversations both in school and in the afterschool program. One of the aims of the program was to create a space for young girls to develop their science identities by providing opportunities to actively participate in science and come to view science as relevant. Wade-Jaimes and colleagues found that all three participants struggled to see themselves as future scientist, drawing a distinction between a science person who is interested in science, a science person, and a scientist. For the participants doing science as part of the activities in the program did not qualify them as a science people; enjoying science was not enough to claim a science identity. The researchers concluded that while the afterschool space accomplished the goal of allowing Black girls to engage with science outside the traditionally exclusionary atmosphere of science in formal education, it did not accomplish the goal of improving their science identities.

They recommended that future efforts to create spaces outside of the classroom for underrepresented groups to engage with science take into consideration other identities, such as race and gender, to more holistically and explicitly support students, which in turn creates a better environment in which to engage in science identity work.

In longitudinally interviewing three women of color in science careers, Johnson and colleagues (2011) found participants had to counter or be subjected to negative identities derived from their status in various social structures, or matrix of oppression (Collins, 2000), and attributed to them by the very individuals from whom they were seeking recognition as science people, which meant identity formation was an ongoing process and often a struggle. However, researchers found that participants' "locations in the matrix of oppression shaped, but did not cement, their authoring opportunities" (Johnson et al., 2011, p. 344). Despite the barriers to engaging in identity work for women of color, researchers found societal structures were not a complete roadblock to these groups as they maintained their agency in the face of inequitable obstacles. The key for these women was finding ways to author science identities that did not simultaneously compete with their other identities (e.g., woman, Black, Latina, Indigenous), but rather made space for all identities to reinforce one another.

Similarly, using data sources including field notes, individual and group interviews, and artifacts, Tan and Calabrese Barton (2018) found that while studying a making space program for youth from low-income communities with a majority of Black participants "youths' STEM-rich making involves an ongoing process of negotiating across scales of injustice and intersecting identities as they work locally and in-the-moment but seek to also challenge and transform existing narratives and locations of

experience" (p. 53). While thinking about science capital or the role of emotions may highlight the ways in which inequities exist in science and science education, they also help uncover the ways individuals exercise their agency to its fullest despite the obstacles put in their way. Only by being aware of the ways in which inequities form and manifest in science can we hope to remedy them (Tan & Calabrese Barton, 2018). By considering many different influences, researchers can better identify the ways in which individuals can be supported in their identity work.

Tan and colleagues (2013) argued that the identity work of women in science is determined in part by the tools, relationships, and practices made available to them; thus, they found a discrepancy between girls' narrated identities, how they viewed themselves, and their embodied identities, how they performed identity through discourse, tools, and resources within a particular social context. Similarly, drawing from observation and interview data on 36 middle school girls, Calabrese Barton and colleagues (2013) found that, beyond what resources were made available to girls in their science education, what mattered was "the ways in which these resources become points of social negotiation and symbolic representations of critical identity work" (p. 67). Resources directly impact how identity work is conducted because they possess social and cultural value. They concluded identity work in young girls was better supported when the context was less hierarchical and more flexible. Their research supported informal science education as a place for groups who have been marginalized to find more entry points to take up a science identity because even girls who shared racial/ethnic identities needed different ways of engaging in science to feel authentic and safe in their authoring efforts. Research,

like this, has typically considered ways to engage students or visitors in science identity work, but this approach is just as meaningful for informal educators.

Tying Research to Informal Educators

Because informal educators are typically diverse with varying backgrounds, they, too, need to find an entry point to science that suits them, just as they are expected to facilitate finding entry points for visitors. As a fellow learner in facilitation interactions, informal educators will also be looking for ways to take up a science identity, which will likely vary among educators, as one's performance of a science identity should not come at the cost of another valued identity merely because they have historically not been seen to coexist (Johnson et al., 2011; Tan & Calabrese Barton, 2018). The ways in which research has focused on the impact of social identities on science identity for students can be applied to informal educators and museum visitors alike.

Informal Education Professional Development

As valuable resources of science education, science museums should be supported to maximize their potential for contributing to the learning of their entire audience. Informal educators provide a crucial connection between museum visitors and the physical space, identifying entry points for learning and exploration for a diverse audience. Because the role of informal educators is complex as both a facilitator of learning and a fellow learner, they should have support to reflect on and refine their practice. Just as teachers in formal education are offered opportunities to improve their practice through professional development and trainings to improve student learning, so too should informal educators receive these opportunities. In this way, informal educators should be considered members of a professional community, deserving of their own

specially designed training and professional development programs. In thinking about what qualities of informal education professional development are essential, a good starting point is the practices that have already been proven effective in formal education professional development.

Many professional development programs have been implemented for informal educators, but the field lacks the level of cohesion seen in programs for formal educators. Studies done by Grossman and colleagues (2001) and by Darling-Hammond and colleagues (2017) on professional development programs for pre- and in-service teachers reveal some key attributes, which can also be helpful in informal education contexts: being equally invested in the educator and learner, recognizing that no one person is the expert and that everyone brings something of value to the program, balancing theory and practice, providing opportunities for self-reflection and receiving feedback from others, allowing educators to experience being the learner, and occurring over a sustained period of time. Because approaches in formal education are not always directly transferrable to informal education, another aspect of good professional development should be included on this list when thinking about supporting informal educators—balancing structure and flexibility.

Table 1 describes studies that have been done on informal education professional development programs. Note that all programs listed in Table 1 are research practice partnerships, as the kind of high-quality program just described requires access to resources such as expertise, time, and funding that many informal institutions do not have on their own and must seek elsewhere. As a result, many studies done in this field involve university participation.

Table 1

Comparing Informal Education Professional Development Programs

Author(s)	Type of institution(s)	Duration of PD (hours)	Duration of PD (months)	Number of participants	Target participants	PD activities
Kelton & Saraniero, 2018	Science center, and art museum	48	8	-	Informal educators from both institutions	Collaborative prototyping with hands-on testing, peer feedback, group reflection
Grabman et al., 2019	Children's museum	-	12	5	Makerspace educators from institution (full-time staff)	Iterative program design and testing, facilitation video review, reading makerspace articles and group discussion
Cil et al., 2016	Natural history museum	5	1	124	Pre-service teachers who come to the museum on field trips	Visual arts, content-based worksheets
Pyatt et al., 2009	Natural history museum	-	<1	9	Undergraduates with relevant content knowledge for a specific exhibit	Hands-on training on exhibit, group discussion of content knowledge
Allen & Crowley, 2014	Natural history museum	-	5	8	Museum educators (college-	Direct instruction,

Author(s)	Type of institution(s)	Duration of PD (hours)	Duration of PD (months)	Number of participants	Target participants	PD activities
					educated retirees)	group discussion
Piqueras & Achiam, 2019	Natural history museum	-	6	3	Museum educators (all had science backgrounds)	Read and discuss research articles, direct instruction
Webb et al., 2012	Science center	-	10	8	Graduate student scientists to be trained on informal education	Direct instruction, group discussion, exhibit-specific capstone project
Degregoria Kelly, 2009	Zoo	-	6	12	Zoo educators and education department administrators	Action research projects, mentorship with a university researcher
Tran et al., 2013	Various institutions that all used the Reflecting on Practice professional learning program	35	6-14	17	Informal educators from various institutions (e.g., science center, zoo, botanical garden, aquarium)	Peer review of video-taped interactions with visitors journaling, readings, online peer discussions

Note. - indicates the information was not provided by the authors. PD is short for professional development.

Grabman and colleagues' (2019) research on a professional development program at a makerspace in a children's museum reflects some of the desired qualities mentioned previously. The five educators who participated in this program were given many opportunities to reflect on their practice and discuss with each other the values they wanted to focus on in their engagements with museum visitors. Furthermore, this program lasted one year, so educators were given enough time to revisit topics of discussion many times, continually refining their understanding of facilitating learning experiences. Researchers, as instructors of the program, scaffolded learning, so that educators developed a community of practice, including a shared language, co-constructed knowledge of practice, and a desire to improve their practice over time. Being invested in participants as members of a professional community is another desirable quality in professional development programs, as ultimately learners benefit from educators feeling valued. As a result of participation in this program, educators demonstrated increased ownership over their work. They not only engaged with existing theories of learning but developed their own framework for understanding how to better support the kind of learning that occurs in a makerspace.

Saraniero and Kelton (2019) conducted research on a professional development program on math education for art and science museum educators. They looked for ways to improve professional learning experiences for informal educators and found professional development programs should reflect the same values as are present in visitor learning (Kelton & Saraniero, 2019). Over the eight-month program, through observations and interviews, they found educators benefitted from having a space where they could interact with the activities they were expected to facilitate with learners.

Furthermore, participants felt comfortable taking risks and using trial and error, thus modeling the behavior they hoped learners would exhibit. Also, participants were supported to bring their respective discipline-based knowledge (e.g., art or science) to the program, so that participants served as resources to one another. Through hands-on experiences in this professional learning environment, educators were given opportunities to reflect on the learner's perspective and how best to create a safe space for exploration and learning (Saraniero & Kelton, 2019). Researchers also made a concerted effort to build some flexibility into the professional development program, so that educators felt empowered to pursue their own interests and take ownership over their professional learning (Kelton & Saraniero, 2018). Saraniero and Kelton (2019) discussed having "to navigate a tension between specific concrete objectives, on the one hand, and, on the other, the need for open-ended exploration and play with unanticipated topics, ideas, and materials" (p. 548). While professional development programs need some structure and objectives to work towards, having an element of choice is essential and a defining characteristic of the informal education field. For this reason, depth over breadth of topics is encouraged in informal education professional development. This professional development program, then, contained many of the desired qualities supported in the literature.

Tran and colleagues (2013) studied 17 educators from 10 different informal education institutions as they participated in professional development programs that ranged from six to 14 months long. They set out to understand what qualities of professional learning for informal educators were successful. Success was identified by changes in educators' behavior, thinking, language, and participation. The program itself

was designed to foster a sense of professional community by building a common language among participants, developing habits of reflection on practice, and building a learning community in which participants could continue to improve their practice beyond the formal participation in this program. Educators were introduced to research done on informal education, and then participated in discussion with each other, so they could reflect on the ways in which theory connected to their practice and real-life experiences with learners in their home institutions. In addition, educators had the opportunity to reflect on their practice through video data of visitor interactions, readings, journaling, and online discussions with other participants. These various avenues for reflection and discussion in community with their colleagues led them to model this behavior with visitors. Researchers found that participants overall demonstrated engaging visitors in discussion more frequently and asking visitors more open-ended questions about their thinking. The justification for incorporating reflection and discussion into professional development of informal educators is thus two-fold: educators as part of a community of practice need space to collaborate and recommit to their work, and this behavior is directly integrated into visitor interactions, thereby benefitting the learner as well.

A professional development program for informal educators should mirror many of the qualities visitors themselves experience during facilitation interactions, such as focusing on individual interests, leaving room for open-ended experimentation, discussing discoveries with each other, and having an enjoyable experience. In fact, learning becomes more substantial when attached to a positive affect in the learner, so encompassing all the elements that make a professional development program effective

must be an atmosphere of fun (Saraniero & Kelton, 2019). As much as researchers should focus on visitor outcomes as a sign of growth and improvement, they should recognize how valuable it is to be invested in informal educators not only as facilitators of visitor learning but as learners themselves and people with natural curiosities. Informal educators are an instrumental part of an institution's mission to make education more equitable and available to communities, and they deserve high-quality professional support.

Studying Science Identity in a Professional Development Program

Research on science identity has largely focused on learners in formal education settings, and when it does center on informal education, the participants are visitors or students, not informal educators (e.g., Burke & Navas, 2021; Wade-Jaimes. 2021). Research on professional development for informal educators has covered many objectives. Some programs aimed to increase content knowledge in its staff (e.g., Porter & Garcia, 2018; Pyatt et al., 2009). Others hoped to instill a collaborative and exploratory attitude in its educators, which they would display in their interactions with learners (e.g., Allen & Crowley, 2014; Piqueras & Achiam, 2019). However, a gap in the literature exists for analysis on science identity development of informal educators.

Because one of the objectives of the professional development program at the Museum of Physical Sciences, that was context of this study, was engaging learners in identity work, it would follow that educators themselves should have engaged in identity work as a result of participation in this professional learning experience. The program at the Museum of Physical Sciences would be considered high quality by the standards laid out in the literature: being invested in students' and educators' learning, recognizing that

no one person is the expert and that everyone brings something of value to the program, balancing theory and practice, providing opportunities for self-reflection and receiving feedback from others, allowing educators to experience being the learner, balancing structure and flexibility, and occurring over a sustained period of time.

This paper adds to the literature on informal education professional development and on science identity work, which tends to focus on students—this research gives more insight into science identity development of adults outside the formal education setting of a classroom or university. Furthermore, this work focuses on adults who may or may not have aspirations in a STEM field, and current literature focuses largely on students and adults along the STEM pipeline. This work also adds to the literature about how science identity may inform informal educators' efforts to engage other people in science identity work. This research can support the importance of informal education contexts as places where individuals can develop a sense of being a science person, describing how this happens and for whom.

Chapter III: Methods

Research Context

The professional development program for informal educators at the Museum of Physical Sciences aimed to support informal educators in developing skills in practice-based facilitation. Practice-based facilitation refers to engaging visitors in the use of science and engineering practices, such as making observations and conducting experiments, as inspired by those included in the NGSS (NGSS Lead States, 2013). Informal educators were instructed to facilitate science learning experiences with museum visitors in ways that made room for learners to construct their own knowledge and develop identities within science.

The professional development program was implemented as a year-long program. Each year, a cohort of 8-10 program participants were selected through an application and interview process. I analyzed data collected from four of the eight members of the fourth cohort of the program (2020-2021). I was familiar with this program and the museum because I was part of the first cohort. While this earlier experience provided some first-hand experience of the program and instructors, the program had changed considerably between the first year and the fourth. In particular, while the idea of learner-centered instruction and engaging visitors in STEM practices had been a part of the program since the beginning, the construct of practice-based facilitation was better refined over the years. Also, the fourth cohort was the first one that was part of an NSF-funded grant to study and replicate the program to be applied in other institutions.

This program was co-created by the museum and a partner university. The instructors for the program included two full-time museum education specialists and a

professor of education from the partnering university. I served as the primary graduate student researcher, collecting data on the program over the course of the year this study took place.

The program had two components. Participants were enrolled in 12 units of coursework on facilitation and other aspects of informal STEM education, as well as employed as (paid) part-time museum staff working with visitors. The coursework included three hours of class each week with supporting homework assignments. Assignments in class were given with the aim of integrating them into informal educators' practice with museum visitors. Coursework for this program heavily emphasized the performance element of science identity, with most of the time dedicated to instructing participants how to engage learners in STEM practices. The other elements of identity may have been engaged with indirectly or as supplementary instruction, but they were not an intended focus.

The professional development program valued different ways of performing being an informal educator, acknowledging that each participant brought a particular set of strengths to the group, enhancing the experience for everyone. Instructors designed curriculum to provide opportunities to lean about constructivism, identity development, and practice-based facilitation through research articles and group discussions. Additionally, some class time was devoted to peer review and feedback in the form of group discussions of both video-recorded interactions with museum visitors and educators' verbal anecdotes of facilitation encounters. Educators in this program regularly took on the role of the learner by engaging with exhibits and programming both with each other and with visitors during facilitation encounters.

Work on the museum floor was expected to include 20 hours of paid work each week; however, due to circumstances surrounding COVID-19, participants did not always reach 20 hours of work for the week. In fact, due to restrictions stemming from COVID-19, classes met virtually as a synchronous remote course. In addition, the museum was closed for the majority of the program, so participants did not have the opportunity to interact with as many museum visitors face-to-face as previous cohorts had. They then facilitated for two weeks at the beginning of the program when the museum was open, but interaction with museum visitors was minimal, as educators' primary responsibility during this time was making sure all guests were safe and exhibits were sanitized. After this two-week period, the museum closed for several months. They facilitated in person on the museum floor for three months at the end of the program, when the museum was re-opened to visitors. When in-person facilitation was not an option, they also gained experience facilitating field trip activities virtually with both their peers in the program and young learners (e.g., siblings who could be in the same room, doing the activity, without wearing masks).

Participants

Eight participants comprised the 2020-2021 cohort of the professional development program. All eight participated in the study and from the data collected on all participants, I selected four focal participants for this paper. I chose them as representative of their cohort based upon their initial and final interviews. First, I made a comprehensive list of all the qualities and definitions of a science person that all eight participants gave in their entry interviews. I then chose the four participants—Stephanie, Madison, Leah, and Sonya (pseudonyms)—to represent the range of definitions of a

science person that were originally stated by the cohort as a whole. These four participants had varied backgrounds (see Table 2), so they brought different experiences across STEM fields and STEM education to the program. At the beginning of the program, Stephanie and Madison had similar career goals to work as directors/developers of informal education and had similar STEM experiences, but while Madison earned a degree in ecology, Stephanie expressed being more interested in social science research and earned a degree in psychology. Leah stood out as the only one in the cohort to have taught science in a formal education setting and at a college-level and as being the only participant not from the United States. Sonya was still an undergraduate student at the time of the program, and she had never worked in STEM or STEM education. Furthermore, while Madison's, Leah's, and Sonya's career goals remained the same from the beginning to the end of the program, Stephanie changed her goal from being a curriculum developer in a children's museum to working in the education field for a non-profit organization. Together, these four reflect some of the diversity among members of this cohort.

Table 2

Information About Participants Upon Entering the Professional Development Program

	Stephanie	Madison	Leah	Sonya
Career goal	Curriculum developer for a children's museum	Director of education for a science center/aquarium	Establish a science center in her hometown	Doctor
Highest education received	Bachelor of Art (psychology)	Bachelor of Science (ecology and evolution)	Master of Science (discipline unknown)	Bachelor of Science (biology) in progress
Worked in STEM (non-educator)?	Yes	Yes	Yes	No
Worked as an informal STEM educator?	Yes	Yes	Yes	No
Worked as a formal STEM educator?	No	No	Yes	No
Country of residence	United States	United States	The Bahamas	United States
Race/ethnicity	Chinese	-	Black	-
Gender	Female	-	Female	Female
Age	23	-	-	21
Languages spoken	English	-	English	English

Note. – indicates participant declined to provide information.

An additional consideration for choosing to focus on these four participants was that they had some change in their science identity from the beginning to the end of the program based on their final interviews. In contrast, some of the non-focal participants did not have any observable change in science identity over the course of the program and left with largely the same ideas and sense of identity they came in with. Therefore, Stephanie, Madison, Leah, and Sonya made the most sense as the representatives of this cohort for their varied definitions of science person, and they made the most sense as the

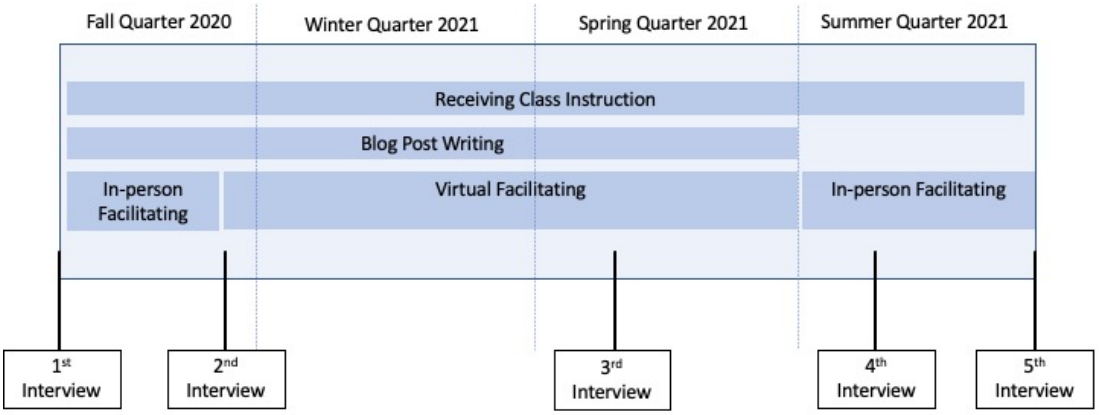
subjects of this study because they demonstrated some changes in science identity during the program.

Data Collection

Data collection for this study spanned the entire year of participation in professional development for this cohort, starting at the beginning of the Fall quarter of 2020 according to the university's calendar through the Summer quarter of 2021. Figure 1 shows the timeline for significant activities and data collection over the course of the year-long program. Data sources included interviews and blog posts (see Table 3).

Figure 1

Timeline of Data Collection for the Duration of the Program



Interviews

I conducted five interviews with each participant over the course of the year-long program (See Figure 1). The 1st (entry) interview occurred within the first week of beginning the program, before participants had an opportunity to explore the museum. In this interview, I asked educators about their ideas around being a science person and

informal science education facilitation. The second (fall) interview occurred after about two months from the start of the program. This interview gave educators an opportunity to reflect and comment on their own facilitation experiences with learners (Davidsson & Jakobsson, 2009; Rennie & Williams, 2006; Tran, 2007). I asked them about details of their interactions with learners, such as their goals for the learner in the encounter and questions and prompts they used with the learner. The third interview (midpoint) occurred about seven months from the start of the program. In this interview, I asked participants the same questions about being a science person as in the first interview. The fourth (summer) interview occurred nine months into the program and focused on the same topics as the second interview. The fifth (exit) interview occurred within the last month of the program. In this interview, I asked the educators many of the same questions from the entry interview both about being a science person and about informal science facilitation, and in addition, educators reflected on their feelings about the program as a whole. All interviews were semi-structured, lasting about 20-60 minutes each. (For interview protocols, see the Appendix.)

Blog Posts

As part of their coursework, educators wrote brief, weekly blog posts about their ideas on and experiences with facilitation based on a prompt provided by the instructors of the program (Degregoria Kelly, 2009; Tran et al., 2013). Participants had access to all blog posts and had the option to read and comment on each other's posts.

Data Analysis

Table 3 describes how each data source contributed to answering the two research questions posed in this paper. The most useful data came from interviews because they

were an opportunity to gather in-depth information about educators' views on science identity as well as their perspectives on and experiences with facilitation. Table 4 lists the interview questions and describes how each question in the interview protocols helped answer the research questions. Many of the interview questions related to the first set of research questions were derived from the work on science identity done by Lucas (2021). It is also due to her research that I asked participants about recognition specifically when I did not ask about any of the other components of identity in this way (See Table 4). Recognition was important to ask out explicitly because of the four components of science identity recognition is the most abstract and least likely to come up in participants' discussions about defining "science person." (K. L. Lucas, personal communication, September 30, 2020). Indeed, I found this to be true. None of the participants discussed recognition until explicitly asked about it. Blog posts also helped answer both research questions as well, as they were written recordings of how thoughts about learning and facilitation evolved over time.

Table 3

Description of Data Collected and Analysis Used to Answer the Research Questions

Research question	Analysis	Data sources
1. How did educators' identities as science people change during participation in an informal science education professional development program?	To show if/how educators' perception of "science person" as a construct and recognition of themselves as science people changed during the program (Tan et al., 2013)	Interview (1st, 3rd, 5th) Blog post (written regularly throughout the program)
	To show if/how educators demonstrated being a science person with learners (Chapman & Feldman, 2017)	Interview (all) Blog post (written regularly throughout the program)
2. How did educators create or aim to create opportunities for learners to be a science person?	To show if/how educators recognized learners as science people (Tan et al., 2013)	Interview (all) Blog post (written regularly throughout the program)

Table 4

Connecting Interview Questions to Research Questions

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
1A) How did their conception of a science person change over the course of the program?	To probe for their definition of who a science person is	What does it mean to you to be a science person?	1st, 3rd, 5th
		What qualities do you associate with a science person?	1st, 3rd, 5th

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
1B) How did recognition of themselves and by others as being a science person change over the course of the program?	To probe for their sense of self within their definition of a science person	Would you describe yourself as a science person?	1st, 3rd, 5th
		Do you think you possess any of the qualities you just described?	1st, 3rd, 5th
		Do you think you possess any qualities that would hinder you from being a science person?	1st, 3rd, 5th
		Can you think of a specific time you did or did not feel like a science person? Can you tell me about it?	1st
		Do you think anyone in your life has seen you as a science person? This can be a teacher, a family member, a friend, etc.	1st
		Have you seen science people either in your personal life or in the media that you identify with?	1st
		What experiences have you had in informal science settings (e.g., museums, after-school	1st

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
		programs, zoos/aquaria)?	
		Do you think being in this program has impacted the way you view yourself as a science person? If yes, which parts of the program were particularly impactful?	3rd and 5th
		Can you describe a time during the program when you felt like a science person?	3rd and 5th
		Can you describe a time during the program when you did not feel like a science person?	3rd
		Can you describe a time before starting the program when you felt like a science person?	5th
1C) How did educators demonstrate different parts of being a science person?	To probe for how they have demonstrated any of the four elements of science identity prior to and during the program	What science experiences have you had?	1st
		What experiences have you had in informal science settings (e.g., museums, after-school programs, zoos/aquaria)?	1st

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
		Think of an exhibit that you have seen at an informal science institution (museum, zoo) that you think is particularly "good" or effective (they can define "good/effective however they want -- good at conveying some science idea, fun, good at engaging people in conversation, etc). What do you think made it effective?	1st
		Can you describe a time during the program when you felt like a science person?	3rd and 5th
		Can you describe a time during the program when you did not feel like a science person?	3rd
2) How did educators create or aim to create opportunities for learners to be a science person?	To probe for how they incorporate any of the four elements of science identity into facilitation experiences with learners	What do you think is the primary role or purpose of informal science institutions like science centers, museums and zoos?	1st and 5th
		How important do you think having content knowledge is for staff when interacting with visitors? For example, having science	1st and 5th

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
		knowledge in a science museum.	
		Think of an exhibit that you have seen at an informal science institution (museum, zoo) that you think is particularly "good" or effective (they can define "good/effective however they want -- good at conveying some science idea, fun, good at engaging people in conversation, etc). What do you think made it effective? If you were working at the museum/zoo that you described above and responsible for facilitating other visitors' experience with the exhibit you described, what would you do? And why?	1st
		What qualities, experiences, or background knowledge do you think you have that will help you when facilitating exhibits at the Museum of Physical Sciences?	1st
		Could you please describe what you think makes a good facilitation encounter?	2nd and 4th

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
		What strategies did you use in your interactions with visitors?	2nd and 4th
		Thinking about this (these) experience(s) do you think they were example(s) of good facilitation? Why or why not?	2nd and 4th
		What was your goal as a facilitator in this situation?	2nd and 4th
		What do you think the visitor took away from this interaction?	2nd and 4th
		Looking back at this experience, is there anything that you would change in your facilitation?	2nd and 4th
		If you were to train someone who had never worked in an open-ended museum like the Museum of Physical Sciences, what advice would you give them?	2nd, 4th, 5th
		is there anything that you came into the program with, like a previous experience or something about your background, that now knowing what's involved in being a science facilitator,	3rd

Research question	Goal of the interview questions	Interview question that answers the research question	In which interview(s) this interview question appeared
		you're really happy you had that experience, like it really helped you in this program?	
		What are your goals in general for visitors? What do you hope they take away?	4th
		What do you think the role of a facilitator is in a space like the Museum of Physical Sciences? How, if at all, do you think this view has changed since starting the professional development program? And, how has that affected your own facilitation practice?	5th

Science Person vs. Science Identity

Throughout this paper the terms "science person" and "science identity" are both used within the findings. Science identity in this case is one part of being a science person. Science identity according the framework used in the analysis of this paper includes competence, performance, recognition, and investment. Participants in this study may have attributed certain qualities to being a science person that would not fit within the definition of science identity and therefore would not be included in the analysis. For example, one participant spoke about a science person needing to be detail oriented.

While science identity was the primary framework used to conduct the analysis, I anticipated that the term science identity might be unfamiliar to participants and so I used "science person" when talking to participants because it would be more easily interpretable, as it would be a term they were more accustomed to hearing colloquially than "science identity." Therefore, all the interview questions that probed about science identity were phrased using "science person." I thought if I phrased interview questions using "science identity," I would have to explain what I meant by that, which would have meant explaining the science identity framework I used for this study. This would have hindered my goal of gaining insight into participants' views on science identity without leading them to a specific answer. Indeed, with the exception of one participant, Stephanie, who asked for clarification on the term "science person," all other members of the professional development program cohort were able to give me a definition for a science person according to their interpretation of the term. Throughout the findings section of this paper, while the data originated from discussions about a "science person," in my analysis I drew out those aspects that related to science identity—competence, performance, recognition, and investment.

Coding

I made codes to consist of two components, including the aspect of science identity and how that aspect was applied with regard to my research questions (Table 5). For example, when Madison recalled an experience she had learning about coral reefs and said, "I began to read scientific journals on the effects of major disturbances vs climate pressures and their effects on the changes in the coral and which was more to cause for the reefs inability to bounce back," I determined that this unit of data was

related to competence, as she referred to gaining more content knowledge through reading journals, and I also determined this was an example of demonstration of competence because it was her own personal experience and a piece of science identity she had displayed (Madison, Oct 6, 2020, Blog Post). Thus, I coded this unit of analysis as “competence: demonstration.”

The codes that include "idea,” “of self/by others,” and “demonstration” related to sub-questions 1a, 1b, and 1c, respectively. The codes that include “facilitation” related to research question 2. In this way, I organized the data according to the science identity framework and according to whether that aspect pertained to a generalized idea of identity, recognizing oneself within an identity, demonstration of an identity, or providing opportunities to learner to assume any of the four facets of science identity. The distinction between the codes used to answer the first research question and the “facilitation” code used to answer the second research question was a necessary one as the professional development program that was the subject of study for this paper was focused on facilitation between informal educators and museum visitors. It stood to reason that participants might have ideas about science identity in a general sense (not restricted to an education setting) and about their own sense of science identity that may differ from their ideas about engaging learners in science identity work. I achieved 80% reliability over 20% of the data with a colleague.

I derived the parts of my codes consisting of “competence,” “performance,” and “recognition” from Carlone and Johnson’s (2007) definition of science identity. However, the “investment” part of my codes emerged from my data. Consistently across participants and over multiple timepoints, I collected data that reflected participants’

belief that an essential part of being a science person was having an interest in or a passion for science. From observing this trend, I created the investment component of science identity, which I define as an external motivation to learn science, which could be an interest, or, for example, it could be wanting to solve a problem in one's community with a scientific solution. These ideas that make up my conceptual framework of science identity—competence, performance, recognition, and investment—comprise the first half of each code in my codebook.

The second half of each code came from my research questions and previous work done on science identity (Lucas, 2021). The competence, performance, and investment codes have the same structure, consisting of "idea," "demonstration," and "facilitation" (See Table 5). This organization of codes by these subcategories was derived from my interview protocols to reflect the kind of responses those questions would elicit. Using interview questions largely from Lucas's (2021) research, I noticed that participants would answer questions about their general ideas about identity, which was the basis for the "idea" codes. These kinds of questions were ones I typically started the interviews with, regarding participants' general conception of the term "science person," and these questions elicited responses about participants' general ideas about identity, not necessarily related to themselves, so I usually coded the data from these questions as "idea" (See Table 4). Furthermore, Lucas gave me the advice to ask for as specific information from participants as possible about their thoughts on identity, which meant asking for anecdotes or personal experiences to support how they may have seen themselves as science people (K. L. Lucas, personal communication, September 30,

2020). Through these kinds of questions that probed about their personal experiences I created the "demonstration" codes.

While recognition is a type of demonstration, just as competence, performance, or investment can be demonstrated, it is distinctly different because Carlone and Johnson (2007) described how recognition is demonstrated in two parts; therefore, in my codebook, recognition follows a different structure than the other three components of identity, consisting of "of self," "by others," and "facilitation." Carlone and Johnson described recognition could be demonstrated by the self or by others, so I made those two distinct codes instead of combining them into a single "demonstration" code. In addition, I predicted that no one would talk about recognition in the abstract general sense when defining the term "science person." That turned out to be correct—no one made any statements to the effect of "to be a science person you have to see yourself as one." Therefore, having a "recognition: idea" code was irrelevant. Instead of coding for idea and demonstration with regard to recognition, I coded for two ways of demonstrating recognition.

With regard to my second research question, about science identity as part of facilitation, all four components of identity—competence, performance, investment, and recognition—had a corresponding "facilitation" code (See Table 5). For example, "recognition: facilitation." In this way, all four components of science identity were coded in the same way for data pertaining to my second research question.

Table 5

Codes and Their Definitions with Examples

Code	Definition	Example
Competence: idea	Attributing being a science person to having science knowledge	"Someone who can name every bird in their area or someone who can tell you why the tides do what they do...Someone who's made their professional life revolve around science."
Competence: demonstration	Showing evidence of science knowledge, or recalling a time they gained/displayed science knowledge	"I began to read scientific journals on the effects of major disturbances vs climate pressures and their effects on the changes in the coral and which was more to cause for the reefs inability to bounce back."
Competence: facilitation	Incorporating/wanting to incorporate science knowledge into facilitation	"This is introing the idea of electricity. And, it starts by asking the question like, "What do we know about electricity?" and then I'm getting ideas from the class."
Performance: idea	Attributing being a science person to practicing science in ways of speaking and doing	"Feeling like you want to understand the world around you in a way that you can collect data on and observe."
Performance: demonstration	Engaging in ways of talking about and doing science, or recalling a time they did so	"We did data collection and looking at what kind of waste, what kind of litter we actually were able to collect to see whether it would be different than it was in previous years."
Performance: facilitation	Incorporating/wanting to incorporate ways of talking about and doing science into facilitation	"My main goal was to get her to learn how to experiment."
Recognition: of self	Identifying oneself as being/not being a science person or as possessing/not possessing the qualities of a science person	"I definitely would consider myself a science person. I think, for me, I like to ask a lot of questions."

Code	Definition	Example
Recognition: by others	Being identified by others as being/not being a science person or as possessing/not possessing the qualities of a science person	"My mom and dad probably the most think of me as a science person. My dad's a doctor, and so when we have scientific conversation, he thrives on that."
Recognition: facilitation	Making explicit statements about guiding a learner rather than instructing or describing the learner's potential for scientific discovery, thus creating space for the learner to recognize themselves and be recognized by others as capable of assuming the identity of "science person"	"As a facilitator, you're more like a guide, not a teacher. And so, I think it's guiding people to get to an answer, rather than as a teacher [who] would tell you the answer to something."
Investment: idea	Attributing being a science person to being personally interested or otherwise invested in science-related subject matter	A science person is "someone who like reads *Scientific American* or gets really excited a big study comes out in *Nature* or something."
Investment: demonstration	Expressing a personal interest/investment in the subject matter	"I love going to zoos, aquariums. Love learning about different animals and species. It's all around us."
Investment: facilitation	Incorporating/wanting to incorporate investment into facilitation, such as through talking about wanting the learner to have fun or get them engaged with an exhibit to get them to stay longer or using the learner's personal background/interests in facilitation to get them invested in the interaction	"I think that their main role is to show individuals whether it's youth or adults, anyone that comes in, that learning can be fun. And that like it shouldn't be intimidating and there should be an excitement about it. And I think that these museums and aquariums and whatever they're doing their goal is to like show there's a fun in the science that they're learning."

Once all the data were coded, I grouped units of analysis according to those second half of the codes, such as "idea," "demonstration," or "facilitation" to compile my

findings for each of my research questions. For example, once I had all a participant's ideas about science identity grouped together from a single interview (competence: idea, performance: idea, and investment: idea), I could determine by code counts or by explicit statements from the participant which element of science identity they most valued as defining a "science person." I conducted this analysis for each interview I conducted with that participant, so I could show a progression over the course of the professional development program of how their emphasis on different parts of science identity changed over time. I grouped the "idea" codes to answer research question 1a. I grouped the "demonstration" codes to answer 1c. I grouped the "recognition: of self" and "recognition: by others" codes to answer 1b. I grouped the "facilitation" codes to answer research question 2.

Chapter IV: Findings: Four Case Studies

Stephanie

Stephanie, the first participant I focus on in this paper, identified her ethnicity as Chinese and her gender as female. She was 23 years old at the time of the program. At the start of the program, Stephanie had earned a bachelor's degree in psychology and aspired to be a curriculum developer at a children's museum. By the end of the program, however, she had slightly changed her career goals to include working in education for a non-profit organization. Before joining the professional development program, she had worked in non-education-related STEM and in informal STEM education.

The changes in her own conception of science identity and in views about how to incorporate science identity into facilitation that Stephanie expressed over the course of the professional development program aligned well. As will be described in this section, Stephanie started out valuing competence, performance, and investment as equally necessary parts of being a science person, but then she shifted to placing more importance on performance, and finally placing the most importance on investment as the core aspects of being a science person in her generalized definition (Table 6). This section will also describe changes in her view of facilitation. Stephanie started out highlighting opportunities to engage learners in investment, briefly prioritized performance early in the program, and then consistently valued investment and recognition for the remainder of the program (Table 7). The main theme with Stephanie across both research questions—how her own science identity changed and how she allowed learners to develop science identities during facilitation encounters—was the investment component of science identity.

Table 6

Aspects of Science Identity Stephanie Emphasized the Most

	Entry	Midpoint	Exit
Definition of science person	Competence + performance + investment	Performance	Investment
Sense of self as a science person	Did not feel like a science person due to weakness in competence	Did feel like a science person due to strength in performance and investment	Did not feel like a science person due to weakness in investment
Own demonstration of being a science person	Investment	Performance	-

Note. - indicates no relevant data was collected.

Table 7

Aspects of Science Identity Stephanie Most Emphasized in Facilitation

	Entry	Fall	Midpoint	Summer	Exit
Opportunities for learners	Investment	Performance + investment	Investment + recognition	Investment + recognition	Recognition

Stephanie's General Definition of "Science Person"

Stephanie had the same three elements of science identity—competence, performance, and investment—within her definition of a science person throughout all three interviews in which I asked about her conception of a science person, from the beginning of the program to the end; however, the relative importance she placed on each of these shifted over time, meaningfully changing her definition from the initial interview to the final one.

Entry

In her entry interview, Stephanie described two kinds of people that could be thought of as science people. One was someone who:

> Enjoys science, someone who reads *Scientific American* or gets really excited when a big study comes out in *Nature*. Or, alternatively, someone who can tell you every bird in their area or someone who can tell you why the tides do what they do. But I feel like the alternative second path is someone who's made their professional life revolve around science, like a nuclear physicist or like someone who researches Zebrafish genetics or something like that. (Stephanie, Entry Interview)

Stephanie described two kinds of science people—first was someone who read science magazines and was excited about new research or was an expert on their backyard wildlife while the second was a professional scientist. The first description focused on the investment component of science identity, the person having a personal interest or motivation to learn about science, as she explained that this person would have a genuine enjoyment of science. She also included the competence piece of science identity, mentioning that the things that this person would be excited about were articles and studies related to science topics, or that this was someone who had a lot of knowledge about something in the realm of science, so content knowledge was important in her definition of a science person. More subtly, she hinted at the performance aspect of science identity in saying that the person with the knowledge of birds would share that with others, and sharing science knowledge within community is an important aspect of

performance. In her second version of a science person, Stephanie put even more emphasis on performance, calling out that a science person would engage in research.

Stephanie then talked further about the investment and performance aspects of science identity as part of her definition of a science person. First, in reference to the investment component, Stephanie mentioned a science person should be curious because "unless you're extremely motivated to learn something, intrinsically, it's hard to sit down and be like, 'Let me learn every single grass type' without enjoying it and wanting to know about it in some way" (Stephanie, Entry Interview). Again, that a science person is someone who enjoys learning came up in her discussion of what defined a science person. She went on to say that a science person would be someone who felt like they "want to understand the world around [them] in a way that [they] can collect data on and observe" (Stephanie, Entry Interview). She called out the practices of collecting data and making observations as a component of being a science person, relating to performance. Ultimately, Stephanie mentioned competence, performance, and investment in her definition of a science person, but competence was the most important to her, as in both statements about investment and performance, these aspects of being a science person were in support of gaining knowledge and an understanding of the world.

When I asked her to give an example of a science person in either the media or her personal life, Stephanie chose Anthony Fauci, saying she appreciated his "approach to disseminating and understanding information that is very backed in 'People did this study, so this is a tangible thing you can do based on that evidence to make life safer and better'" (Stephanie, Entry Interview). In this example, Stephanie associated a science person with possessing knowledge (competence) and then sharing that knowledge with a

wider community (performance) to have a positive impact on people's lives. She brought attention to the competence, or knowledge-having, and performance, the practice of communicating and sharing knowledge, aspects of science identity.

Overall, in her initial definition of a science person, which included science identity, Stephanie recognized competence, performance, and investment were all necessary pieces. Although she talked the most frequently about performance in this first interview, mentioning it four times compared to twice for each of the other two components, she felt each of these three components had to be present for a person to be a science person (Table 8). She valued performance, mentioning things like collecting data, making observations, and disseminating information as things a science person would do. Additionally, she placed importance on competence, gaining and possessing knowledge, and expressed that a science person must feel enjoyment in or otherwise independently motivated to learn science.

Table 8

Stephanie's Summary of General Science Identity in the Entry Interview

Identity component	Quote	Code count
Competence	…someone who can tell you why the tides do what they do	2
Performance	… can collect data on and observe	4
Investment	Enjoys science, someone who reads *Scientific American* or gets really excited when a big study comes out in *Nature*	2

Midpoint

When I spoke to Stephanie about seven months into the twelve-month program to see how her definition of science person had changed, she had shifted her view of a science person to be even more focused on performance, specifically the scientific practices a person engages in, although her definition still included all three elements of science identity she had originally described. She said a science person was "a person who participates in scientific practices, like trying to make observations and using those data to explain the world in some way, like, I think mainly in terms of quantitative and qualitative data" (Stephanie, Midpoint Interview). She identified a science person solely by their ability to engage in scientific practices. Immediately following this response, I asked her which qualities she attributed to a science person. She said, "Observation, a desire to understand things and be curious, and maybe a sort of rationality, a desire to understand things through logic and reasoning" (Stephanie, Midpoint Interview). Here, she hit on performance and investment in a short, succinct response. Observation as a scientific practice related to performance. Being curious and having a desire to understand things was a part of investment.

When I asked her whether being in the professional development program had influenced this change in perception of a science person, she recognized that her definition of science person had indeed changed from her initial interview, saying:

> I think the initial answer I provided was more based in content knowledge and, like, "You can identify these 15 species of birds based on feather patterns and foot shape," or something. And, now, it's more processes or habits of thought that people follow to understand things and reason through things. So, I think that's a

> more inclusive definition that's less like, "You know this versus you don't know this," and more like, "You could figure this out if you had enough time and resources and energy." (Stephanie, Midpoint Interview).

Stephanie recognized that she had previously valued competence more in her idea of a science person and now she placed less importance on it, especially in comparison to how much she valued performance as a key aspect of being a science person. Shifting her definition to focus more on performance also opened up the possibility of being a science person to more people, acknowledging that basing this identity on engaging in scientific practices rather than having and gaining knowledge meant that "science person" became a more attainable identity and thus more inclusive. I asked her to clarify if possessing content knowledge was still a requirement of being a science person, and she explained that if a science person:

> Includes all the practices, there's definitely a subset that's content knowledge for me still, like someone knows a ton about astronomy or natural history. I'll be like, "I guess that person has spent a lot of time studying science. That person is a science person." (Stephanie, Midpoint Interview)

In her initial interview, Stephanie expressed expertise in a field of science was a core component of a science person, but later in the program she had demoted it to a subset of the definition that was not required of everyone with that identity. She further explained her shift in view, comparing how she felt in the professional development program to how she felt being in school previously. She said in school, it was more, "Oh, do you understand what these three types of rocks are?" while in the professional development program, it had been more, "Oh, how do you deepen or broaden the inquiry that someone

already has, like the things they're curious about?" (Stephanie, Midpoint Interview). In the former example, the goal was competence; in the latter, the goal was performance and investment, taking someone's interest or curiosity and following a path of inquiry to explore it more deeply. Overall, Stephanie talked about performance as part of science identity four separate times during the interview, while she only mentioned investment and competence once. Further, she said that competence was no longer a requirement to be a science person (Table 9).

Table 9

Stephanie's Summary of General Science Identity in the Midpoint Interview

Identity component	Quote	Code count
Competence	… there's definitely a subset that's content knowledge for me still, like someone knows a ton about astronomy or natural history	1
Performance	…trying to make observations and using those data to explain the world in some way, like, I think mainly in terms of quantitative and qualitative data	4
Investment	… a desire to understand things and be curious	1

Exit

By the end of the program, Stephanie included competence, performance, and investment in her definition of science person, but it had changed yet again, so that in the end, investment was the most important. Stephanie gave the following definition of a science person in her final interview:

> I feel like a science person could be an enthusiast, like, I don't know, someone who takes people on walks through the Channel Islands and identifies different

> birds while commenting on restoration programs…I also feel like a fifth grader who is really into chemistry sets and bought a microscope to look at bugs would be a science person to me. (Stephanie, Exit Interview)

The first thing Stephanie mentioned was enthusiasm, implying the person needs a degree of personal investment in learning to be a science person. Next, she commented that a science person could also have specified knowledge about something science-related; however, this was not a requirement of being a science person as she pointed out immediately following that that a child who had a genuine interest in chemistry, for example, would also qualify under her definition. Similar to how Stephanie's performance-focused midpoint interview definition of "science person" expanded who she could consider to be a science person, in this updated definition where investment was the defining characteristic, Stephanie saw the potential in children to be science people (something she had not discussed previously). Ultimately, she arrived at a three-part definition, saying, "It's enthusiasm, knowledge seeking, and sustained interest over time" (Stephanie, Exit Interview). She reiterated that enthusiasm and interest (investment) were essential and that it had to be interest prolonged over time, which was a new addition to her definition compared to her previous responses—this idea that a science person is an identity that must be sustained for more than a fleeting moment. She added, "I wouldn't call people 'science people' just because they visit the Museum of Physical Sciences" (Stephanie, Exit Interview). A one-time museum visit would not be enough for Stephanie to consider assigning a science identity to a person. This insight from Stephanie aligned with the concept that any identity needs to be revisited multiple

times over a sustained period. Alongside enthusiasm, the pursuit of knowledge, a part of competence, was also important to Stephanie.

At the end of this final interview, Stephanie mentioned all three components of science identity again. In her final reflection on this idea of science person as it related to her role as a facilitator, Stephanie commented:

> What has changed is more of my idea of how to nurture someone and their interest in science as being encouraging [of] different ways of thought and investigation and thinking very rigorously and analytically about things they're observing and curious about. And, not just, "Oh, I really want you to, I don't know, know a lot about birds. Then, you'll be a science person." It's like more of a process or a way of interacting with the world than a fixed set of knowledge. (Stephanie, Exit Interview)

When thinking about how to help museum visitors see themselves as science people, she ended up deciding to put more emphasis on investment by paying close attention to their personal interests and curiosities while also engaging them in scientific practices (performance), and highlighting process over fixed knowledge (competence). Stephanie ended up mentioning investment twice and competence and performance once each (Table 10). Although she added that, "my definition of science person is still rooted in a knowledge base, I guess, to some degree," this was no longer the most prominent aspect of her conception of science identity (Stephanie, Exit Interview).

Table 10

Stephanie's Summary of General Science Identity in the Exit Interview

Identity component	Quote	Code count
Competence	My definition of science person is still rooted in a knowledge base, I guess, to some degree.	1
Performance	…different ways of thought and investigation and thinking very rigorously and analytically about things they're observing	1
Investment	What has changed is more of my idea of how to nurture someone and their interest in science…	2

Summary

From the beginning of the program to the end, Stephanie shifted from basing her definition of a science person on a combination of competence, performance, and investment to basing it more heavily on performance, and finally primarily on investment. Stephanie began the program talking about science people as needing to have all three components: competence, performance, and investment. By about halfway through the program, Stephanie had prioritized performance, no longer necessitating competence as part of being a science person. Whereas previously, the first thing that came to Stephanie's mind when I asked her for a definition of science person was competence, the idea of gaining and possessing science content knowledge, when I asked her this same thing in the midpoint interview, she immediately started talking about performance, scientific practices. By the end of the program, Stephanie shifted her definition yet again and talked about science people as primarily recognized for their investment and performance and secondarily for their competence, with investment being the most important of all, saying that a science person must be enthusiastic about or interested in science.

Stephanie's Self-Perception as a Science Person

Stephanie's perception of herself as a science person evolved alongside her definition of science person. She went from seeing herself as a science person, at least in some ways, at the beginning of the program to not seeing herself in that way at the end of the program as she shifted her sense of self as a science person from an emphasis on competence, to performance, and then to investment.

Entry

In her entry interview, Stephanie thought there were ways in which she did and did not fit her original definition of a science person. She commented:

> I really enjoy understanding things through observation and reason. But I think the reason I would be reluctant to describe myself as a science person is that it feels like there's some sort of knowledge or expertise that the term carries, and I feel like I'm so bad at identifying birds and trees right now. I feel like it's something I need to work toward and earn. (Stephanie, Entry Interview)

She acknowledged that she enjoyed learning about science (investment) and that she engaged in observation and reason (performance); however, she felt she fell short in terms of knowledge and expertise (competence).

At this time Stephanie viewed a certain level of competence as a requirement of being a science person, so she did not feel comfortable claiming the identity. She did however recount a time she felt like a science person when attending a psychology conference, saying:

> I think I felt like a science person because I could just go up to other people and ask them questions based on their posters or their presentations, or people would

> come up and ask me questions about like the definition of loneliness and the literature, and I could answer them. Maybe that goes alongside the expertise thing. (Stephanie, Entry Interview)

This having and sharing of knowledge, examples of competence and performance respectively, made Stephanie feel like a science person in that moment. Moreover, she felt recognized by others as an expert in the topic she was presenting on, and being recognized by others as possessing a certain identity is key to assuming an identity for oneself. However, even with recognition by others in her field, Stephanie did not consider this singular experience significant enough to assign the label "science person" to herself at the time of the interview. Ultimately, Stephanie did not recognize herself as a science person for reasons related to the competence aspect of science identity but shared some examples of ways in which she fulfilled part of the definition of "science person."

Midpoint

Midway through the program, recall that Stephanie's definition of "science person" started to rely less on competence and more on performance, which led her to recognize herself as a science person, something she had been hesitant to do at the beginning of the program due to a self-perceived lack of scientific expertise. Considering that according to her definition of a science person at this time, they were someone who engaged in scientific practices (performance) and had a genuine curiosity about the world around them (investment), Stephanie more readily associated herself with this definition of science person, saying:

> I think I meet this definition of a science person. I feel like I am very curious, and I like trying to understand things through logic…I feel like something I've noticed

> is that throughout the program, I'm more likely to be like, “Ah, yes, I want to try to observe this thing and understand how it works by perceptible phenomena.” (Stephanie, Midpoint Interview)

While she still mentioned competence by saying she wanted to understand science phenomena, she no longer put as much importance on knowledge possession as she did in her initial interview, so she more easily saw herself as fitting the science person definition. She saw herself as someone who wanted to engage in scientific practices, like observation, and who had an authentic curiosity about the world.

Because Stephanie offered a perception of herself as a science person who leaned more on the investment aspect of science identity, I probed her to think about whether there was a time she felt like a science person for the performance aspect. Stephanie went on to give an example of exploring one of the museum exhibits with another informal educator early on in the professional development program and making observations. The exhibit dealt with thermal energy and heat maps, and they tested different objects to see how they looked under an infrared camera. Stephanie said, “I felt like a science person then, I guess, in terms of trying to use observations to understand things more deeply and carefully” (Stephanie, Midpoint Interview). Stephanie recalled a time she successfully engaged in scientific practices, confirming that this experience with the performance aspect of science identity made her feel like a science person, which reinforced her revised definition of science person that gave more value to performance.

Exit

By the end of the program, Stephanie reflected on how she viewed science person as an identity and what that meant for how she applied it to herself in comparison to how

she applied it to others. Ultimately, Stephanie did not feel she fit the definition of a science person because her definition by the end of the program put the most emphasis on investment over performance and competence. In this regard, Stephanie felt labeling herself as a science person was assuming an identity that was not authentic to her. She still acknowledged she had a natural curiosity for science, but:

> I'm curious about other things more, I guess, like I really like art and literature and music. I feel like I identify more with these things than science. I feel like I can definitely put on the [science person] hat, but I feel like it's not a central part of my identity. (Stephanie, Exit Interview)

Stephanie had shifted to putting so much importance on investment as a core component of science identity that she did not feel she had enough investment to assume that identity. Engaging in this discussion about how taking on the label "science person" implied taking on an identity led Stephanie to also comment about the disconnect between an identity she assigned herself and an identity others assigned to her.

She gave an example of working at an afterschool program since joining the professional development program. While doing an airplane building activity with children in the afterschool program, Stephanie ended up building the best plane, but her boss commented, "'It's not fair. She works at the Museum of Physical Sciences.' I was like, 'That's so funny,' because I guess, now, I'm associated with being a science person because of the Museum of Physical Sciences" (Stephanie, Exit Interview). Even though she did not view herself in this way, Stephanie completely understood how people arrived at this conclusion about her, saying, "It's easier to reduce other people to labels than it is yourself…because the primary way I interact with [museum visitors] reinforces the idea

that they're really enthusiastic about science and over other interests they might have" (Stephanie, Exit Interview). Stephanie felt recognized by others as a science person, but she did not interpret this as a sufficient reason to see herself this way because she viewed her own identity as more complex and not aligned with science enough to make science person a part of her core identity. Furthermore, she acknowledged that she did the same thing to museum visitors that her boss at the afterschool program did to her, assigning someone an identity based on brief experiences and little evidence that that was an identity they would also assign to themselves.

While Stephanie ended up deciding not to recognize herself as a science person, more than just constructing a definition of science person, she came away with a thoughtful view of identity on a higher order and what it means to see yourself one way while others may see you another. The ultimate reason Stephanie did not view herself as a science person was not because she did not fit the definition—recognizing she had a personal interest in science (investment) and the capability to engage in scientific practices (performance)—but because she weighed her feelings about herself as a science person against other possible identities and felt she identified with other ones more strongly, so it was science identity in the context of all other identities that entered the conversation in her final interview, something that she had not explored in previous interviews. Stephanie concluded that no matter how other people viewed one's identity, recognizing oneself in an identity was necessary first and foremost, and she simply did not see herself that way when taking a holistic view of all her identities.

Summary

Throughout the professional development program, Stephanie recognized pieces of a science person within herself, but decided they were not enough to claim a science identity, thus she did not demonstrate the self-recognition aspect of science identity. At the beginning of the program, Stephanie did not view herself as a science person, citing a lack of content knowledge and expertise (competence) even though she felt she had a genuine interest in science. Midway through the program, Stephanie put greater emphasis on performance and acknowledged that she was capable in this area, identifying herself as a science person. By the end, Stephanie still saw herself as invested in science, and capable of performing science and gaining new science knowledge, but she considered investment the most important piece. For this reason, she did not feel comfortable assuming an identity as a science person, saying that although she was interested in science, she had greater interests in other things, and a science identity did not feel significant enough to outweigh other identities.

Stephanie's Demonstrations of a Science Identity

Stephanie recalled moments prior to joining the professional development program as well as some during the program in which she demonstrated the competence, performance, and investment components of science identity. Regardless of her evolving definition of science person and view of herself within that definition, I identified at least one example of competence, performance, and investment as they related to science identity within her recounting of her own science experiences, demonstrating she had almost all the components needed to make up a science identity.

Entry

When I asked Stephanie if she had any experience with science prior to joining the professional development program, the first thing that came to mind were her school experiences, in particular a marine biology internship she had during college. She recalled, the internship "was really exciting because I thought the research was incredibly important. It was about coral health and disease, which I care a lot about" (Stephanie, Entry Interview). Stephanie mentioned performance and investment in this example, saying she conducted research and that it was important. Additionally, she felt she gained some content knowledge out of the experience, commenting, "I could probably identify three kinds of coral'" (Stephanie, Entry Interview). Thus, Stephanie demonstrated three components of science identity through this singular example of a previous science experience. Although she expressed the research process itself ended up being a little too tedious and repetitive to hold her interest, she mentioned she had also done some research in the field of psychology:

> On things like meaning in life and educational motivation and girls in STEM. And, those have been, I think, better experiences, because, I don't know, there's something about trying to understand humans through a databased lens that's really appealing to me. So, yeah, that's the kind of science I've enjoyed most. (Stephanie, Entry Interview)

While Stephanie had the opportunity to develop research skills in both marine biology and psychology, she highlighted her personal investment in the subject matter, referring to the work done on coral as important and to the work done in psychology as the most enjoyable.

Later in the interview, when I asked her about experiences in informal science settings, Stephanie stayed focused on the investment aspect of her experiences. First, she remembered being a volunteer instructor for a program where children learned about the science involved in cooking. The reasons she gave for this experience being memorable were:

> I love to cook…I think it's amazing that science can inform it. Like throw baking soda into your onions, the reaction proceeds faster, and you have caramelized onions a minute sooner than you would have had otherwise. Something that you get to eat and be excited about and all of that. But yeah, I think the science experiences I've had that were most meaningful were very directly experiential in that way. (Stephanie, Entry Interview)

While she mentioned a piece of science knowledge she picked up along the way, competence was not the focus for Stephanie in this experience. Her investment in the hands-on nature of the experience, the excitement it brought to science learning, was the real draw for her.

Similarly, Stephanie recalled the planetarium at the Academy of Sciences in San Francisco as being one of her favorite exhibits she had ever experienced when I asked her for an example of a memorable exhibit. As in the previous example, Stephanie attributed her positive experience to the way the exhibit made her feel, describing:

> It just made me feel like the universe was so incredibly vast and wonderful. I feel like it was a very immersive experience. Like, you just sat and looked up and the entire dome filled with stars and colors and planets. And it felt like we were zooming in and out. And, videos are good, but you don't feel them in the same

> way all the time. So, I feel like that affective aspect was really important to me, even if I don't remember how many stars are in the galaxy anymore. (Stephanie, Entry Interview).

This experience was so memorable for its emotional aspect that Stephanie felt the content knowledge that was passed on during that encounter was negligible in the long run. Coming into the professional development program, Stephanie expressed that she had had opportunities in various settings to develop her competence, performance, and investment in science. However, she focused most heavily on the investment aspects of her past science experiences, explaining that the investment aspect of science was what made these past experiences meaningful, whether it was during a school-related activity or in an informal education setting.

Midpoint

Stephanie recalled on two separate occasions two experiences she had in the professional development program that reflected her engagement in the performance and competence aspects of science identity. First, in a blog post from about three months into the program, Stephanie reflected on an engineering activity the entire cohort of program participants had just done, in which the goal was to design a parachute with the slowest descent possible. Within this single activity, Stephanie described drawing on science knowledge while engaging in scientific practices, saying, "We observed that weight distribution influenced devices' propensity to tip, and that increased surface area slowed the fall rate," and also, "We tested three designs" (Stephanie, Jan 17, 2021, Blog Post). Through this activity, Stephanie demonstrated the competence aspect of being a science person by drawing on her knowledge of how surface area affects the rate of fall of an

object, and the performance aspect of being a science person by conducting an experiment and comparatively testing three different designs.

A few months after this blog post was written, in the midpoint interview, I asked Stephanie if there was a time during the program she could remember feeling like a science person as a result of engaging in scientific practices (performance) because she had been talking about scientific practices as a key component of being a science person. She described an experience she had with a fellow participant in the program at an exhibit centered on thermal energy involving a heated surface and an infrared camera. They were exploring this exhibit very early on in the program before they had formally learned about scientific practices. She explained they were:

> Examining the different types of objects there, like there's some plastic discs, there's some metal ones…We were investigating together like, "Why the metal discs didn't behave like they were expected to," and, "Why they almost reflected unexpected colors." And then, we were trying to figure out, based on that, maybe how the infrared cameras work, like, "Maybe it's about what gets reflected back into the camera on top or stuff like that." (Stephanie, Midpoint Interview)

Stephanie expressed engaging in the scientific practice of conducting investigations in an effort to gain more knowledge about infrared cameras, thus demonstrating a time since joining the professional development program she demonstrated the performance and competence aspects of science identity.

Summary

When Stephanie reflected on her own science experiences prior to joining the program, she focused the most on the affective aspect (investment) of being a science

person. She mentioned performance and competence as well, but she put the most importance on investment and attributed how she remembered feeling during those experiences as the main reason they were memorable. Even though her definition of a science person at this time centered on competence, she demonstrated through her own experiences that investment played a significant role in her conception of science learning, which aligned well with the definition of science person she ended the program with that prioritized investment. When reflecting on experiences during the program, she focused mostly on performance and engaging in scientific practices, but this made sense because the primary focus of the professional development program was to teach science by engaging people in the practices of science. That in the middle of the program Stephanie most readily thought of science experiences that allowed her to engage in those practices stood to reason. With the exception of the planetarium example, competence was mentioned in each recalled science experience but not prominently. Despite declining to view herself as a science person, Stephanie demonstrated over the course of the program that she had engaged with competence, performance, as well as investment in various science experiences, leaving the possibility open to assume a science identity. In the end, however, Stephanie chose not to assume a science identity for herself, so she denied the recognition aspect of science identity. Having a science identity requires all four elements, and Stephanie lacked one of them.

Table 6 shows which aspects of science identity Stephanie placed the most value on in her definition of a science person, her self-concept as a science person, and her demonstrations of being a science person over the course of the professional development program.

How Stephanie Created Opportunities for Learners to Engage in Science Identity Work

Through looking at the ways in which Stephanie viewed facilitation over the course of the program, I inferred which aspects of science identity Stephanie gave the most attention or value to and, thus, which aspects of science identity learners had the most opportunity to engage with when interacting with her. Stephanie started out focusing solely on competence and investment as ways to engage learners in science. Shortly into the program, Stephanie added performance and recognition into her perspective and facilitation practice as well. However, by the end of the program, Stephanie placed the most value on recognition and investment, with performance close behind, and competence the least important.

Entry

Stephanie began the program focusing on the competence and investment aspects of science identity as important components of facilitation. In the entry interview, when I asked her if she thought content knowledge was important for an informal educator to have, she responded, "I definitely want to have the knowledge in case someone wants me to," acknowledging that in certain instances the learner may be seeking factual knowledge about a scientific concept or phenomenon (Stephanie, Entry Interview). Later in that same interview, Stephanie mentioned, "I feel like a lot of [facilitation] is just encouraging people to enjoy the experience" (Stephanie, Entry Interview). She could think of times where having content knowledge (competence) would be useful in a science museum; however, it was not the most important quality of an informal educator, citing the importance of creating an enjoyable experience (investment). Stephanie

expanded on this idea of investment as part of facilitation the day immediately following this initial interview when she wrote a blog post about her first experience exploring the Museum of Physical Sciences. She reflected:

> As a facilitator, I think one of my most important decisions will be how I choose to engage learners. As I played with exhibits, I wouldn't necessarily have wanted to be interrupted with a lecture about sound waves or Newton's laws; I might have simply appreciated being offered different ways to interact with the exhibit to bring new behaviors out of them. I just enjoyed seeing how exhibits reacted to thoughtful play! (Stephanie, Oct 2, 2020, Blog Post)

Before receiving any instruction about how to facilitate in the Museum of Physical Sciences, based on a first impression of the museum, Stephanie felt creating an atmosphere of enjoyment (investment) would be the most important task ahead of her, more important than content knowledge transfer (competence), as she stated that being lectured about science concepts would have been a distraction from her main activity—play.

I gained further insight into Stephanie's initial ideas about how to create learning opportunities for learners in a blog post following her first week in the program in which she described different goals for learners based on their ages. She focused on competence and investment in the entry interview, and she elaborated more on this once she had some experience with the exhibits in the Museum of Physical Sciences. For one exhibit dealing with infrared cameras, she explained that museum visitors could:

> Wonder about how infrared cameras react to different materials, make thermal mosaics, or simply marvel at seeing the imprint of their hands on the globe. I can

> imagine younger visitors getting excited about the multicolored images and older visitors wondering about systematic rules behind temperature inputs. (Stephanie, Oct 10, 2020, Blog Post)

When thinking about the kinds of outcomes learners could have at this exhibit, she associated content knowledge gains (competence) with adults and a fun experience (investment) with children. Thus, at the beginning of the professional development program, Stephanie was most concerned with engaging learners in the competence and investment aspects of science identity, but she prioritized investment and talked about that aspect the most.

Fall

After being in the professional development program for two months, Stephanie expanded her goals for facilitation to include creating opportunities for learners to engage with the performance and recognition aspects of science identity as well. Having had a few experiences facilitating in the museum, during the fall interview, Stephanie recalled an encounter with a girl about seven years old while at a circuit board exhibit. At this exhibit several magnetic wires could be connected to various ports that would make letters on the board light up with different colors depending on the placement of the wires. Stephanie led this girl to the circuit board, saying:

> "Hey, it's one of my favorite exhibits over there." And she was immediately like, "Wow, now it's one of my favorite exhibits, too!" And I was like, "Right now it's all white but you can also make colors which is really cool." And she was like, "I want to make colors." And she was trying to plug and unplug some of the different connectors and was like, "I can't figure out how it works." And I was

like, “What if we just try one like that one, plugging and unplugging. What do you see happen?” And she was like, “Oh yeah I can see the light turning on and off.” And she kind of grasped that the way light turned on was [by] connecting the bottom ones to the top ones, and I guess the next sort of engagement was like, “Can you see any other ways you might be able to get from point A to point B?” And she couldn’t think of any at the time, so then I kind of showed her an example… And she came over maybe like 10 minutes later to say, “I made purple.” And she had showed me the way she made the O turn purple. (Stephanie, Fall Interview)

Stephanie guided this learner to use an exhibit in a new way, and through experimentation (performance) Stephanie led this learner to see how her actions with the wires and connectors caused changes in color and whether the light was on or off. Stephanie’s effort to get this girl to think more deeply about the exhibit was effective, as was illustrated a little later when she came up to Stephanie to show her that she had continued exploring the exhibit on her own (investment) and learned how to make the letter O purple. She engaged this learner in the practices of experimentation and observation while also keeping her interested in the process and inspiring her to continue playing even after Stephanie had moved on to another exhibit. Stephanie commented further that this learner “came up to me at different exhibits and was like, ‘What do I do here? How does this work? Can you show me a trick or something?’” (Stephanie, Fall Interview). Not only did Stephanie’s interaction with this girl inspire her to continue exploring the circuit board but it led her to continually seek out Stephanie’s input at other exhibits, so she could discover new ways to engage with other exhibits too. For this

reason, the investment component of the interaction, Stephanie considered her initial facilitation experience with this learner to be a success.

However, Stephanie knew there was room for improvement. In this case, Stephanie thought her facilitation:

> Was a little too directive like, "Oh, if you plug things in by alternative paths, then something different might happen" …there has to be a balance between, "This is what you can do," and, "This is how you do it." And I think I would have backed off a little bit from, "This is how you do it exactly." (Stephanie, Fall Interview)

Although a successful interaction with regard to performance and investment, Stephanie acknowledged she could have made more room for the learner to come to her own conclusions and try out her own ideas about how to work the exhibit, alluding to the recognition aspect of science identity.

Another facilitation experience Stephanie chose to talk about in her fall interview focused mainly on performance through scientific practices. At an exhibit that involved holding a sensor, so that a drum would beat in rhythm with the person's heartbeat, Stephanie tried to get a couple of kids to test whether the drumbeat was indeed affected by their heartbeats. She asked them:

> "What are some ways you can change your heartbeat?" and one of them started running in place while holding the bar... "I'm going to stand and look at it to speed up my heartbeat." Both of theirs went faster, and they were like, "Oh yeah, that's probably it. Cool." (Stephanie, Fall Interview)

Through Stephanie's prompting, the learners engaged in an experiment and were pleasantly surprised by the results having confirmed their hypothesis that the drumbeat

was in sync with their actual heartbeats. She felt good about this facilitation, saying she accomplished her goal of getting the learners, "To test out an idea, to have a thought about like 'Why am I seeing this thing that's happening?' and then to receive some feedback based on what they did about whether their initial idea might be right" (Stephanie, Fall Interview). In this instance, Stephanie's focus was on creating an opportunity for the learners to engage with the performance aspect of science identity through testing ideas.

Stephanie concluded this interview by revisiting the ideas of investment and recognition. When I asked her to talk about what it would mean to label something as good facilitation, she commented on investment, saying:

> I feel like maybe one of my metrics for the success of facilitation is how much longer the person interacts with the exhibit and how much depth. And also, effectively, how do they feel? Like, are they happy or more stressed out or more curious as a result of me trying to facilitate the exhibit? (Stephanie, Fall Interview)

Stephanie focused on how the learner felt after an interaction to evaluate whether it was good. In reflecting on areas of facilitation she wanted to improve on, Stephanie mentioned she would like to ask "more open-ended questions and maybe [try] less to hint people to the answers which I tend to sometimes do" (Stephanie, Fall Interview). She wanted to work on letting learners come to their own answers in their own time instead of giving them the answers, thus realizing learners' capabilities to think and act like science people, relating to the recognition aspect of science identity.

This focus on recognition was reflected in a blog post Stephanie wrote two weeks after the fall interview when she thought about how her views on informal STEM learning had shifted over the course of the first 10 weeks of the program. She said:

> Coming into the position, I had been somewhat concerned that my unfamiliarity with the physical sciences would hold me back as a facilitator. I am less concerned about this now, given that scientific practices feel deeply rooted in acquiring new information and developing conceptual explanations through observation. I appreciate the idea that visitors might start with different knowledge bases and that I might be able to help them find ways to engage with exhibits that challenge them, nonetheless. (Stephanie, Dec 8, 2020, Blog Post)

Stephanie had broadened her view of science learning by this point in the program and realized that performance through scientific practices could be a way to engage all learners regardless of what science knowledge they entered the museum with. While she had originally been concerned that content knowledge would be a significant part of her role as facilitator, she came to see that existing knowledge of science concepts (competence) had little bearing on the extent to which a learner could engage with scientific practices, thus Stephanie ended the first quarter of the program focused mainly on creating opportunities for learners to engage with performance as well as giving significant attention to investment and wanting to improve on incorporating recognition. This was a sharp contrast to her initial views on facilitation which focused solely on competence and investment. She mentioned performance and investment much more (eight and nine times respectively) than she talked about competence and recognition (two and four times respectively).

Midpoint

At around the midpoint of the professional development program, Stephanie highlighted the recognition and investment aspects of science identity within facilitation. Four months into the program, Stephanie wrote about the role affirmation could play in learning experiences, saying, "I also think that the absence of affirmation might be especially discouraging for learners who interpret silence as negative feedback…Positivity is an important part of my facilitation style, and I'll continue working on affirming people's contributions" (Stephanie, Jan 31, 2021, Blog Post). To Stephanie, positivity as part of the learning process was crucial, confirming how important the investment aspect of science identity was to her.

This point of view was further supported in her midpoint interview with me, three months later, when we talked about how being in the professional development program had influenced her view of who could be a science person. She talked about a time when she volunteered at a science afterschool program, saying:

> I can see kindergarteners, I don't know, building boats and thinking about them and why things float and don't float and asking questions about like, "Why do bubbles go to the top of the bubble wand when I shake it?" And, those are questions and thought processes that I feel like a scientist would use, and I'm like, "Wow, you, just by asking something, you're behaving like a science person, so to speak." (Stephanie, Midpoint Interview)

In contrast to an earlier belief she held, that adults would be more inclined to achieve content learning goals (competence) in a science education setting, and children would be more inclined to enjoy a fun experience (investment) in such a setting, Stephanie now

thought young children could engage in practices by asking questions about things they were observing, thus acting like science people through performance. With this shift in perspective, Stephanie showed that she broadened her view of who could fruitfully engage in science and be a science person, thus incorporating recognition more prominently into her view of facilitation than it had been previously. The data collected in the middle of the program showed that Stephanie's primary foci in how to engage learners in science were investment and recognition, making an effort wherever possible to build learners' confidence around science learning and reinforcing the idea that everyone is capable of assuming a science identity through engaging in scientific practices, thus catering to the recognition and investment aspects of science identity in an interaction could lead to greater engagement with the performance aspect as well.

Summer

About ten months into the program, Stephanie continued to talk a lot about recognition and investment in her summer interview and also paid significant attention to performance. When I asked her how she defined good facilitation, she described two types, saying:

> One is one that makes the guests have more fun or builds rapport [investment]… And, maybe the second type is one that gets people to engage more deeply with the exhibits, like using the scientific practices [performance], or asking questions and answering questions about exhibits or just spending more time. (Stephanie, Summer Interview)

Stephanie categorized two ways facilitation could be successful with one centering on investment and having fun while the other centered on performance and people engaging

in scientific practices. These were the primary ways Stephanie defined good facilitation, showing that she valued creating opportunities for learners to engage in these aspects of science identity.

To illustrate this perspective on facilitation, Stephanie recalled a successful facilitation encounter she had with a learner at an exhibit that spun plastic tubes to produce a sound with the air passing through them and also at a big piano exhibit. Stephanie focused on the performance aspect of this facilitation when reasoning why she considered it successful, saying:

> Asking why questions sometimes provokes the thought, even if it was already brewing, it verbalizes and forces you to explain and think through it a little bit more. For the piano, the [scientific] practices would be conducting an investigation, playing with different strings and identifying the pattern, and I feel like that might be a different type of play that someone might do on their own. I felt like it was successful facilitation my book. (Stephanie, Summer Interview)

Stephanie felt that asking questions as the facilitator would lead the learner to voice their thinking out loud and engage in a scientific practice to better support their thinking. Furthering someone's performance aspect of science identity made for a successful facilitation in her view.

Similarly, Stephanie gave an example of what she would do to create a positive facilitation experience, focused on investment. She explained:

> I might just be like, "Hey, did you know if you hit the piano, it sounds like there's a cow in it?" And, they'll be like, "What?" and then they'll like try to find the cow in the piano by hitting it. And, I feel like those are different kinds of

> facilitation strategies. Like, with kids, if you don't get their attention will just go away. Sometimes it's gauging what keeps their attention and how much attention they have that makes it meaningful. (Stephanie, Summer Interview)

She considered it a meaningful facilitation experience if, for young kids, she was able to prolong their time at an exhibit and keep their attention, perhaps by showing them something cool and exciting, creating buy-in for the exhibit. A little later in the interview, she explained why prolonging a learner's time at the exhibit would be important. She commented:

> If you don't have the time there, then I think it's a lot harder to access the scientific practices. I also feel like it's a sign that curiosity has been unlocked. Instead of just being like, "Okay, this is really flashy and exciting, and then I'll go on to the next flashy and exciting thing," I think it's about, "Hey, what can I do to explore this?" It makes the guest a more active participant, I guess, in the exploration and the processes. (Stephanie, Summer Interview)

In this statement, Stephanie touched on three aspects of science identity: performance, investment, and recognition. She first acknowledged that staying longer at an exhibit could provide a learner with the opportunity to engage in more scientific practices (performance), some of which require deeper, more critical thinking that only becomes plausible if one devotes the time to it. Second, Stephanie talked about a longer interaction implying that the learner had some sort of investment in the experience, that they had tapped into their own curiosity as a motivator for continuing the interaction. Finally, she acknowledged that this kind of experience could lead to a learner becoming a more active participant in the learning and exploration process. In this way, she expressed wanting to

make room for the learner to take ownership of their performance and investment, which could open the door for the learner to reinforce their view of themselves as a science person (recognition).

Furthermore, Stephanie gave an example of when performance and investment could be used in the same encounter, using one to support the other. When I asked Stephanie to explain a bit more why having learners be comfortable with her was important, she said, "I think it's more of being regarded as a playmate almost, and then using that social credibility as a sort of peer [to] these children to be like, 'Hey, have you considered asking this question or investigating this thing?'" (Stephanie, Summer Interview). Stephanie prioritized investment over performance, but as she pointed out here, performance can be better accessed if investment has been firmly established because once Stephanie built a relationship with a learner, she could more seamlessly offer suggestions that would guide the learner to engage in scientific practices. While investment was important to Stephanie, she explained how it could be used in service of other aspects of science identity to create a more holistic science experience.

At the end of the summer interview, when I asked Stephanie what her overall goal for learners was, she expressed that investment and recognition were her top priorities. She responded to me by saying she wanted learners to feel, "They are capable of like building a race car, that they can conduct scientific investigations at a museum or something like that, and giving a little bit of support in those explorations and also lots of positive feedback" (Stephanie, Summer Interview). Building up a learner's confidence in their scientific capabilities (recognition) and allowing them to feel comfortable in a science space, having positive associations with it (investment), were the most important

aspects of engaging learners to Stephanie. For her, recognition and investment were the most important aspects of science identity to incorporate into facilitation as she neared the end of the professional development program.

Exit

At the end of the program, Stephanie still emphasized investment, recognition, and performance in her interactions with learners but also revisited the role of competence, which she had not discussed since the beginning of the program. We began the exit interview by talking about what the primary role of a science museum was. Stephanie commented:

> I feel like the primary role is to get people excited about science. I feel like a lot of the times when people encounter science in school and elementary school, it's very interactive and experiential. And then, as more technical knowledge gets built up, it becomes more about that, and sometimes people start disliking science or not seeing themselves like science people. (Stephanie, Exit Interview)

Stephanie noted the investment and recognition aspects of science identity should be emphasized in science museum learning the most through her discussion of wanting to remedy the feeling of disliking science, a lack of investment, and the feeling of not seeing oneself as a science person, a lack of recognition, both of which may have been negatively impacted by science experiences in formal education. In her view, science museums had the capability of sparking people's interest in science and providing opportunities for people to change the way they see themselves in science. Stephanie went on to explain that science museums like the Museum of Physical Sciences had the capacity to bring "back the play part and also the non-evaluative part" of science

(Stephanie, Exit Interview). Thus, with these initial statements, she put the most emphasis on the ways science museums could support the investment and recognition aspects of a person's science identity.

This perspective was reinforced in the next question I asked Stephanie, which was about what she hoped would be the main takeaway after learners interacted with the museum and its informal educators. She said:

> [Ideally learners would come away saying] 'Wow, science is really cool, and I possess skills that could make me a good scientist.' Not that everyone needs to be a scientist, but it would be cool if people who had those inclinations walked away feeling like that if they hadn't before. But I think more realistically within short visits or maybe repeat visits for members [of the museum] a more realistic goal is to explore things and be curious about things and have fun while becoming more comfortable in science-driven spaces. (Stephanie, Exit Interview)

Stephanie hoped that everyone walked away from the Museum of Physical Sciences with an improved sense of self within a science space, alluding to the recognition aspect of science identity. However, she qualified this expectation by saying not everyone will have put in the time to feel this change, so her more realistic desire for learners was for them to be curious and have fun with science, relating to the investment piece of building a science identity. While Stephanie considered recognition the most important goal for learners, investment was a close second.

When I asked Stephanie when she felt like a science person in her role as facilitator, she referenced moments that included competence and performance. She

described experiences she had had with one exhibit where people tended to have content-based questions. She said if learners approached her at this exhibit and:

> If they ask me [questions] and seem to genuinely want to know instead of being given evasive answers, then, I'll be like, "Hey, it's about alpha and beta waves, and those are electrodes which are registering electrical impulses that your brain is making." And, I feel like, "Wow, I contributed knowledge to their bank, which may immediately seep out, but I did." That feels like maybe something that a science person would do. And, I also feel like when I can guide people through sort of like the scientific method a little bit, like designing mini experiments for themselves and modeling that sort of inquiry. (Stephanie, Exit Interview)

While over the course of the program Stephanie's statements about learners and facilitation experiences did not center on competence, this description she offered toward the end of the final interview showed that competence was nonetheless a satisfying part of her role as a facilitator, using an example of helping people better understand the concepts behind an exhibit to demonstrate a time she felt like a science person. Additionally, this example included references to performance when she said she felt the same way about imparting content knowledge (competence) as guiding a learner to use scientific practices (performance), both of which offered her opportunities to put on the science person "hat" and to help others do the same.

Summary

Even though all four aspects of science identity were mentioned as parts of Stephanie's final views on facilitation, she gave the most weight to recognition, only slightly less to investment, followed by performance, and finally competence. This was

different from her initial statements which focused only on competence and investment. While Stephanie consistently saw the value in giving learners opportunities to engage with the investment aspect of science identity, she shifted from viewing gaining content knowledge (competence) as one of the most beneficial aspects of facilitation for learners to viewing feeling capable of engaging with science and seeing themselves in a science context (recognition) as the most beneficial, and thus the most important aspect of science identity to give learners opportunities to engage with.

Overall, investment played a major role in how Stephanie defined a science person as well as in how Stephanie chose to provide opportunities for learners to assume a science identity. While the other elements of science identity shifted over time, investment—having a genuine interest in or motivation to learn science—remained a constant and important piece of science learning for Stephanie over the entire program. Ultimately, Stephanie's facilitation practice of providing opportunities for learners to take on a science identity and her definition of science identity were well-aligned. She provided opportunities for learners to engage with all four aspects of science identity, but she prioritized those opportunities that were likely to improve a learner's sense of investment, which supported her view of a science person as someone who was primarily identified by their investment in science.

Table 7 contains a summary of which aspects of science identity Stephanie most valued as components of facilitation and creating opportunities for learners to engage with a science identity, and prominently featured at various points throughout the professional development program.

Madison

Madison's definition of science identity in the general sense shifted from investment-based to performance-based (Table 11), so that she prioritized performance for most of the professional development program. With regards to facilitation, while there was an instance early in the program where Madison most valued creating opportunities for learners to engage with the performance aspect of science identity, she ended up focusing primarily on recognition (Table 12).

Table 11

Aspects of Science Identity Madison Emphasized the Most in her General Conception

	Entry	Midpoint	Exit
Definition of science person	Competence + investment	Performance + competence + investment	Performance
Sense of self as a science person	Did feel like a science person due to strength in investment and recognition by others	Did feel like a science person due to strength in performance and investment	Did feel like a science person due to strength in performance
Own demonstration of being a science person	Investment + competence	-	Performance

Note. - indicates no relevant data was collected.

Table 12

Aspects of Science Identity Madison Focused on the Most within Facilitation

	Entry	Fall	Midpoint	Summer	Exit
Opportunities for learners	Investment	Performance + investment	Investment	Recognition	Recognition

Madison's General Definition of "Science Person"

Starting this discussion with how Madison defined "science person" in the general sense, she began the program thinking about a science person as someone with two elements of science identity—competence and investment—but over the course of the program, she added performance to her definition as well. In the end, performance and investment were the defining aspects of being a science person for her.

Entry

In the entry interview, I asked Madison what being a science person meant to her. She responded that being a science person meant:

> Being curious about the world around you and asking questions and really kind of taking that knowledge into your own hands. I think being a science person is wanting to learn more about the world that you're in, whether that's like physical science or nature or anything you can turn into science. (Madison, Entry Interview)

In this definition, Madison referenced the investment portion of science identity when she talked about being curious about the world and having a desire to learn more. She linked this curiosity to content knowledge, thus also referencing competence, offering that there were different fields within science that someone could be interested in such as physical science. She reinforced the investment piece of her definition when she went on to add that a science person "is curious and kind of looks at the world in wonder" (Madison, Entry Interview).

She returned to the idea of competence when I asked her if she could think of anyone she knew who she viewed as a science person, and she used competence as the

hallmark of identifying someone as a science person. She spoke about her dad and sharing science knowledge with him, explaining that he was a geophysicist at Stanford, so they:

> Would have conversations in like car rides to volleyball games and stuff about these science phenomena and whether it was global warming or things that I was curious about in the ocean. He was always someone willing to talk and get curious with me and share his knowledge with me and so he's definitely someone who I see as a "science person." (Madison, Entry Interview)

Her dad was a science person in Madison's eyes because he possessed science knowledge that he shared with her. Both competence and investment were defining characteristics of being a science person in Madison's view, as she made two statements about each of these aspects during this first interview (Table 13).

Table 13

Madison's Summary of General Science Identity in the Entry Interview

Identity component	Quote	Code count
Competence	…share his knowledge with me and so he's definitely someone who I see as a "science person."	2
Investment	… wanting to learn more about the world that you're in	2

Midpoint

By the midpoint interview, about seven months into the program, Madison had been introduced to scientific practices, such as making observations and conducting experiments, which are related to the performance aspect of science identity, so while

keeping competence and investment as parts of her definition of science person, she added performance to the mix. This time when I asked her to define a science person, she began with the investment and competence components, saying, "A science person is someone who is curious and always asking questions. Someone who's interested in science. Someone who's curious about the world [investment] around them and wants to find answers to questions they have about that world [competence]" (Madison, Midpoint Interview). For Madison, a science person had a personal interest in learning about science and wanted to grow their knowledge about the world around them. This was a similar definition to the one she gave in the entry interview, which also included references to competence and investment, but then she added a science person is "someone who's curious, inquisitive, observant, who notices things. Yeah, definitely, observant and curious" (Madison, Midpoint Interview). Madison mentioned being observant as part of the definition of a science person, which I consider part of performance. Later in the interview, she went on to add, "Anyone can be a scientist if you are using those [scientific] practices" (Madison, Midpoint Interview). From these quotes, I determined that she valued performance as a factor in determining whether someone was a science person. By the midpoint interview, Madison had equally incorporated competence, performance, and investment into her definition of a science person, mentioning each three times (Table 14).

Table 14

Madison's Summary of General Science Identity in the Midpoint Interview

Identity component	Quote	Code count
Competence	… wants to find answers to questions they have about that world	3
Performance	Anyone can be a scientist if you are using those [scientific] practices	3
Investment	Someone who's interested in science	3

Exit

By the end of the program, Madison defined a science person similarly to as she had at the midpoint interview. She said, "To me, being a science person is someone that is curious about the world around them and asks questions and tests those ideas." She added this aspect of performance, testing ideas, to her updated definition of a science person, expanding the ways in which she saw a person could perform being a science person. And then, she went on to say a science person "is a critical thinker, who explores their own ideas that follows their own ideas and explores them to get their own answers, kind of paves their own path in their own way, in whatever they're wanting to learn more about" (Madison, Exit Interview). She still included investment ("curious" "wanting to learn more about") and performance ("tests those ideas") in this definition, mentioning each twice, but competence was no longer a focus (Table 15). A science person had to be curious and have a desire to learn more about science, and they had to test ideas and explore.

Table 15

Madison's Summary of General Science Identity in the Exit Interview

Identity Component	Quote	Code Count
Performance	… asks questions and tests those ideas	2
Investment	…being a science person is someone that is curious about the world around them	2

Summary

Madison started out the program not including performance in her definition of science person at all; instead, she focused on competence and investment. Midway through the program she had changed her definition to not only include performance but to make it at least as important as competence and investment, as reflected in the frequency with which she talked about each of these components. If anything, competence, which started out as the most important to her, became the least important of the three, as it was nonexistent in her final definition. In the end, Madison prioritized performance and then investment as the most important characteristics of being a science person.

Madison's Self-Perception as a Science Person

Madison saw herself as a science person throughout the professional development program, but her sense of self within that identity grew stronger by the end of the program than it had been at the beginning. This shift aligned with how her definition of science person changed over time as well, putting more significance on performance and investment. An increased emphasis on performance helped Madison feel even more like a science person than when her definition was based only on investment and competence.

Entry

> In the entry interview, Madison recognized herself as a science person. She said: I think that I get really curious about things, and I consider myself a lifelong learner. Like I love to learn new things, and I'm constantly reading and consuming new information, and, yeah, I think my curiosity about the world hasn't stopped just because my formal education has stopped. (Madison, Entry Interview)

The reasons she gave for feeling like a science person were related to investment and competence. She explained that she was a curious person with a desire to learn more about the world beyond the requirements of formal education (investment) and that she liked to gain new knowledge through reading about science (competence).

Madison recalled that she did not always feel like a science person, however. She talked about her experiences with science in a formal education environment, saying:

> I think, a lot when I was in school, I had a really hard time with learning the harder science principles in formal science settings. And so, when I was in college, I contemplated switching my major from my science background because I was having difficulties with a lot of the harder science classes. I think that the way science is taught sometimes can be really competitive. And so, I think that I felt that I wasn't smart enough, or I wasn't grasping things as fast when I was in college, and so that was a point in my life I felt like I wasn't a science person. (Madison, Entry Interview)

She remembered a time when being a science person meant she had to have content knowledge and gain it quickly. Even though she enjoyed science and learning new things,

the expectations of science learning in formal, higher education led her to doubt her identity as a science person, showing how much importance she had placed on competence as defining that identity. At the time of the entry interview, she identified as science person, basing this on her desire to learn and gain knowledge at her own pace. While she still valued competence in her definition of a science person, she drew a distinction between gaining content knowledge in a university setting and gaining content knowledge (competence) informally, when it was personally motivated (investment).

Another factor that reinforced her recognition of being a science person was that other people in her life viewed her this way (recognition by others). She talked about her family, saying:

> Especially my mom and dad see me as a science person because they've watched me from a young age be really excited about science and about learning and about discovering new things. And yeah, they've really also encouraged that and helped me continue to see myself as someone in science. (Madison, Entry Interview)

Madison's parents recognized the interest in and excitement for science learning in her. Moreover, they encouraged her to hold onto the identity of science person, helping her see herself that way early in her life. Coming into the professional development program, Madison and other people in her life recognized her as a science person for her investment and genuine interest in science. Recognition from other people, thus, was an important factor in allowing Madison to see herself as a science person.

Midpoint

In the midpoint interview, Madison continued to recognize herself as a science person, giving similar reasons related to investment as in the entry interview; however,

she also introduced the idea of performance as a strength of her science identity. She referenced her desire to learn and gain new knowledge, saying, “I definitely would describe myself as a science person. I think I am very curious about the world around me. I’m always asking the question, always looking for answers to those questions, trying to learn more and more” (Madison, Midpoint Interview). She saw the investment aspect of science identity within herself, identifying her own curiosity about the world and her desire to learn more.

When reflecting on ways she might struggle to identify as a science person, she felt she was lacking in competence at times, but made up for it in performance. She described herself as:

> Really creative and stuff like that. I’m always looking to learn, but when it comes to some of the cognitive science things, like math and stuff, I tend to struggle there. So, I think sometimes that hinders me from being able to find those answers on my own, but the cool thing about science is that it’s really collaborative, so someone who has those skill sets can help me learn the things that I’m curious about…I do think I’m a scientist in the way that I think and the practices that I use and the way that I look at the world around me. (Madison, Midpoint Interview)

She talked about not always having the content knowledge expected of a science person and about seeing herself as more so creative. Then, she explained that science could be collaborative, and she would not necessarily need content knowledge (competence) if someone was helping her fill in those gaps. What she did think she could bring to the table were scientific practices and ways of thinking scientifically (performance).

Performance, she felt, was a stronger characteristic of her science identity than competence.

When I asked later in the interview whether there were times during the professional development program that she felt like a science person, she said there were. Specifically, she felt like a science person when engaging in scientific practices and feeling invested in the experience, saying:

> I'm less likely to employ those science practices when I'm uninterested. And so, I feel more like a science person when we're learning about things I'm really passionate about… I think when you're learning about something that you're really interested in, then you're then using those practices, especially when you're exploring phenomena, but I think when there's things you're not as interested in, I feel less like a science person because I'm not delving deeper. (Madison, Midpoint Interview)

When reflecting on the program, Madison focused on times she felt invested in the content and could perform being a science person through practices. For her, these were deeply linked because investment led to greater performance, use of more scientific practices. By this point in the program, Madison felt strongly about herself as science person for the performance and investment aspects of that identity.

Exit

By the end of the program, Madison felt even more strongly about herself as a science person than she had at the midpoint interview. When I asked her whether she identified as a science person, she said:

> I would describe myself as a science person. I think that I am really curious and always looking to learn more. I also, especially through this program, have really employed iteration and testing ideas and then seeing if they work in the classroom and taking away from that and redesigning, like all of those aspects of testing an idea and seeing if it works and making changes, I think, is something that I employ in my job. (Madison Exit Interview)

Similar to previous responses, Madison cited her desire to learn (investment) and engagement in scientific practices (performance) as reasons for identifying as a science person. She felt she could bring a scientific mindset to the work she did at her job every day.

By the end of the program, Madison had incorporated more facets of her personality into her view of herself as a science person. When I asked whether she felt being in the professional development program had affected the way she viewed herself as a science person, she said it had and explained, "I would say before I definitely viewed myself as a creative who was interested in science, and now, I see myself more as a science person who can use creativity" (Madison, Exit Interview). In the entry interview, Madison told me she viewed herself as a science person, but over the course of the program, her definition of science person changed, and the revised definition gave her even more reason to recognize herself as science person. Putting more emphasis on performance and ways of thinking about and doing science allowed Madison to see her creativity as a strength that supported, as opposed to hindered, being a science person, which made her feel more confident assuming this identity.

I then asked which aspects of being in the professional development program she thought had the biggest impact on her changing sense of self as a science person. She said:

> Learning about the practices in general played a big role in it. And then, I think, too, having so much hands-on experience allowed me to have a shift. The more I was doing it and practicing, the more I felt like a science person. (Madison, Exit Interview)

The more opportunities Madison had to perform being a science person through scientific practices, the more she felt assured in her identity as a science person. As with any identity, having repeated opportunities to practice a science identity helped reinforce it. Facilitating science experiences with children helped reinforce this identity too. Madison explained, "If I was encouraging kids that all of them in some way had an inherent scientist within them, then, I was like, 'If that's something I believe, then I have to believe that about myself'" (Madison, Exit Interview). Encouraging other people to view themselves as capable of engaging with science and to feel like they belonged in science helped Madison further support her own capabilities and belonging in science.

I then asked her to think about a time she felt like a science person prior to starting the program. Madison described that feeling like a science person was much more dependent on the specific context before the program, saying:

> I think before, when I was in more life science spaces where I understood things really well [competence], and I picked it up really fast, and I had more of an inherent interest, I felt more like a science person than when I initially started working at the Museum of Physical Sciences because I was intimidated by the

> content that it claims to teach…I feel much more comfortable [now]. And again, it's using physics and chemistry as the mode to teach the scientific practices [performance], and so, the content really is not the emphasis of the curriculum, but it's these ways of thinking that I think I feel really comfortable in. (Madison, Exit Interview)

Prior to joining the professional development program, Madison had based her definition of science person on competence and investment, two things she felt she had in the context of life sciences but not in the physical sciences. As her definition of a science person changed over the course of the program to include performance, Madison realized she could be a science person in any context regardless of her level of competence and existing knowledge because she rooted the identity in performance, in ways of thinking about and doing science, which she could apply to any science topic.

When I asked her to think of a time she felt like a science person during the program, she said in general it had had a big impact on her and the way she viewed the world. Again, she focused on the performance aspect of science identity, saying:

> Because I spend so much time around science and in this space and talking about it, I think that in general I feel like I'm more curious about the world around me. I feel like I do so much more research on things that I have questions about. I feel like I have taken more of an active role in forming my opinions and testing ideas…I think that scientific practices, because I deal with them so much in many ways, have become part of my personality in some ways. I've become more curious, and I ask better questions about things that I read online and explore

those more. So, I think I look at things through a slightly different lens because I've become so ingrained in all that I'm doing. (Madison, Exit Interview)

Investment, being curious, and competence, gaining new information, were still parts of her experience as a science person; however, performance had the biggest impact on her by the end of the program. Engaging in scientific practices, which was the main focus of the professional development program, was the most influential in making her feel like a science person. Madison had many opportunities to engage with the performance aspect of science identity over the course of the program, and she used the scientific practices so much as an informal educator that they became ingrained in how she viewed her life more generally, bringing a scientific mindset into more areas of her life.

Summary

As her definition of science person shifted, so did Madison's view of herself as science person. She grew more confident in assuming that identity over the course of the program because she centered performance more prominently in that identity. She felt more strongly about her capabilities with regard to performance than she did with regard to competence. Additionally, she felt she had sufficient time to develop the performance aspect of science identity, which helped reinforce that a science identity was something she could claim for herself.

Madison's Demonstrations of a Science Identity

Madison demonstrated being a science person through competence, investment, and performance in recollections of science experiences she had prior to starting the professional development program as well as of science experiences she had during the program.

Entry

Madison had a personal interest in science from a young age, and that interest only grew as she got older. She remembered:

> When I was younger, I was really into marine biology and stuff, and so I happened upon working at the Aquarium of the Pacific when I was in high school. And that was where my love for science really started [investment]. I worked in their program for their high school team program probably for three years. And I worked as the volunteer side where we did a little bit of curriculum development and content [competence]. (Madison, Entry Interview)

She demonstrated the investment and competence aspects of science identity in pursuing her personal interest in science and working at an aquarium where she had the opportunity to develop content knowledge-based curricula. She also gave an example of demonstrating the performance aspect of science identity when she told me, "I got my degree in Ecology and Evolution, and so I worked in a lab for a little bit" (Madison, Entry Interview). Madison worked in a lab and conducted research related to her degree in a formal education setting, displaying an instance of performing a science identity. Additionally, earning a degree in the sciences implied a level of content knowledge, further supporting her competence in science. Prior to starting the professional development program, Madison had engaged with the competence, performance, and investment parts of science identity. These examples further supported her claim from this same interview that she had felt like a science person from a young age.

Fall

Once Madison entered the Museum of Physical Sciences, she recalled having fun exploring the exhibits and testing out ideas to try to understand them. Madison reflected on her first visit to the Museum of Physical Sciences in a blog post during the first week of the program. Madison's first impression of the exhibits in the hands-on museum, which had little to no signage explaining the exhibits, was how exciting it was, saying:

> I found [the minimal signage] extremely cool, as it made me feel as if I was discovering the science behind the exhibit on my own, which was much more exciting than if someone had told me exactly what to do and why it happened that way. (Madison, Oct 2, 2020, Blog Post)

Madison's first impression of the Museum of Physical Sciences was how much opportunity it offered for making science exciting and personalized to whatever the individual wanted to explore, which is reflective of the investment aspect of science identity. Madison also appreciated the opportunity to test out her ideas and perform being a science person at various exhibits. She said she:

> Got to do a little trial and error. I also liked how easily it was to understand the exhibits through exploration. Especially with the more mechanical physics like the roller coaster or the race cars, I could see the effects of the changes I made, and the reasons were very straight forward. (Madison, Oct 2, 2020, Blog Post)

Madison's first experience in the museum involved conducting experiments to see how exhibits would react to her manipulation of them.

Her concluding thoughts about her first experience in the Museum of Physical Sciences centered on the investment aspect of science identity. She said, "Ultimately,

today at the museum I got to feel like a kid again and really have fun with science" (Madison, Oct 2, 2020, Blog Post). Madison's first experience with the museum provided her opportunities to demonstrate being a science person through investment and performance.

The following week, Madison wrote a blog post entry about a memorable science experience in an informal education setting, which illustrated how she demonstrated being a science person prior to joining the program, focusing on the competence and investment parts of science identity. She recalled:

> My family took our annual trip to the island of St. John in the USVI. Hurricane Maria had just hit the season before, and we had taken a snorkel boat out to local reef spots that we had snorkeled years prior. The coral makeup had significantly change, it was much less dense and diverse and much of it had bleached. This experience prompted me to ask our guide about the changes in the reef and whether he thought it was due to coral bleaching or the hurricane. He was able to give me some knowledge, but ultimately, I left unsatisfied…I began to read scientific journals on the effects of major disturbances vs climate pressures and their effects on the changes in the coral and which was more to cause for the reefs inability to bounce back. I also began to watch documentaries on coral reefs on Netflix and BBC. This experience of seeing a natural phenomenon first-hand rather than maybe hearing about it in a class or a news article made me have a much greater interest in the topic, because I had a personal connection to the environment and the look of the reef before and after. (Madison, Oct 6, 2020, Blog Post)

Madison talked about a time personal investment in a science phenomenon led her to seek out her own knowledge and better understand the world around her. She continued, "My memorable science knowledge has come from the need to know more and the ability to connect the science I am learning to myself in some way" (Madison, Oct 6, 2020, Blog Post). Early in the professional development program, when Madison thought about what her most memorable informal science education experiences were, she thought of examples centered on gaining more knowledge and connecting science topics to her personal life, so that she felt more invested in the content and more inclined to keep learning.

Exit

While her most memorable science experiences prior to the professional development program were focused on competence and investment, only briefly mentioning performance, Madison felt the most significant aspect of feeling like a science person during the program was performance. She explained, "I think that scientific practices, because I deal with them so much in many ways, have become like part of my personality in some ways" (Madison, Exit Interview). Madison mentioned that she had spent so much time engaging in scientific practices through the many opportunities to facilitate science the program provided. This makes sense because engaging in scientific practices was the main focus of the program, so Madison was meant to spend a lot of her time engaging with them. Even so, for Madison, the performance aspect of being a science person was particularly impactful over this year-long program because they became a part of how she viewed the world in general, not just during facilitation experiences.

Summary

Madison claimed throughout the program that she felt like a science person, and in fact, she had felt that way for most of her life, especially with her parents recognizing her as a science person, too. Through her statements in interviews and in blog posts, Madison showed evidence that throughout her life she demonstrated competence, investment, and performance in various contexts. She always had an interest in marine biology (investment), which came to fruition when she worked at an aquarium where she taught content knowledge (competence). Additionally, she took an interest in coral reefs due to a family trip and used that experience as the motivation to learn more about climate change impacts on coral ecosystems. Once in the professional development program, Madison engaged in scientific practices on a regular basis. In this way, Madison embodied all aspects of science identity: competence, performance, investment, and recognition of herself as well as by others.

Table 11 shows which aspects of science identity Madison placed the most value on in her definition of a science person, her self-concept as a science person, and her demonstrations of being a science person over the course of the professional development program.

How Madison Created Opportunities for Learners to Engage in Science Identity Work

Madison provided opportunities for learners to engage with all four aspects of science identity—competence, performance, recognition, and investment—over the course of the professional development program. However, the importance she put on each aspect changed as she moved through the program. At the beginning of the program,

Madison did not mention performance at all, but she recalled previous experiences in informal science education in which she focused on recognition, competence, and investment. Shortly into the program, she incorporated performance into her facilitation as well. By the end of the program, although she included all four elements of science identity into her facilitation, she placed the most importance on recognition, followed by performance and investment, and finally competence.

Entry

Madison came into the program having incorporated the investment, recognition, and competence aspects of science identity into her facilitation in previous experiences in informal education. When I asked Madison in her entry interview what she thought the primary purpose of an informal science institution was, she said, "[An informal science institution's] main role is to show individuals, whether it's youth or adults, anyone that comes in, that learning can be fun" (Madison, Entry Interview). Madison placed primary importance on the affective aspect of a museum visit, prioritizing investment. She also talked about recognition when I asked her if there was a particular exhibit she remembered as being effective. She recalled an exhibit she facilitated when she worked at the Aquarium of the Pacific, saying:

> At the Aquarium of the Pacific, I worked at the shark tank I thought was really cool because having a hands-on approach and having people be able to touch and feel and learn things was a really cool aspect…I think when you're able to touch and kind of explore, you're able to develop more questions and come to [your] own learning [recognition], versus having something behind a tank with a plaque. (Madison, Entry Interview)

The recognition aspect of science identity was most prominent in this response, as in a facilitator's role, creating space for the learner to do the work and lead the discovery allows them the opportunity to view themselves as capable of engaging with science and helps reinforce how they can see themselves as science people. Madison highlighted that the reason this exhibit was effective was that it led people to come up with their own questions and discover their own answers, allowing them to direct their own learning. The most valuable part of this exhibit for Madison was that it gave individuals the opportunity to be hands-on and gain new information in a more autonomous way, rather than be handed the information.

When I followed up by asking her how she would facilitate this exhibit, she incorporated recognition, investment, and competence into her response. She said:

> I would probably invite them to touch and explore and then ask them if there's anything that came up that they were curious about and questions as like how something felt and ask them open-ended questions about their experience and then have them try and come up with the answers to their questions with their own conclusions. So, if they said like, "The skin is rough," "Why do you think the skin is rough? How could that benefit them maybe?" and have them come up with their own conclusions but give them questions that kind of lead them down an educational path. (Madison, Entry Interview)

Madison imagined she would let the learner's own curiosities lead the exploration, thus allowing learners to engage with the investment aspect of science identity. She would want them to come to their own conclusions about the questions they had, and she would guide them to think more deeply about their ideas, thus incorporating the recognition

aspect into the facilitation. Additionally, she imagined these questions would be about content knowledge and gaining new information about a specific topic, thus incorporating competence. While she spoke about incorporating recognition and competence into facilitation, Madison placed the most importance on investment, which includes the affective aspect of engaging with science, as shown in her first statement, expressing that the primary role of an informal science institution is to show learners that science is cool and fun. This relative importance was also reflected in the frequency with which she talked about each of the three components in this first interview—seven times for investment compared to three and four times for recognition and competence respectively.

Fall

After the program started, Madison kept all three previously mentioned aspects of science identity in her facilitation and added performance, through scientific practices as she learned to do in the program. Before interviewing Madison about her facilitation experiences in the program, I gained insight into how Madison viewed learning as a whole. In a blog post she wrote one month into the program, in which she reflected on what learning meant to her, Madison wrote:

> Learning is the accumulation of new knowledge [competence]. How this knowledge can be accumulated can vary person to person. I think learning is very personal, and the styles and the way people learn vary greatly between individuals. However, one common thread I've notice is that people take ownership of their learning for two main reasons: They are genuinely curious about a topic [investment], or gaining more knowledge about a topic has the

> ability to improve their life in some way [investment]. (Madison, Nov 1, 2020, Blog Post)

Madison felt competence and investment were at the core of learning. The goal was to gain new knowledge, and the motivation to engage in learning stemmed from a personal investment in the subject matter, whether through a genuine curiosity or because the information would impact their life. Recall that investment includes having genuine curiosity or enjoyment in science as well as having a personal investment in the subject matter as it relates to the individual or one's community.

In her interactions with learners on the floor of the museum, Madison recalled instances of facilitation that incorporated all four elements of science identity, providing learners the opportunities to engage with various aspects of being a science person. In the fall interview that occurred two months after the start of the program, she talked about an interaction with a young girl at an exhibit where people could build and race cars, which occurred about six weeks into the program. She gave an example of one of the prompts she gave the girl, saying:

> She noticed that her mom's car went faster, so I asked her what she noticed was different about her mom's car rather than her car. And, she pointed out her mom's car was longer. So, I suggested, "Why don't we go back and see if we can make our car as long as your mom's car?" So, then she went back, and her mom's car was I think a blue, longer car, and then hers was a yellow, longer car. And so, they went back up and raced them again. (Madison, Fall Interview)

Madison led this learner to experiment with variables on her car to try to reach the desired outcome of winning the race. When I asked her more about this experience, Madison explained:

> My main goal was to get her to learn how to experiment. So, it was less about the outcome, about the science content, because of how little she was, but I was just trying to get her to think about other ways that she could test why her mom's car was going faster. (Madison, Fall Interview)

In this interaction, Madison was primarily concerned with getting the girl to test her ideas, an example of making space for a learner to take on the performance aspect of a science identity.

She cited this experience as a good example of facilitation. When I asked her to elaborate on how she could tell when a facilitation encounter went well, she explained it was when, "Kids are responding to my questions and interested in digging deeper and going further and not getting super frustrated or confused by things I'm trying to ask them" (Madison, Fall Interview). Madison focused on the emotional, investment aspect of the encounter to judge whether it was successful because having a positive affect to the experience led learners to go further with their learning. When I asked Madison if there was anything she would have liked to change about this encounter, she said, "I think I kind of led her a little bit too much with the changes in mass. I would have let her experiment more a little bit and have her come to her own conclusions" (Madison, Fall Interview). Madison identified room for improvement regarding the recognition aspect of science identity and allowing learners to feel more in control of their learning and making the space for learners to try out their ideas. Through this one facilitation encounter,

Madison showed that she placed value on getting learners to test their ideas (performance), on sparking genuine interest without causing excess confusion or frustration (investment), and on allowing learners to feel capable of reaching their own conclusions (recognition).

In the second facilitation experience Madison talked about, she focused on competence, performance, and investment. She was at an exhibit that beat a drum in rhythm with the learner's heartbeat. She was interacting with two children at this exhibit, when she asked them:

> What they noticed the Heartbeat Drum was doing, and they said, "It was making beating sounds," and so then, I asked them, "Can you think of something else in your body that beats?" And then the older brother responded, "Your heart." And so, after that I asked them how we could make our heartbeat faster. And, the brother decided that he was going to run laps around the entire room, so he started sprinting laps and came back and put his hands on, and his sister just stayed there because she wasn't interested in running laps. And, he was able to notice. He said that his heart was beating faster than his sister's, and then they got really excited about it. (Madison, Fall Interview)

Madison incorporated performance by leading them to experiment with how to increase a heartbeat by running around and making comparisons between each other's heartbeats. Additionally, she said they were excited about the experience and ability to manipulate the exhibit, which implied investment.

At the end of the fall interview, Madison concluded that an informal educator should be, "A tool that guests can use to find their own answers, so helping them by

using guiding, open-ended questions" (Madison, Fall Interview). Although engaging learners in the recognition aspect of science identity was something Madison admitted to struggling with, in not giving away answers too easily, she acknowledged the importance of this aspect of facilitation and allowing learners to feel in control of their own learning.

Overall, Madison tried to incorporate the performance and investment aspects of science identity into her facilitation practice the most. She valued creating opportunities for learners to engage with the performance aspect of science identity, as this was her primary goal in both facilitation encounters she recounted in this interview. She valued creating opportunities for learners to engage with the investment aspect, as she believed facilitating a positive experience for the learner was important for getting them to interact longer and learn more and that their affect during the encounter was an indication of how successful the facilitation was. Although she mentioned competence as an important part of learning in general, she did not give any examples where this was a prominent aspect of her facilitation experiences. Lastly, she acknowledged the value in incorporating the recognition aspect into facilitation but did not feel she had done this.

Midpoint

Approaching the midpoint of the program, Madison reflected on the things she wanted to improve upon as an informal educator, focusing on performance and recognition. In a blog post written about four months into the program, she said she wanted to learn "how to elevate and engage students in more scientific practices [performance]," and work on "not giving students the answer but rather guiding them to answer their own questions [recognition]" (Madison, Feb 2, 2021, Blog Post). She valued engaging learners in acting and thinking more like scientists as well as guiding learners to

answer their own questions through scientific exploration rather than giving them the information. On the same day, Madison wrote another blog post. This one was about how she defined identity and the role learners' identities played in an informal education space. She wrote:

> By creating a space within the Museum of Physical Sciences where visitors can feel safe to be wrong, to be themselves, and to explore science in a pressure-free way, we allow individuals to have a positive interaction with science [investment], so that they may have a positive science identity. (Madison, Feb 2, 2021, Blog Post)

She viewed one way of fostering a positive a science identity to be to create a positive environment in which to practice that identity, showing that Madison valued providing the right conditions for learners to engage with the investment aspect of science identity.

Three months after these blog posts were written, I conducted the midpoint interview with Madison, in which she talked about the importance of including each of the four aspects of science identity within facilitation in response to my asking about her experience as a science person so far in the program. Regarding the performance aspect she described an activity that focused on engaging learners in scientific practices, and she said:

> People that were doing that activity feel like science people because even though they weren't being bombarded with science content, they were finding science information on their own [competence], based on the things that they were actually curious about [investment] by asking those questions and making observations [performance]. (Madison, Midpoint Interview).

Through engaging in practices, learners gained new knowledge, and they were able to follow their curiosities, thus incorporating opportunities to engage in the performance, competence, and investment aspects of science identity, respectively. To conclude her thoughts, Madison added:

> There's information everywhere that anyone can find if they're really curious. But, if you're not engaging in those science practices, you're not going to find things that you're curious about that you want to learn more about. So, I almost think teaching people to think like scientists leads to that content knowledge on their own. If someone's really curious, they're going to go out and find the stuff that they're interested in. But, if you're dumping science content onto someone who's not interested in that topic at all, and you haven't created a space for them to be interested, they're not going to absorb it anyways. (Madison, Midpoint Interview)

For Madison, these elements of science identity were linked, so that together they created a powerful learning experience. Performing scientific practices was a way for learners to dig deeper into their science learning and discover topics they were genuinely interested in, which led to knowledge acquisition. She explained that without incorporating investment in their facilitation experiences, learners would not have the interest to pursue content knowledge, so any effort to convey information would be less effective.

Immediately following this response, Madison further explained how investment and performance were linked. When I asked her about instances of feeling like a science person in the program, she gave an example of a parachute design activity she did with field trip groups at the museum, saying:

> One can be really excited about the actual building aspect of creating a parachute, and another kid could be really excited about the testing aspect, and they could both be employing science practices in different parts of that activity…I think if you create the right environment, anyone can be interested in anything. (Madison, Midpoint Interview)

In Madison's view, the performance and investment aspects of science identity worked together to give learners autonomy to follow their interests and engage in practices in the ways they wanted to, which led to a greater feeling of being a science person. To Madison, different elements of science identity were intertwined and supported each other. She consistently centered investment in her statements about facilitation.

Summer

At the beginning of the summer interview, which took place about nine months into the program, I asked Madison what she considered good facilitation to be. She responded:

> I think what makes a good facilitation encounter is something that feels memorable and impactful to the guests, so less so of, "Oh, did they learn this content knowledge," but seeing a kid get really excited about something or make a connection to some prior knowledge. (Madison, Summer Interview)

The first thing that came to mind about good facilitation was investment—getting the learner excited or making connections to something in their background. Then, she gave some examples of the prompts she liked to use with learners, such as, "What do you know about this?" "What can you tell me about this?" "Do you know anything about this?" "What comes to mind when you hear this word?" (Madison, Summer Interview).

Through these prompting questions, Madison centered the learner and their experience in the interaction, thus through attending the affective nature of the encounter and trying to make connections to the learners' backgrounds, Madison was allowing learners to engage with the investment aspect of science identity, allowing them to find an entry point into the experience that was personally meaningful.

She moved on to talking about specific facilitation experiences she had had recently, focusing on the ways in which she was able to incorporate competence, performance, investment, and recognition into the interactions. She recalled a summer camp she facilitated with a group of first and second graders. She began the day by discussing electricity and conductivity and trying to elicit kids' initial ideas of what these terms might mean. She recalled one boy volunteered, "'Metal is conductive.' And, I asked him where he got that idea, what does he think conductivity means, and have him elaborate for me more," and eventually she explained to the class "how conductivity works really simply of how electrons flow through metal, and then getting more ideas from the class of what they think some conductive things are, so we got ideas like a metal, a penny, wire, stuff like that" (Madison, Summer Interview). Madison engaged learners in the competence aspect of science identity by discussing a science concept with them and then giving them some information about that concept.

Next, Madison moved onto the performance and investment aspects of the activity. For performance, Madison wanted learners to make predictions and test their ideas. Moreover, presenting science in a fun way was important to her. She provided them with a device that would indicate whether an object was conductive, so she explained:

> I had kids from the class, everyone, pick something that they wanted to test and see if they were conductive and then have them make a guess. Told them, "Doesn't matter if it's right or wrong," but had them make a guess of what they think it's going to be, so that was a wire that someone picked, and they guessed that it was going to be conductive, and then the computer goes off and it says "Conductive," and so we did that with all of the kids. So, I thought it was really cool to have them be able to explore it on their own and get the answers without me telling them yes or no. They got to do this fun, interactive thing with a fun little game that makes this silly little voice that kind of helps them remember more what things are conductive and what aren't, rather than just being like, yes, no. (Madison, Summer Interview)

To Madison, having the students test their ideas (performance) in a fun way (investment) was valuable and made for a more memorable learning experience.

Then, Madison focused our discussion specifically on one individual in the summer camp and how he demonstrated agency in his learning while engaging in scientific practices. A young boy in the class tried to construct a circuit but was having some trouble. He:

> Was trying to figure it out himself, and he was doing that thing where he was testing ideas. I came over, and I was like, "Do you remember which side is negative and which is positive?" and he's like, "I don't really remember." And, I was like, "How do you figure it out?" and he's like, "Well, I know that this side of the battery is positive." And, I was like, "Okay, well, do you think that there's a way you could test it?" and he was figuring it out, putting the light bulb on each

> way and then was starting to put the battery, and he kind of went through this throughout the rest of the activity of trying to figure out which way his light bulb worked. So, it was cool that he was able to think critically. (Madison, Summer Interview)

Rather than giving him the answer about which side of the battery was positive and negative, which would have been easy and quick, Madison took the opportunity to let him find a way to get the answer himself, making space for him to engage with the recognition aspect of science identity and see himself as capable of engaging with science. Madison elaborated more about her goal in this instance of facilitation, saying it was to make him see that:

> He has the tools and that understanding to be able to test both ways out and find out which is the correct way and which way the electricity actually flows, so empowering him to take agency over his own learning. (Madison, Summer Interview)

Madison valued the learner being in control of the experience. Additionally, with this individual, Madison had the opportunity to work with him in another summer camp and saw growth in his science identity. She continued:

> It was cool because we had [him] in both this camp and then another camp, like two weeks later, and he was really shy at the beginning of the week, and by the end of the second camp, he was the first person to volunteer ideas and share stuff that he knew, and stuff like that. So, it was cool to see him grow and evolve and become more confident. And, I think having moments like this where he was able to explore and learn on his own, he became more confident in voicing his own

> ideas, by being able to figure out if they're right or not, and he's valid in his thinking. (Madison, Summer Interview)

She attributed this growth and increased confidence to the repeated opportunities to be recognized as a science person who was capable of figuring out problems and finding answers to questions that she provided for him, such as in the instance of building the circuit.

After giving this example of one individual, Madison talked about facilitation more generally and what she hoped learners came away with after interacting with her. She said:

> I think my goal especially right now and being in camps is really to empower kids to realize that there's a scientist in everyone, and there's science everywhere…I want them to take away when they leave camp [that] they feel empowered about their learning and feeling like, "Science isn't scary, and it's fun, and it's something I actually already know how to do because I ask these questions, and I make observations, and I do all these things all the time at home and in my daily life." (Madison, Summer Interview)

Nearing the end of the professional development program, Madison focused on the investment and even more so on the recognition aspect of science identity, making sure learners felt that science could be fun and that they were capable of engaging in science. Additionally, she mentioned performance by saying that the way learners knew they were doing science was through making observations and asking questions. She made one more statement about scientific practices at the end of the interview, saying:

> I think focusing on practice-based facilitation allows there to be more accessibility to science. It's like when you're focused on content, it feels almost sometimes intimidating, but being able to focus on having guests explore through practices they already do and know those things and have been doing them and showing them that you can apply these to everything and be able to learn anything you want I think is really cool and makes it feel like this information is accessible to people. (Madison, Summer Interview)

For Madison, engaging in scientific practices reinforced the idea that everyone can be a science person and helped support the recognition aspect of science identity. In addition, through performing being a science person, learners could gain more access to content knowledge and improve their competence.

Thus, based on Madison's comments in this interview, she viewed the performance aspect of science identity as linked to the recognition and competence aspects. Towards the end of the program, Madison emphasized recognition the most in the kinds of opportunities she could offer learners to engage in science identity work, saying that incorporating opportunities for learners to recognize themselves as science people was her goal as a facilitation. The importance she put on recognition was also reflected in her mentioning it seven times over the course of this interview, which was more than any of the other aspects of science identity.

Exit

In the final interview, Madison further solidified her emphasis on recognition over other aspects of science identity in facilitation, as she viewed recognition as essential to

access the other three. Madison summed up her view on the role of an informal educator, saying:

> It really is just being there to support kids through trying all these new practices [performance]. So, being able to help them persist through failure or ask better questions, really helping them make their own discoveries [recognition] but without them feeling the frustration or fear of trying to figure it all on their own [investment]. (Madison, Exit Interview)

For Madison, an informal educator was someone who was primarily a support to learners rather than a teacher or instructor, highlighting the importance of incorporating the recognition aspect of science identity into facilitation. An informal educator was tasked with creating a good environment for science learning to take place, which involved providing encouragement to keep trying things out even if some ideas did not work, providing the space to figure things out, and also providing the partnership and positivity needed to keep frustration and fear at a minimum, relating to the investment aspect of science identity.

At the end of the interview, Madison again focused on recognition. I asked Madison what her main goal for a learner would be coming away from an interaction with her. She responded:

> My goals are that they have discovered something on their own that they were curious about, or they've explored something and come to that a-ha moment. And, whether that's a short interaction or a longer interaction where they really get to explore and deepen their practices and all of that, or if it's just a toddler figuring out how to put a car together, right? Like knowing how to fit the two

> pieces together. It's like that's my goal with everything is kids and families and guests in general being able to have those a-ha moments of, "Wow, I did that myself, and I figured that out, and that's really cool." (Madison, Exit Interview)

More than building content knowledge, engaging in practices, or feeling genuine curiosity, Madison hoped learners would make a discovery and feel empowered by that experience. Granted throughout the program, she showed that she valued all four aspects of science identity as essential components of facilitation, but, for Madison, recognition played the most important role in facilitation and was the primary way learners could feel like science people because if they had the opportunities to take charge of their own learning and feel capable in that role of science learner, they could more meaningfully engage with the other three aspects of science identity.

Summary

Over the course of the professional development program, Madison increasingly emphasized recognition as the most important aspect of science identity to incorporate into facilitation. In addition, over time Madison placed less importance on competence and more importance on performance as aspects of facilitation. Meanwhile, she consistently valued investment as an essential part of facilitation because she thought investment was the only way to ensure the learning experiences she facilitated were memorable and impactful for the learner. Even though Madison prioritized recognition, she demonstrated many times over the course of the program that all four aspects of science identity were intertwined and that each played an important role in helping learners feel like a science person as part of her facilitation.

In Madison's own definition of a science person, she focused on performance more than anything else. However, in giving opportunities to learners to develop a science identity, recognition and then investment were the most prominent elements of facilitation. I do not view these as contradictory because how Madison viewed herself as a science person meaningfully differed from how she viewed her role as an informal educator.

When it came to viewing herself as a science person, Madison always felt the investment aspect was a strength of hers. She gave many personal examples of times when a genuine interest or investment in a science topic led to a deeper learning experience. Additionally, she had always viewed herself as a science person, and received recognition from her parents that she was indeed a science person, so recognition was also a strength of her science identity prior to joining the program. However, she did not feel she had enough competence in all areas of science to claim that aspect of science identity. When she was introduced to the idea of scientific practices as a way of being a science person during the professional development program, this opened the door for her to minimize the role of content knowledge and focus on developing skills that she could feel confident about, putting her creativity, which she had originally seen as a hindrance to being a science person, to good use in the scientific method. In my opinion, Madison focused the most on performance in her own personal journey because it was a new aspect of science identity she had not considered before, and, moreover, it was an aspect of science identity that made her feel more comfortable with her shortcomings in competence, making for an all-around stronger sense of science identity than she had started the program with.

On the other hand, when Madison reflected on how she wanted to facilitate science learning and science identity development for others, she focused the most on recognition and investment. While performance was personally significant to her, she could see in the more general sense that performance could only be meaningful for learners once recognition and then investment were firmly established. Madison may have considered performance the defining facet of being a science person, but she acknowledged that in order to access performance, science learners first needed to feel seen as capable of being a science person, and they needed to feel invested in the experience.

Table 9 contains a summary of which aspects of science identity Madison most valued as components of facilitation and creating opportunities for learners to engage with a science identity. and prominently featured at various points throughout the professional development program.

Leah

Leah identified as Black and as female. She was a resident of the Bahamas at the time of the program and largely participated remotely from there. She visited the Museum of Physical Sciences in person for a couple weeks at the end of the program and facilitated on the floor of the museum alongside members of her cohort. Coming into this program, Leah had earned a Master of Science degree and had experience working in a non-education-related STEM field, in formal STEM education, and in informal STEM education. One of her goals throughout this program was to learn how she could start a science center in her hometown.

Leah's sense of science identity as well as her view on how to incorporate science identity into facilitation remained largely the same over the course of the entire professional development program, consistently emphasizing performance and investment, respectively (Tables 16 and 17). However, she recognized that these views had strengthened and improved as a result of being in the program.

Table 16

Aspects of Science Identity Leah Emphasized the Most

	Entry	Midpoint	Exit
Definition of science person	Performance + competence	Performance	Performance
Sense of self as a science person	Did feel like a science person due to strength in competence	Did feel like a science person due to strength in performance	Did feel like a science person due to strength in performance and investment
Own demonstration of being a science person	Performance	Performance	-

Note. - indicates no relevant data were collected.

Table 17

Aspects of Science Identity Leah Most Emphasized in Facilitation

	Entry	Fall	Midpoint	Summer	Exit
Opportunities for learners	Investment	Investment	Investment + recognition	Investment	Investment + recognition

Leah's General Definition of "Science Person"

Leah's definition of a science person remained largely the same over the course of the professional development program, including competence, performance, and

investment as key pieces. Competence and performance were the most important parts of being a science person for her at the beginning of the program, but in the midpoint and exit interviews, performance had become the biggest factor in determining whether someone was a science person.

Entry

In the entry interview, when I asked Leah what being a science person meant to her, she provided a definition that included the competence and performance aspects of being a science person, equally valuing them. She said:

> Well to me, to be a science person, it means that I'm always learning. I have to continually adjust my thinking. I have to continually read research papers and textbooks….As a scientist, I think you have to be willing to look at the data, look at what's changing, look at the research that's happening, and then adjust your thinking. You may not agree with it, you may not even believe it, but if there's proof and there's research that says, "OK, this is where we're at now," then we, I mean, look at this pandemic. Who would've thought? (Leah, Entry Interview)

She focused on gaining new knowledge continually (competence), so that science people would always be reexamining their beliefs. Leah acknowledged that within science new data, new research was always coming out, and interpreting that data to incorporate it into existing knowledge structures fell to the individual. She supported the idea of a science person being someone who engaged in ways of thinking like a scientist in order to expand their knowledge base. She went on to say that science people had "to be willing to be lifelong learners. We have to be willing to discover new things" (Leah, Entry Interview). This idea of constantly trying to gain more information to be better informed

about the world, which relates to the competence aspect of science identity, was central to Leah's initial idea of a science person.

She added another element of being a science person to her definition at the end of her response—helping others be science people and sharing information with them. She recalled an instance of trying to help a friend be more informed about science, and she said:

> I think that people have to be open-minded, but I think we still have to help them understand and yes, you know, you may not be able to read a book, or you may not want to do it this way, but guess what? I can make it easy for you, I can make it fun for you, even. (Leah, Entry Interview).

A core part of being a science person for Leah was communicating scientific information to others (performance) in a way that they would be open to. Interacting with other members of the community is a key part of performance which Leah identified as important to the overall identity of being a science person. At the beginning of the program, competence and performance were both important aspects of being a science person to Leah (Table 18).

Table 18

Leah's Summary of General Science Identity in the Entry Interview

Identity component	Quote	Code count
Competence	I have to continually adjust my thinking. I have to continually read research papers and textbooks.	2
Performance	… I think we still have to help them understand	1

Midpoint

By the midpoint of the program, Leah became more explicit in how much she emphasized performance in her definition of a science person. In the midpoint interview, when I asked Leah what it meant to be a science person, she responded:

> It means that I think scientifically. It means that I engage. I always said that science is all around us. So, I think that we interact with our environment. We are observant. And, of course, to me, being a scientist means that I share these observations and these interactions with people around me, so to be engaged in the environment and observing what's around me, adjusting to what's going on in the environment and trying to always, I guess, be aware of the science around me. (Leah, Midpoint Interview)

Leah mentioned thinking scientifically and engaging in scientific practices, such as making observations, and communicating scientific information (performance), and she also mentioned that a key piece of being a science person is sharing those insights with other people (performance). In Leah's view, because science is all around us, a science person could bring a scientific mindset to many different contexts. Thus, she emphasized performance the most in this definition of a science person.

Next, when I asked her which qualities she thought would be associated with a science person, she again focused on performance. She replied:

> We have to be observant, first of all. We have to be willing to look at the data that you have. Whatever when you observe, you have to be able to look at it and see what does that actually mean, and you have to be able to follow it, and say, "Hey, yes, this is what I observed. This is the data that I got." And then, to me, you have

to be able to also follow it and say, “Well, what does it mean?” (Leah, Midpoint Interview).

Leah emphasized needing to make observations and interpret scientific data and then do something with it. The impact of those interpretations was important to her, so at this point in the program, Leah was focused exclusively on performance as the hallmark of being a science person (Table 19).

Table 19

Leah’s Summary of General Science Identity in the Midpoint Interview

Identity component	Quote	Code count
Performance	We are observant. And, of course, to me, being a scientist means that I share these observations and these interactions with people around me…	2

Exit

By the end of the program, Leah incorporated competence, performance, and investment into her definition of a science person, but she still emphasized performance the most. In the exit interview, Leah’s response to what being a science person meant was:

> To be a science person to me means that you are observant, interested in processes and the way things happen, the way things are done, or the way something works. Yeah, I guess that’s it. You know, you’re interested in the world around us, the science that’s happening around in our own environment. (Leah, Exit Interview).

She thought a science person needed to be observant (performance), and they need to be interested in figuring out different phenomena (investment); moreover, she placed this interest in the context of the person's own environment, implying there also needed to be a sense of investment in one's community and the science that could impact it.

She also included competence in her description of the qualities a science person would possess. She explained that a science person was "looking for answers, thinking, trying to figure things out" (Leah, Exit Interview). She included gaining knowledge as part of being a science person, and then, she connected this to performance as she had done in previous interviews. She said that in terms of being a science person, having science knowledge was "not even halfway there. I mean if you can't be able to share it and bring some joy" (Leah, Exit Interview). For her, having science knowledge served no purpose if it was not shared with others and it had an impact of some kind. Even though she valued gaining new scientific knowledge (competence) as an essential part of being a science person, sharing that knowledge was even more crucial (performance). This was reflected in her mentioning performance twice and competence once (Table 20).

Table 20

Leah's Summary of General Science Identity in the Exit Interview

Identity component	Quote	Code count
Competence	… looking for answers…	1
Performance	… you are observant…	2
Investment	… you're interested in the world around us, the science that's happening around in our own environment.	2

Summary

From the beginning to the end of the program, Leah's definition of a science person firmly revolved around competence and performance, prioritizing performance and ways of thinking and acting like a scientist in one's daily life. The differences from the initial definition of a science person to the final one included the incorporation of investment as a supplementary aspect, and the increased emphasis on performance over competence.

Leah's Self-Perception as a Science Person

Leah had always viewed herself a science person in all respects of science identity—recognition, competence, performance, and investment—however, being in the professional development program gave her the opportunity to develop an aspect of performance that was important to her—her ability to communicate her science knowledge with others and help them understand science. The educator aspect of her science identity was key for Leah. While she felt firm in her sense of self as a science person throughout the program, she acknowledged she had grown in terms of her role as a science educator, which was reflective of her definition of a science person that revolved around being able to share science knowledge with other people, thus focusing on performance.

Entry

Leah expressed in the entry interview that she had always seen herself as a science person and gave examples of the ways other people had recognized her as a science person. When I asked her if she considered herself a science person, she replied, "I hope so, because I say it a lot. And I don't just say it about science things, I think, in

general, we have to be willing to be lifelong learners, we have to be willing to discover new things" (Leah, Entry Interview). She felt she had the open-mindedness required to be a science person, constantly adding to her understanding of the world (competence). Moreover, she felt seen as a science person by other people in her life. When I asked whether anyone in her life had seen her as a science person, she said:

> I have a lot of people think of me as their science guru, I guess…Parents always call and they'll say, "Well, my son or my child has this project and they need to do, and I don't know what to do. I don't know how to help them. Can you help them? Can you walk them through whatever?" (Leah, Entry Interview)

At the beginning of the program, Leah felt secure in her sense of self as science person because she viewed herself that way and because people in her personal life had reinforced this identity as well, coming to her for help teaching their children science and sharing her science knowledge with them (performance).

Midpoint

In the midpoint interview, Leah remained firm in her sense of self as a science person but spoke about how the program had helped her develop the science educator side of her. When I asked whether she felt like a science person, Leah offered:

> I'm observant. My only problem is that a lot of times I feel like I don't follow through on the data. I saw an article that came out the other day, and it said that, I'm not even sure where it was quoted from, but it said that the Bahamas has the best air quality in the world. And I thought, "Okay, overall, that might be true," but I sat here at my desk, and in the last couple of days, before the article was forwarded to me, and I kept having to close my window because I had the smell

> of kerosene. I had to close my window again on a different occasion because someone was spray painting their vehicle. And it was just, it was choking to the point where I had to close my window. Yesterday evening, I had to close my window and actually leave the inside and go outside and look for fresh air because the breeze is blowing, and somebody was burning a fire, and it was coming right into my window again. And so, I feel like I've fallen down as a scientist because of course, here it is that we have an article that's circulating says we have the best air quality in the world, but yet this is happening, and I know it's not just happening in my neighborhood. But to me, my next step needs to be to create an awareness of everybody to understand that this isn't something that we should be doing….It's just hard to be able to, you know, to be able to say, "You know, guys, this isn't good for your health. It's not good for the people around you, for their health." I mean, maybe on a one-to-one basis, I can do it, and I know like I say I have done it before, but one person out of that large community of people who are doing it, it's not really a big impact. So, yeah. I'm not very brave, I guess. (Leah, Midpoint Interview)

Leah felt like a science person in so far as she was able to keep herself informed about the science affecting her community by engaging in practices such as making observing (performance). And then, she was able to make decisions about what should be done to improve her community. However, she felt her shortcoming was sharing that information (performance) and creating a greater community awareness and investment around the science topics that could impact them.

When I asked Leah if being in the professional development program had impacted her view of herself as a science person, she said her feelings about herself had remained largely the same, but she did have the opportunity to work on being a better communicator of science. She commented, "I think I've always felt like a science person… I think that I'm just becoming a better scientist maybe. But yeah, I think the techniques are helping me to improve aspects of helping other people, especially to understand science" (Leah, Midpoint Interview). I asked her to elaborate on how she felt she was becoming a better scientist. Leah explained how learning about the NGSS scientific practices had helped, saying:

> I think I really liked the standards. I like to be able to, you know, observing, the data gathering, the asking questions, and all the rest of that stuff, so I like being able to look at a session or look at an activity that I'm doing and being able to think back or being able to build it in there. (Leah, Midpoint Interview)

Focusing her activities for learners on scientific practices (performance) opened up a new way for Leah to present science learning. This improvement to her teaching helped her feel better equipped as a scientist to support others engaging with science. Improving her sense of self as a science educator contributed to an overall more confident feeling of herself as a science person.

Exit

In the exit interview, Leah recognized herself as a science person, focusing on her embodiment of performance and investment. When I asked whether she felt she had the qualities of a science person, she said, "Yeah, I'm observant. I like to explore. I like to play. I like to experiment. I like to get other people involved in that experimenting"

(Leah, Exit Interview). She talked about being observant and liking to experiment (performance) as part of being a science person, and she referred to science as a form of play (investment).

Summary

While over the course of the professional development program, Leah invoked various aspects of science identity to recognize herself as a science person, she focused the most on performance, especially as it became a more prominent feature of the program. Leah's recognition of herself as a science person remained consistent throughout the program, especially as she said she had always viewed herself in this way. The element of her identity that changed was regarding her role as science educator, which will be more fully explicated in the analysis for research question 2, regarding her incorporation of science identity into facilitation.

Leah's Demonstrations of a Science Identity

Leah offered multiple examples from before joining the professional development program of demonstrating a science identity primarily through her experiences performing being a science person. She included examples of investment and competence as well, but performance was the most commonly cited example of being a science person.

Entry

In the entry interview, I asked Leah what her experience in science had been before joining the program, and she centered her experiences on the performance aspect of science identity. She said:

> I've always worked in science. My first real job was after my associate's degree. I worked in a lab at the university...I guess I just always loved science. I remember my tenth-grade teacher telling me that I asked too many questions, and for me, I guess it was always a thing, but for me, I always thought that if you're gonna learn, you need to ask questions. And currently, I teach part-time at the university, and I also run a hands-on science program for primary school-aged children. And so, you know, my thing is you have to ask questions in order to able to understand. And, I also think kids need to be able to see in order to be able to truly understand, and then they have to be able to get their hands in there. They have to get their hands dirty figuring things out, play with it, manipulate it, in order to be able to really, really see how it's working. (Leah, Entry Interview)

Leah spoke about working in a science lab, conducting research, and about her work as an educator, where she focused her activities with learners on being hands-on and manipulating things to figure them out, both experiences displaying her performance as a science person. She also spoke about always having loved science and being interested in it (investment). Competence played a supplementary role in this recounting in that she had some background knowledge that she taught to kids, and she wanted them to figure things out to arrive at an answer about how things work, but primarily she demonstrated how she engaged in ways of doing science (performance) in her previous experiences.

Midpoint

In the midpoint interview, Leah focused again primarily on performance, but competence and investment also played significant roles in her recollections of science experiences that happened outside the professional development program. In giving an

example of how she was a science person, Leah talked about doing a beach clean-up in her community. She recounted:

> We just celebrated Earth Day, and one of the things that I did was to go on a beach clean-up because 2019, in the Bahamas, we did a ban on plastic bags and other single use plastics…This 2021 beach clean-up was kind of important to me because I wanted to see if there would be changes and what we would find, because the ban went into effect I guess sometime in 2019. And so, being a part of the beach clean-up to me was just following the science, you know, a lot of times we get laws put into place, supposedly to help the environment, but nothing ever changes. And to me, I wanted to be able to see because I always talk to my students about recycling and about the environment and about how we can protect the environment. And so, for me, being able to be there and see what was going on, we did data collection and looking at what kind of waste, what kind of litter we actually were able to collect to see whether it would be different than it was in previous years. And so, that was important to me in terms of, I guess, being able to look at it from a perspective of what we've done in the past, and what we're doing now. Has anything changed? Are we doing better, or are we doing worse, or are we doing the same? (Leah, Midpoint Interview)

In this instance, Leah participated in collecting and interpreting data (performance) for the purpose of evaluating how her community was doing in terms of helping the environment and local ecology. She cared about comparing data from previous years to see whether their attempts to lessen the amount of litter on the beach were successful. Moreover, this work felt important to Leah and to her community (investment).

Similarly, Leah recalled a time she demonstrated performance and investment when she grappled with the problem of air quality in her community. When a friend sent her an article claiming the Bahamas had the best air quality in the world, as introduced above, Leah was critical about this when reflecting on her own experience living there. She recalled:

> I sat here at my desk, and in the last couple of days, before the article was forwarded to me, and I kept having to close my window because I had the smell of kerosene…I had to close my window again on a different occasion because someone was spray painting their vehicle. And it was just, it was choking to the point where I had to close my window. Yesterday evening, I had to close my window and actually leave the inside and go outside and look for fresh air because the breeze is blowing, and somebody was burning a fire, and it was coming right into my window again…I can only speak for where I live. I can't speak for anywhere else. But yeah, to me, if you get this designation of the best air quality that means we shouldn't be doing these things because if we continue to do these things, we're not going to have the best quality for long. So, I feel like, yeah, okay, I'm falling down, I guess, on the science awareness on being able to, yeah, I can observe. I can look at statistics because I've done air quality monitoring before, but when it comes to sharing that scientific data, yeah, I think I fall down on that…When you have so many people who just don't know that it's not a good thing, to burn a fire is not a good thing, you know, I had a brother, a half-brother, who did the spraying of vehicles without proper respiration and proper PPE, and

> he actually developed a brain tumor and died badly, you know, it's like, "Come on, this is not something we should be doing." (Leah, Midpoint Interview)

Leah referenced her performance as a science person in recounting how she has been observant of the environmental impacts within her community, how she has collected and analyzed data related to air quality. Furthermore, she was deeply invested in this topic, not only because it was an issue affecting her local community but because she had a family member die as a result of the pollutants she observed. She acknowledged she could have done better in one aspect of performance—communicating science to other people. Nevertheless, she demonstrated the performance and investment aspects of science identity in this experience.

Additionally, she demonstrated competence when she talked about being a science educator. I asked her about what in her background she thought helped prepare her for the professional development program, and she responded:

> I've got a lot of science background, so a lot of times I find that when you look at the core of the exercise that's being done, you might require a little bit more knowledge than just that core of information. And so, I think that my science background has helped with that. (Leah, Midpoint Interview)

During interactions with learners, Leah felt her science background knowledge (competence) was a plus, allowing her to go beyond the basic, core information needed to facilitate the activity.

Summary

Leah gave many extensive examples of being a science person in her personal life and professional life over the course of these two interviews. She incorporated

competence, performance, and investment into her recounting of past experiences. She connected almost all her science experiences to a personal investment that motivated her to engage with science in the first place. However, she gave the most attention to the ways in which she performed being a science person both through communicating with others about science and through practices such as making observations and collecting and analyzing data.

Table 16 shows which aspects of science identity Leah placed the most value on in her definition of a science person, her self-concept as a science person, and her demonstrations of being a science person over the course of the professional development program.

How Leah Created Opportunities for Learners to Engage in Science Identity Work

Throughout the professional development program, Leah valued creating opportunities for learners to engage with all four elements of science identity—competence, performance, recognition, and investment. However, she consistently prioritized investment over the other three, and by the end of the program, she highly valued investment and recognition over performance and competence as the main ways to create opportunities for learners to take on a science identity.

Entry

At the beginning of the program, Leah believed all four aspects of science identity should be incorporated into facilitation. In the entry interview, I asked Leah what she felt the primary role of an informal science institution was, and she focused on investment and competence. If informal educators cover:

> Topics that [kids] only see in textbooks and explore them and have some hands-on activities with them, number one it's gonna be fun! It's gonna be fun, and if it's fun, they're going to learn. That's my thing, and I think that getting out of the classroom and into a museum is a perfect way to change their mind about science. (Leah, Entry Interview)

Leah's view of an informal institution was that they served two purposes: to extend the learning children received through textbooks in a traditional classroom setting, adding to their knowledge (competence), and to have fun and find a way to be invested in learning science that they may not have been in the classroom (investment).

Later in the interview, Leah spoke about the giving learners the opportunity to engage with the performance aspect of science identity. When I asked her how she would engage with children at a time-release exhibit she had just described as having had experience with at another institution, she said:

> I really, really like to encourage children to observe for themselves, so I would put a couple of questions to them, like, "What do you think is gonna happen when it's five minutes to? What do you think is gonna happen when we hit the hour?" and encourage them to say what they thought would move, what they thought would change, how they thought it would change, and what would happen once everything resets, once the hour resets, what they thought was gonna happen, and to encourage them to give a hypothesis: What's your best guess? What do you think? (Leah, Entry Interview)

Leah's inclination was to lead children to make hypotheses and observe the outcome (performance). Scientific practices were already a part of Leah's perspective on facilitation prior to joining the professional development program.

Next, Leah introduced recognition into her ideas on facilitation. When talking about her love of exhibits, she said that because she liked to try to understand how the exhibits work, "I can then be able to guide people and help them to discover all the fun and all the exciting things that they can learn about this exhibit" (Leah, Entry Interview). Leah described the exhibits as exciting and that people could have fun with them (investment). She also talked about guiding people to their discoveries (recognition), as opposed to giving them the answers right away.

At the end of the interview, Leah reiterated the importance of investment once again. I asked Leah what she hoped to gain through the professional development program. She responded:

> Everybody is not as curious as I am. Everybody may not be as observant as I am, but how do we give everybody who walks in the [museum] door that excitement, that fun experience that they can go away saying, "I had so much fun. I wanna come back. I gotta go back there. I gotta go to another museum. I gotta go visit another science center"? And so, that's the goal for me. (Leah, Entry Interview)

While Leah spoke about how she valued the incorporation of each of the four elements of science identity into interactions with museum learners, she gave the most attention to the investment aspect, mentioning it three times. For her, the ultimate goal was making sure learners had a positive, fun experience, so that they would be more inclined to continue their learning beyond a single museum experience.

Fall

In the fall interview, two months into the program, Leah recounted her initial experiences facilitating at home with various family members, using the techniques she had learned in the program, and she incorporated all aspects of science identity into the encounter. First, she explained that this instance was an opportunity to practice a facilitation technique called visual thinking strategies. This technique was meant to elicit learners' ideas by asking them to make observations and support their explanations of either a still photo or a video of a scientific phenomenon. Thus, Leah's facilitation automatically included performance, as she used the visual thinking strategies talk moves she had learned and asked the participants:

> "What do you see? What do you observe?" and then trying to get all of the persons who I had involved in giving their opinion or giving their view as to what they thought was going on and not trying to give them information, trying to get them to bring their own information, gathering their own information, that kind of thing. (Leah, Fall Interview)

In this description, Leah showed how she incorporated performance through her prompting questions, eliciting learners' observations, but also, she referenced recognition when she said she wanted them to gather their own information instead of giving it to them.

In an instance of practicing visual thinking strategies with her two young nieces, Leah described facilitation that incorporated investment. In this iteration, she used a photo of some school children looking at a solar eclipse using cardboard boxes. Her nieces went through the process of making observations and making guesses as to what

was happening. Leah told me they did not arrive at the correct answer, so at the end of the exercise, she told them it was of a solar eclipse. She then referenced the solar eclipse that happened in the Bahamas a couple years prior and asked them:

> "Did your class go out and look at it, and did your teacher tell you about it?" And they were like "No, no, no," and I was kind of disappointed because I really thought that they would have somehow connected that, because it wasn't that long ago, and, really, that was a big event. I mean it was the first one I can remember in my lifetime, and so it should have been a big thing for their teachers to be like, "Hey, we're gonna go make sure we're ready to see this, to view this," so yeah, that was kind of disappointing. (Leah, Fall Interview)

Unfortunately, Leah's attempt to engage learners with the investment aspect of science identity was not successful in this example, but she showed that she valued making connections between the immediate activity and prior knowledge and experiences learners may have had (investment). Making these kinds of connections are related to the investment aspect of science identity because they may make science learning more relevant to the individual.

When I asked her what she thought participants got out of engaging with visual thinking strategies with her, Leah focused on recognition and competence. She recalled one girl, who offered her opinions, and explained:

> I think that was really important because we always talk about girls, and little girls, not being able to speak their mind, and I think it's important for them to be able to do that, whether they wanna ask a question or whether they wanna answer a question, but you have to feel comfortable to be able to do it. And, you're not

> gonna ask questions or feel comfortable unless you are given an opportunity to express yourself without being judged, without feeling as if someone is grading you all the time. (Leah, Fall Interview)

Leah valued giving learners the opportunity to engage with the recognition aspect of science identity by talking about the need to create opportunities for learners to feel comfortable in a judgement-free zone, particularly for girls in a science space. For Leah, making room for someone to engage in science and take on a science identity required taking their other identities into account, such as acknowledging that a girl may need to build up more confidence than a boy in order to participate to the same extent in science activities. Leah also went on to say that the facilitation "was good in terms of them actually saying 'Yes, I understand the phenomenon that's happening now, and I can link it back to something I've learned, or something that I know,'" showing that she valued learners coming away with a greater understanding of a scientific phenomenon (competence; Leah, Fall Interview).

Leah concluded the interview by revisiting the idea of investment. When I asked Leah what advice she would give to new informal educators, she emphasized investment. She expressed informal educators should:

> Try to listen to what the participants are saying, and then try to gauge the situation. See if the person is eager to move forward, or getting frustrated, or not understanding what's expected, what you're asking of them, because I think that all those things give a negative experience to the participant…I think it becomes a

> negative experience, and they probably won't leave with anything. (Leah, Fall Interview)

For Leah, learning would only be accessible if the learner had a positive experience, so this was of the utmost importance to her. While she incorporated competence, recognition, and performance into her facilitation experiences towards the beginning of the program, she still valued investment the most because without feeling positive about the experience, learners will not come away with any of the other aspects of science identity.

Additionally, Leah gave examples of how she could incorporate different aspects of science identity into facilitation at some of the exhibits at the Museum of Physical Sciences via blog posts. About a week after the fall interview, Leah wrote about an exhibit that used solar energy to spin a wheel. She said, "I think that this exhibit is an excellent way of learning about one the possibilities of solar energy usage. Hopefully it will inspire visitors to continue to explore the uses of solar energy when they leave the museum" (Leah, Nov 30, 2020, Blog Post). Leah recognized an opportunity to convey content knowledge at this exhibit, a way to incorporate competence into facilitation. Next, she talked about an exhibit that runs water through various mechanisms that learners can manipulate. She explained that at this exhibit:

> Guests could look at how the water flows. They could evaluate how heavy objects move versus how light objects move. They could look at which objects sink and which ones float. They could make dams and stop or divert the flow of water. What happens to the water behind the dam? What happens to the water in front of the dam? (Leah, Nov 30, 2020, Blog Post)

At this exhibit Leah could easily imagine learners engaging in scientific practices such as making observations and conducting experiments, thus identifying the possibility of incorporating performance into facilitation. In this blog post, Leah gave a couple examples of how she could imagine incorporating the competence and performance aspects of science identity into facilitation at specific exhibits in the museum.

Midpoint

In the midpoint interview, which occurred seven months from the start of the program, Leah mentioned three of the four aspects of science identity, investment, recognition, and performance, as being important components of facilitation. When talking about the impact the professional development program had had on her, she said:

> It has improved my approach to helping people understand science…When you talk about asking people questions instead of giving them the answers, the program has really helped me to improve in that area. I've always been about trying to help people to get the answers for themselves, but the techniques that I've learned have definitely made it easier. It's given me more tools to be able to do that. Before I would tell my students, "I'm not going to give you the answer." …Now I can say, "Well, what do you think?" or I can use the techniques that I've learned the in class now…because a lot of times I think maybe students might get frustrated because they're taught if they have a question, the teacher's going to give them the answer. That's the first thing. And then secondly, you know, if I say to you, "Well, no, I'm not going to give you the answer," right out, then that means that you realize that you have to do something. But, if I continue to talk to you and have a conversation with you, then I can help you draw out that answer

without you feeling frustrated or overwhelmed because I'm not giving you the answer. (Leah, Midpoint Interview)

Leah's goal in using the facilitation techniques she learned in the program was to help learners not feel overwhelmed by trying to figure out science on their own and becoming discouraged. This is related to investment within science identity—which is in part about leading learners to feel positively about science experiences.

After this response, I asked Leah to clarify why avoiding frustration was important for her as an educator. She continued:

> A lot of times students don't come to you with a question, or they don't come to you saying, "You know, I've really been trying to do so and so, and I can't figure this out." They don't say that. They'll just say, "Well, I don't know how to do this," and they're just gonna throw up their hands…so definitely, being able to step back and not just say, "Okay, this is yours, and you got to figure it out." But to be able to say, "Hey, okay so what is it you're trying to do? Why is it that you want to do that?" because really, what I've also learned is that when we do that, and we ask those questions, it clarifies it for the child as well. It clarifies it for the person you're talking to. It's like sometimes before you even get to the third or fourth question, they were like, "Oh, wait a minute, I didn't do this," or, "I just realized that." So, it's amazing that just being able to actually ask that person those questions puts them in the frame of mind where they're kind of reviewing what they have done…It gives them that opportunity to check themselves and say, "Okay yeah, this is what I need to do to help me," and sometimes they will be

like, “You know what? No, no, I think I got it. I think I can figure it out from here.” (Leah, Midpoint Interview)

Leah recognized that if learners did not feel frustrated, they could spend more time thinking about what they had done and were more likely to problem-solve without assistance. Learners would often come to the realization that they could figure it out on their own (recognition), which would not be possible if they got frustrated and gave up early in the experience. Leah viewed paying sufficient attention to the affective aspect of the interaction (investment) as leading to a greater possibility for learners to recognize themselves as capable of engaging with science; thus, the incorporation of investment set the groundwork for engagement in recognition.

Leah also mentioned performance in this interview, though it played a lesser role in facilitation than investment and recognition. Regarding performance, Leah said since starting the professional development program, she realized she liked the “observing, the data gathering, the asking questions, and all the rest of that stuff, so I like being able to look at a session or look at an activity that I’m doing and being able to think back or being able to build it in there,” (Leah, Midpoint Interview). Leah consistently tried to incorporate the scientific practices (performance) she had learned about in the program into activities she created for children in her afterschool program because engaging in ways of acting like a scientist was an important part of science learning for her. Even though performance played a significant role in Leah’s facilitation practice, ultimately, she emphasized investment and recognition the most at this point in the program.

Summer

By the summer interview, about nine months into the program, Leah valued the incorporation of all four elements of science identity into her facilitation, offering concrete examples of how she had engaged learners in many of these during interactions on the museum floor. First, she talked about the importance of recognition and competence. When I asked her what made for good facilitation, she said that good facilitation was "basically new knowledge, but the participant being able to participate in gaining that new knowledge" (Leah, Summer Interview). In this short statement, Leah mentioned both gaining new knowledge (competence) and the learner actively working to gain that knowledge (recognition), rather than being given it, as the hallmarks of good facilitation.

Next, Leah talked about an experience she had with a ten-year-old boy, which focused on performance and investment, at an exhibit where learners could construct roller coaster tracks. She noticed he was not able to roll a ball and complete the track. The ball would stop short, so she intervened. She asked:

> "Well, what do you think is going on?" He rolled it. I had him look at the fact that there was a white ball and a brown ball and what was the difference between these two balls, and so one was heavier. The white one was heavier than the wooden one. He was using the wooden one all along. And so, he tried the plastic one, the white one. And, it came closer to completing the track than the brown one. And so, that was kind of like, I think something for him. Then, he started using that to test. (Leah, Summer Interview)

Leah began this facilitation encounter by leading the learner to ask questions and bringing his attention to possible variables. He continued to test his track (performance)

with minimal prompting from Leah, and he adjusted the track until he was successful in getting the ball to go from start to finish (investment). Leah explained how she considered this a good interaction, saying:

> It was just about me giving him ideas on things that he could check, or "Did you check this, or did you check that?" or, "Look at this area." And, once I pointed out something to him, like at one point, the peg wasn't all the way into the wall, and it was the ball was jumping at that point, so I said, "Well, what's going on here?" and he looked at it and said, "Oh, the peg's not in all the way," and he fixed it and went on and tested it again. And, it took a while to still get it to fix all the little tiny things that was wrong, but he got it, and he was so happy when he was finished. (Leah, Summer Interview)

Leah led him to experiment and manipulate variables (performance) until he reached his goal. For her, keeping his goal at the center of the interaction was important (investment). This approach of supporting him in what he was already doing was a way of incorporating investment into the interaction and keeping him motivated to engage in scientific practices. Thus, he had opportunities to engage in the performance and investment aspects of science identity through Leah's facilitation.

Another facilitation experience Leah recounted in this interview involved competence and performance. Two adult women were interacting at an exhibit where they could make cars and race them down a track. One of the women kept winning the races, so her friend was wondering why her car lost every time. Leah saw them feeling the weight of the cars to compare, and she offered, "If you really think it's about the weight, you can use the scale, and actually see the difference between the two parts that

you want to use, and then, you can weigh the whole car if you wanted to" (Leah, Summer Interview). She led them to be more methodical about the variable they were testing, in this case weight. Then, a little later in the interaction:

> I talked to them about the track to say that they can change the track. Maybe one car would perform better. Then, she was saying that the track was high on one side, so the one lane was higher than the other lane. (Leah, Summer Interview)

Leah pointed out a new variable they had not considered, so she consistently included performance in her interaction with these two women. She also showed that she valued competence in facilitation when I asked her to reflect on this experience and whether there was anything she would have liked to do differently. She responded that given more time, she believed the learner "would have moved forward in her knowledge (competence) in terms of understanding what makes the car and what makes the car go fast" (Leah, Summer Interview). Leah would have liked the opportunity to incorporate competence into the interaction and add to the experience of manipulating variables by leading the learner to consider what science concepts were related to those variables to explain why the outcomes she observed made sense.

Finally, Leah reiterated investment at the end of the interview. My last question was about what her overall goal for learners was coming away from an interaction with her. She responded:

> For me, it's more about can I help them to get where they trying to go. Every visitor is different. I definitely learned that from being in the museum. They're all different. And, they all are different levels, and they all come there for something different. They all want something different. And so, for me, my point, my thing

> is always, "Okay. How can I help you achieve what it is that you're trying to achieve without telling you and giving you answers and all the rest of that?" (Leah, Summer Interview)

Leah explained that she as the educator did not think she had a goal in mind because the goal was completely learner dependent. Keeping the learner's goals and motivations at the heart of the interaction (investment) was important to Leah. The rest of the important aspects of facilitation, such as not giving away answers (recognition), came after. She offered concrete examples of incorporating or at least wanting to incorporate competence and performance into her facilitation, showing that she valued these aspects as part of science learning and identity work; however, investment remained her top priority.

Exit

At the end of the program, Leah talked about including all four elements of science identity into her facilitation, but prioritized investment and recognition. I began the interview by asking Leah what she thought the role of an informal science institution was. She mentioned competence, performance, and recognition in her response, saying:

> I think it definitely will fill the gaps for a lot of kids, get opportunities to all of the things that they learn in school that they never get to experience that they never get to explore…whether it's a zoo, and they're learning about animals and how animals interact and how they have babies, or even if it's a botanical gardens where they're learning about plants and how plants provide for us as humans…especially because I had a lot of little kids, little tiny kids like maybe under the age of four and watching them put together the cars, watching them watch the balls go round the ball machine. That in itself is a lesson, right? They're

> learning to be observant. They're learning to try to figure out things. I think that is a part of our learning that a lot of our kids are missing. They tend to sit back. They don't observe. They don't try to figure things out. They wait for the answer. And, if you're sitting there waiting for the answer, you're going to miss the whole experience. (Leah, Exit Interview)

In Leah's view, informal science institutions offered opportunities for kids to explore science in ways that they would not normally have in a traditional classroom. In these kinds of educational spaces, kids could build their content knowledge (competence) as well as engage in scientific practices (performance) to figure things out and be an active participant in their learning (recognition).

I then asked Leah what she most hoped learners would come away with after being in a place like the Museum of Physical Sciences, and she focused on investment. She replied:

> I want them to have had fun. I want them to walk away saying, "I didn't get that experiment, but that was cool. I'm going to look that up, and I'm going to come back and see what I can figure out from that, or what I can learn from that" …To me, that's what I think the goal is, to continually learn something new, to continually want to come back, to continually have fun. (Leah, Exit Interview)

Leah believed having fun with science (investment) was key to getting learners to keep learning beyond that immediate interaction or activity. Similar to statements she made in the entry interview, Leah thought long-term about what aspects of the facilitation experiences would lead someone to seek out more, similar experiences. She concluded

engaging in the investment piece of science identity would have the biggest impact, so that was her main goal for learners.

Next, when I asked Leah about how important she thought it was for informal educators to have content knowledge, she spoke about a realization she had as a result of being in the professional development program. She explained:

> It's not about me answering [the learner's] questions. It's about us having a dialogue and figuring it out, more than me just giving them the answer." And, my fear was always that I had to be able to give the answer. And, I realized that I don't have to be able to give the answer. I just need to be able to facilitate us finding out the answer together. (Leah, Exit Interview)

Over the course of the program, Leah had realized that content knowledge, contrary to what she had previously believed, was not essential to be effective in her role as an informal educator. She valued incorporating recognition into facilitation, giving learners the opportunity to engage in mutual exploration to figure out answers to their questions. She further emphasized the recognition aspect of science identity, saying, "As much as people really want the answer, I think they appreciate being able to be walked through the process to find the answer" (Leah, Exit Interview). She thought it would be more beneficial for the learner to be a more active participant in their learning.

Leah combined the ideas of recognition and investment in response to my asking whether her concept about the role of informal educator had changed since starting the professional development program. Leah said her view:

> Has broadened. In my work, I've always believed that we shouldn't give kids the answers. That was always something that I believed. However, my understanding

> of how to get around that has broadened. I used to probably say, "Well, we have to work on this. Let's talk this through. Tell me what you know." And sometimes, it led to kids getting frustrated because they just couldn't pull it out. I couldn't get it out of them the way that I was doing it, I guess. Now, I have a whole arsenal of techniques that I can use to kind of relax the situation to help them to be comfortable, to be able to say "Hey, you know, we can get this done." (Leah, Exit Interview)

Leah saw that the incorporation of recognition and investment into facilitation reinforced one another because through creating a more comfortable and positive atmosphere in which to explore science (investment), learners would be more inclined to keep exploring and finding their own answers (recognition).

When I asked Leah what advice she would give to newly hired informal educators, she reiterated the importance of investment and recognition. First, she spoke about the importance of keeping the learner's goal at the center of the interaction to create a sense of buy-in. She explained:

> Everybody comes to the museum for their own reason. They come to learn. They come to explore. Whatever their reason is, if we're gonna facilitate them, if we're going to help them, then we have to be able to try to understand why they're here. (Leah, Exit Interview)

Leah thought one of the first things an informal educator should understand was that learners' goals and motivations should determine which direction the facilitation went in (investment). She continued to offer another piece of advice, regarding recognition, explaining that learners:

> Are going to want answers, but they will have a better experience if they can figure those answers out on their own, or if you just facilitate and help them to figure out those answers that as opposed to telling them, or explaining to them, what is going on. So, I think that will be the first day advice. (Leah, Exit Interview)

She reiterated that guiding people to their own learning (recognition) was more valuable than simply giving them the answers. Leah thought the most important things informal educators could do when they were starting out was to offer learners opportunities to engage in the investment and recognition aspects of science identity through facilitated learning experiences.

Later in the interview, Leah gave examples of specific experiences she had had in and out of the museum with learners that demonstrated how she incorporated various aspects of science identity into those experiences. First, she recalled an activity she had created for a child's birthday party as part of the science program she had been running for ten years. She described:

> This is a party for kids where I actually called it, "It looks like magic, but it's all science." So, I put together this string of experiments…It's meant to be fun. But, every bit of it is science, and being able to share that and have them at a birthday party having fun, thinking that they're just having fun, but actually they learning, so, when you see their eyes, and they just light up, but they're gonna remember that, and they're going to connect that science, I hope, to the science that they're learning in the classroom. (Leah, Exit Interview)

Leah created a learning opportunity for children that allowed them to build on their content knowledge (competence) and make connections to things they had learned in school as well as have fun during the process (investment).

Additionally, she recalled an experience facilitating a summer camp at the museum, which included the performance, recognition, and investment aspects of science identity. She talked about one boy, who was the youngest in the group, a 5 year old in a group of 7-12 year olds. The engineering activity the kids were engaged in that day was constructing parachutes that had a slow descent. Leah described:

> He was like, "I don't know. I don't want to start. I don't know what I'm supposed to do." So, I sat down with him. I said, "Remember what we did with the parachute," and I said, "What did you find out when you made your three parachutes?" and he gave me information back. And I said, "So, what made the parachute work?" So, I said, "So, this is the material that you have now. How can you take the material that you have now and make something similar that would deliver this coin to the ground slowly?" and I could see the wheels start to turn. (Leah, Exit Interview)

Leah reminded this boy that he already had the knowledge and the tools necessary to do the activity (recognition). She gave him the opportunity to see himself as capable of accomplishing this engineering task (recognition). At the end of the activity, Leah noticed:

> Out of all the kids that were there, he was the youngest. He got the concept. He got the coin. He had the slowest delivery. So, when I have interactions like that, it just makes me understand that anybody can learn, anybody can understand. If we

> give them what they need and without giving them answers, they can come up with it on their own if they have enough information, give them enough information, we allow them to go through the process of learning, experimenting, observing, and collecting their own data, they can move on to the next level. (Leah, Exit Interview)

She recognized the potential for anyone to be a science person given the right supports and guidance. She also mentioned the role of performance in facilitation, acknowledging that part of allowing learners to figure things out on their own involved engaging in scientific practices.

On a separate occasion, Leah experienced something similar when she made recognition an explicit part of her facilitation. She led a group of kids through an experiment related to climate change, and at the end of it, she told them:

> "Thank you all for being great scientists." They were like, "What?" I said, "Yes, you acted like scientists today, and you experimented, and you gathered," and they were so excited because I called them scientists, and I didn't really expect that response, but I was happy because, to me, they were scientists. That was the beginning of being able to understand what the scientific process is, how you go about carrying out and conducting an experiment and gathering the data. And, they were so excited, you know, "We were scientists today." (Leah, Exit Interview)

Leah explicitly called out that by engaging in scientific practices (performance) they were being scientists (recognition), which had a visible and positive impact on the learners. When reflecting on how this point of view of incorporating recognition into facilitation

may have changed as a result of being in the professional development program, Leah said, “There’s no doubt my mind the program definitely had an impact on me in the way that I do think” (Leah, Exit Interview). Leah talked throughout the professional development program about how this opportunity had allowed her to improve upon things she already believed as an educator. For example, she knew she did not want to give learners the answers to their questions. She wanted them to find out things for themselves; however, prior to joining the program, she had struggled with learners becoming frustrated in this process of figuring it out. With the techniques she had learned, she could create a positive, collaborative atmosphere that encouraged learners to keep going. While Leah described the importance of incorporating all four aspects of science identity into interactions with learners, she spoke the most about investment and recognition in this final interview.

Summary

Leah was consistent throughout the program in prioritizing investment and later recognition as key components of facilitation. She valued giving learners opportunities to engage with these aspects of science identity the most. She gave many examples of incorporating competence and performance into her interactions with learners as well, both in and out of the museum setting. However, she believed in order to gain new knowledge and engage with scientific practices, learners had to first feel comfortable in the space and overall have a positive experience engaging with science and also to feel they were capable of engaging with science and leading their own learning because that ensured they would commit to the experience long enough to engage in the other aspects of science identity. In Leah’s view, investment laid the groundwork for recognition,

which then in turn increased the possibility that learners would stay long enough to engage with the performance and competence aspects of science identity.

Leah focused on performance the most when defining who a science person was and based her own sense of self as a science person mainly on her strength in the performance aspect; however, in talking about facilitation she prioritized investment and, only to a slightly lesser degree, recognition. While Leah may have considered performance the primary way of defining a science person, for learners to access that part of science identity, she believed these other aspects had to be firmly established. To get learners to the point of meaningfully engaging in performance, or even competence, Leah demonstrated that she first wanted to engage them in the investment and recognition aspects, to set the right affective tone to the interaction and to build their confidence as active participants in their learning.

Table 17 contains a summary of which aspects of science identity Leah most valued as components of facilitation and creating opportunities for learners to engage with a science identity. and prominently featured at various points throughout the professional development program.

Sonya

Sonya identified as Black and female, and she was 21 years old at the time of the program. She was in the process of earning her Bachelor of Science degree in biology and aspired to become a doctor. She had not had any experience working in STEM or in education prior to participating in this program.

Sonya gave equal weight to competence, performance, and investment as markers of being a science person but ultimately decided investment was the most important facet

(Table 21). However, in terms of engaging learners in science identity work, she prioritized the recognition aspect of science identity (Table 22).

Table 21

Aspects of Science Identity Sonya Emphasized the Most

	Entry	Midpoint	Exit
Definition of science person	Competence + performance	Investment + competence + performance	Investment
Sense of self as a science person	Did feel like a science person due to strength in competence	Did feel like a science person due to strength in performance	Did feel like a science person due to strength in investment
Own demonstration of being a science person	Competence + investment	Competence	-

Note. - indicates no relevant data was collected.

Table 22

Aspects of Science Identity Sonya Most Emphasized in Facilitation

	Entry	Fall	Midpoint	Summer	Exit
Opportunities for learners	Competence	Recognition	-	Competence + recognition	Recognition

Note. - indicates no relevant data was collected.

Sonya's General Definition of "Science Person"

Sonya's concept of who a science person was remained largely consistent over the course of the professional development program. She included ideas relating to competence and performance at the beginning of the program. Midway through she added investment to the mix. By the end the of the program, she focused solely on the

competence and investment aspects of science identity as the defining characteristics of being a science person.

Entry

In the entry interview, I asked Sonya what it meant to her to be a science person, and she included competence and performance in her response. She said, "Science is a lot of exploration and experimentation and trying to understand how things work and function and the reason that they do so" (Sonya, Entry Interview). For her, engaging with science entailed experimenting and exploring (performance). In addition, a science person tried to understand how and why things work (competence). At the start of the program, Sonya viewed a science person as someone who equally displayed the performance and competence aspects of science identity (Table 23).

Table 23

Sonya's Summary of General Science Identity in the Entry Interview

Identity component	Quote	Code count
Competence	…trying to understand how things work and function and the reason that they do so	1
Performance	Science is a lot of exploration and experimentation…	1

Midpoint

In the midpoint interview, I asked Sonya again to define "science person," but she placed emphasis on the investment piece of science identity, an element that she had not mentioned at all in the entry interview. She responded:

> To be a science person is to have a passion or an engagement with science in any aspect of it, whether it's life science or engineering or anything around that realm,

> just being engaged with it, whether you're professional or not, just like a normal person, everyday person. (Sonya, Midpoint Interview)

The first thing that came to mind when I said "science person" was a sense of passion for science (investment). Moreover, Sonya acknowledged that this passion could come from someone who had chosen to make their profession science-related, but it did not have to; it could come from an everyday person who had a natural interest in science topics.

I then asked Sonya what qualities she associated with a science person, and she returned to her initial notions of performance and competence. She said:

> I think someone who's a science person asks questions a lot. I feel like a lot of science is based on asking questions and trying to come up with a sort of solution to that, or understand how something works, or the design behind something, or how to make something better. I think a willingness to learn as well because I feel like with science you're always learning new things, and so if you're closed off to learning, you're not going to get very far in science. So yeah, I definitely think asking questions and a willingness to learn are key aspects of being a science person. (Sonya, Midpoint Interview)

She identified a science person by their willingness to learn new things, to add to their understanding of the world (competence). She also mentioned asking questions and coming up with solutions (performance). She elaborated on these ideas of a science person a little more than she had in the entry interview, but they remained core aspects of her definition, nonetheless. She incorporated investment, competence, and performance into her conception of who a science person was, but she did not give emphasis to any of

these aspects over others and appeared to value all three equally as signifiers of a science person (Table 24).

Table 24

Sonya's Summary of General Science Identity in the Midpoint Interview

Identity component	Quote	Code count
Competence	… understand how something works, or the design behind something…	1
Performance	I feel like a lot of science is based on asking questions and trying to come up with a sort of solution…	1
Investment	To be a science person is to have a passion or an engagement with science…	1

Exit

In the exit interview, Sonya's definition of a science person had changed slightly from the one she offered in the midpoint interview by focusing only on investment and competence. When I asked her what being a science person meant to her, she replied:

> I think being a science person is just someone who's active and engaged in the sciences, or learning or wanting to explore about anything in the realm of science. It can be being like, "Oh, I like earthquakes, or something, or how earthquakes work," and that's sort of a science person, you know, doesn't have to be like you have to study, well, you do study it for anything in the realm of science if you're active, engaged, and want to know more about it and have questions about it. I think that makes you a science person. (Sonya, Exit Interview)

Sonya focused mainly on the investment aspect of science identity in her final definition of a science person, saying they needed to be actively engaged in science learning and

wanting to explore a topic of interest to them (investment). She also mentioned studying the topic of interest (competence) to answer questions the person may have. Though she only mentioned investment and competence once each (Table 25), Sonya centered most of her statement on a desire to learn as the primary quality of a science person.

Table 25

Sonya's Summary of General Science Identity in the Exit Interview

Identity component	Quote	Code count
Competence	…you do study it for anything in the realm of science if you're active, engaged, and want to know more about it and have questions about it	1
Investment	… wanting to explore about anything in the realm of science	1

Summary

Sonya ended up emphasizing investment the most in her definition of a science person, a quality that had not shown up at all in her original definition, but instead became part of her definition midway through the program. Competence which had been a focus of her definition at the beginning of the program gradually became less important as investment became more important, and although it was present in her final definition, it was not as prominent in her conception of a science person as it had been. Performance, on the other hand, started out as a prominent part of her original definition of a science person but was not present at all in the final definition. This contrasted with the main goals of the professional development program itself, which emphasized performance over all other aspects of science identity as important to engage learners in. Granted, defining a science person is different from deciding which kinds of opportunities to

engage in a science identity to give to learners, but this was an interesting departure from the planned takeaways of the program that performance did not show up anywhere in her final conception of what it meant to be a science person.

Sonya's Self-Perception as a Science Person

Sonya expressed throughout the professional development program that she recognized herself as a science person and, in fact, had always seen herself this way. Her reasons for feeling this way were reflective of the definitions of a science person she gave at various points in the program.

Entry

When I prompted Sonya to think of a time she did or did not feel like a science person, she focused solely on the competence aspect of science identity. She said overall she did consider herself a science person, but there were times she could remember in college not feeling that way. She explained, "I started being a bio major and doing science-related classes. Everyone was seeming to understand the material very well, and I wasn't for the first time in my life, not being able to understand STEM" (Sonya, Entry Interview). Sonya's sense of herself as a science person depended on her being able to understand STEM topics (competence), and when some science classes at the beginning of her college experience proved challenging, she questioned this identity. This response supported her overall definition of a science person as someone largely defined by the competence aspect of science identity.

Going back to her overall feeling of being a science person, I asked Sonya whether anyone in her life had viewed her as a science person, and she mentioned her parents. Both having careers in STEM, Sonya's parents "probably the most think of me

as a science person. My dad's a doctor, and so when we have scientific conversation, he thrives on that" (Sonya, Entry Interview). Having the recognition from her parents of being a science person supported Sonya feeling like a science person from a young age. Thus, for most of her life, barring the instances like the ones in college where she struggled to grasp concepts, Sonya had felt like a science person and felt confident in this identity.

Midpoint

Sonya remained firm in her sense of self as a science person at the midpoint interview, explaining how being in the program had helped her solidify this view of herself. When I asked whether she considered herself a science person, she responded:

> I definitely would consider myself a science person. I think for me, I like to ask a lot of questions. I'm always asking questions about like, "Why does this do this?" or "How does this work?" or wanting to learn about those things that I asked questions about because I asked the question because I want to learn more, and I want to expand my understanding or scope of my science practices and stuff. (Sonya, Midpoint Interview)

In this description of herself, Sonya included all three parts of science identity from her definition of a science person. First, she mentioned asking a lot of questions and later mentioned wanting to expand the scope of science practices she engaged in (performance). Second, she mentioned wanting to learn more about how things work and wanting to expand her understanding of things, simultaneously implying investment and competence.

When I asked whether she had any qualities that would prevent her from feeling like a science person at times, she introduced the idea of recognition that informal educators in this program typically employed in facilitation encounters. She acknowledged:

> I like to ask the question and have an answer to that question, and I think with some aspects of science, there is no one set answer, and so then, not that I'm frustrated, but I'm like, "Okay, so how do we get to an answer?" trying to find some way to find some type of answer to it… I think especially with our facilitation where we're told to guide people to get to their own understanding or own findings, rather than just telling people what they're supposed to do at an exhibit, or telling people what the specific science phenomena is, we have to allow them to explore it on their own, and if they don't get to an answer, we encourage them to be okay with that. And, I think I had to first get myself into that mindset that it's okay if I don't know exactly what I'm supposed to do here. I just need to explore it and see what I can find for myself. (Sonya, Midpoint Interview)

Sonya recognized that she preferred to be given a definite answer to the questions she had about science, but she needed to work on accepting that sometimes being a science person entailed working to find one's own answers.

Later in the interview, Sonya gave a specific example of how her view of an exhibit had changed over the course of the program. The exhibit involved a rotating table where learners could roll or place different objects on the surface. Sonya recalled:

> When I first got to them, [the instructors] wouldn't tell us what we were supposed to do with the exhibit, so for me, it was frustrating because I was like, "What am I supposed to do here? What am I supposed to be gaining out of this experience? What am I supposed to be learning at this exhibit?" and I felt like I couldn't get myself in a mindset to be able to explore that specific exhibit to understand it more or the science behind it...[Now] I might not understand the actual physics of why this ball stays on this table when it's at this speed or whatever, but I know ways to engage myself more with the activity to feel a desire to go and want to interact with it as best as I possibly can, or every time I go want to try something new, where before I was like, "I don't want to work on this exhibit ever again." (Sonya, Midpoint Interview)

Sonya recognized growth in herself in the way she approached science learning, not always needing an answer anymore and developing a mindset of seeing what she could discover on her own (recognition). Once she developed this mindset, she realized she had a desire to explore and wanted to interact with the exhibit to figure out new things (investment). She acknowledged that this was an area of being a science person she still struggled with that prevented her from claiming the science person identity at times, but she showed at least one example in how she had improved in this regard.

Another way in which her view of herself as a science person had shifted from the beginning of the program to this point was the incorporation of performance. When I asked her whether the program had impacted her view of herself as a science person, Sonya responded, "I always saw myself as a science person, but I think the scope of who I am as a science person has definitely expanded" (Sonya, Midpoint Interview). When I

asked her to explain a little bit more what she meant by "expanded," she said in terms of "methods, everything like scientific practices, how you get from one place to another place. It's all changed. My viewpoint has changed because it's now an informal setting, and all of the science I've ever learned is in a formal setting" (Sonya, Midpoint Interview). Scientific practices (performance), a new aspect of being a science person Sonya had not considered before, allowed her to expand the ways in which she recognized herself as a science person. Previously, Sonya commented that her sense of self as a science person depended almost completely on her demonstration of competence, which largely stemmed from her experience of science in a formal education setting, but now, she could also consider her demonstration of performance as an indicator of her identity as a science person, meaning her sense of self in this identity did not have to be as precarious as before. Sonya recognized the competence, performance, and investment aspects of science identity within herself, and these were reflective of her definition of a science person at this point in the program. Moreover, she recognized at least one way that she was trying to improve as a science person, in her efforts to spend more time exploring to obtain answers to her questions.

Exit

Sonya still recognized herself as science person by the end of the program, and she incorporated the competence and investment aspects of science identity into her description of herself, aligning well with the final definition of a science person she gave in this same interview. When I asked whether she considered herself a science person, she said:

> I would consider myself a science person both in my own personal life and my career goals. I am a bio major, so that kind of sets me up to be a science person because I'm studying science a lot, but also, I just like learning about why does this do this or anything like that…I want to know about how stuff works and, "What does this do?" or "How do I make something better?" So, I think a thirst for knowledge is important for being a science person. (Sonya, Exit Interview)

Sonya thought she was a science person because she was always wanting to learn more about science (investment) and was devoting a lot of time to studying science in school (competence).

In further support of her embodiment of competence and investment, she recalled feeling like a science person from a young age. She said:

> Growing up, I liked science a lot. I was always better at science and math than I was English and history and stuff, so I liked doing science. But I was never really proficient at the reading charts and how many pages can you read. It was more like, "Oh, I want to do more science experiments," or, "I want to do wacky science," or something like that. I would sign up for those things, after school care programs and stuff, so I think for me I was always excited. (Sonya, Exit Interview)

For Sonya, competence and investment in science were always linked. She had a passion for science and a wanting to always be doing more science activities (investment) because it came easily to her (competence), and she was good at it in school. From a young age, she thought of herself as a science person because she embodied the

competence aspect of science identity the most, and that was the aspect most paid attention to in a formal education setting.

Sonya further reiterated her investment in science, highlighting this aspect of science identity that was most impacted by the professional development program. When I asked Sonya whether being in the program had impacted her view of herself as a science person, she responded:

> I think it established more that I am definitely a science person…I think working in sciences, seeing STEM education in the informal setting, which is, I feel for a lot of students, not as common, and then also seeing how STEM education can impact students who might not have the resources for it but obtain those resources through [the Museum of Physical Sciences] and stuff, it just solidified how important science was to me. (Sonya, Exit Interview)

Sonya felt more assured in her science identity by the end of the program due to an improved sense of investment, and this was aligned with her overall definition of a science person at the end of the program that emphasized investment the most. Spending so much time in the museum and interacting with children, many of whom did not have such exciting and hands-on learning opportunities at their home institutions, increased her investment in science and science education, seeing even more the value in engaging students in science in an informal setting. Sonya left the program feeling even more like a science person than she had come into the program feeling, and this was in large part due to the investment aspect of her science identity.

Summary

Even though Sonya had felt like a science person from a young age, and entered the program feeling confident in that identity, participating in the program enhanced this identity. She felt confident in the competence aspect of her science identity, but over the course of the program, she also started to see herself as science person with regards to the performance aspect. While she had always felt invested in science, her experiences in the program strengthened this aspect of her identity even more. Through each of these phases of self-recognition as a science person, her reasoning aligned with how she defined "science person" overall in her interview statements.

Sonya's Demonstrations of a Science Identity

Sonya demonstrated being a science person both in recollections from before starting the professional development program and in experiences she had during the program. She offered many examples of demonstrating the investment and competence aspects of science identity and one example of demonstrating performance.

Entry

The first way in which Sonya demonstrated being a science person was through competence. When I asked what science experiences she had had prior to joining the program, she said, "I'm currently a bio major, so my whole career path right now is science related, so I think I'm very in depth in the sciences right now" (Sonya, Entry Interview). Sonya thought of her experience studying science in a formal education setting (competence) as a way she had meaningfully engaged with science.

In this first interview, Sonya also offered a way she demonstrated the investment aspect of science identity. When I asked what science experiences she had had in an

informal setting, she talked about being in zoos, aquaria, and afterschool programs. She explained:

> I'm obsessed with zoos and aquariums, so gone to a couple here in United States and outside in other countries as well. And then, I'm an only child, and both my parents work, so a lot of times over the summer, they would send me to summer camps. And so, oftentimes they were summer camps where I would do STEM and then do something fun afterwards just so that I was still in that mindset. And then, I worked at the summer camps I went to, so I've done like geology classes and wacky science class and those kinds of things, taking them and teaching them. (Sonya, Entry Interview)

Sonya had a genuine interest in visiting informal science education settings. Furthermore, she had a lot of fun experiences participating in science programs outside of school. Both examples related to the investment aspect of science identity.

She further supported her investment in science, as well as competence, in a blog post she wrote a few days after the entry interview. She reflected on a significant science memory, and she wrote about an experience learning about a specific animal at the zoo, saying:

> I think my most significant science memory was in high school when I became obsessed with this baby hippo named Fiona at the Cincinnati Zoo. She was a premature baby, and the zoo documented her entire life which was amazing. From the videos, I learned that mother hippos can reject their babies if they are separated from them for a period of time or they smell other pheromones. The staff at the zoo had to make sure not to touch Fiona too often and also allow her

> mother to have access to see her even though they couldn't be physically together. Also, another interesting thing I learned was that hippos in fact can't swim but can manipulate their breathing and configuration of their body (how much air inside) to sink to the bottom and push themselves up. Also, although they have very few actual teeth, they have extremely powerful jaws and crush things easily. (Sonya, Oct 6, 2020, Blog Post)

Sonya listed many facts she learned about hippos (competence) as a result of this experience with Fiona, and her motivation for learning these facts was a genuine curiosity and amazement at the process (investment). In this first interview, Sonya offered compelling examples of having demonstrated both the competence and investment aspects of science identity prior to joining the professional development program.

Midpoint

Midway through the program, Sonya offered examples of demonstrating performance, competence, and investment while in the program. First, in a blog post she wrote about three months into the program, Sonya described an engineering activity they had all done in class. She described designing various parachutes and comparing them, writing:

> For my three designs, design one fell at about the same rate as the quarter with 2/5 of the trials the quarter falling first. Then, design 2 fell faster every single time. Lastly, to my surprise, my most parachute-like design, design 3, fell faster than design 2 four out of the 5 times. (Sonya, Jan 12, 2021, Blog Post)

She described how she tested and systematically compared her three parachute designs, thus engaging in the scientific practice of conducting an investigation (performance).

Additionally, in the midpoint interview, Sonya talked about an experience she had preparing for a facilitated activity, in which she demonstrated both investment and competence. When I asked her about a time she felt like a science person while in the program, she said:

> I think when we were practicing facilitating a phenomenon. When I watched the video of what I was going to do, it was a very plain version for students, kids, to do it. And then, I did more research on why it was working. Well, I'll explain it…I did a Sharpie marker and trying to lift the Sharpie marker off of glass with water. And so, for me, I didn't understand why it was working. So then, I did more research on why it was working, and it's because Sharpies are oil based, and with the water it lifted off, and glass is non-porous, all this type of stuff that made me enjoy science in a way that was fun as well. (Sonya, Midpoint Interview)

Even though Sonya was preparing an activity for kids to participate in, she found personal enjoyment in learning more about the phenomenon she was teaching. Thus, she recalled a time she engaged with the competence and investment aspects of science identity.

Summary

Coming into the program, Sonya offered ways she had engaged with science that included competence and investment. Once scientific practices were introduced to her in the professional development program and the performance aspect of science identity entered her definition of a science person, she gave an example of engaging in that as well. When prompted to think of her science experiences in a general sense, Sonya gravitated towards those centered on her displays of competence and investment. This

was consistent with Sonya's overall emphasis on competence and investment as parts of being a science person for the majority of the program, with only minimal attention paid to performance.

Table 21 shows which aspects of science identity Leah placed the most value on in her definition of a science person, her self-concept as a science person, and her demonstrations of being a science person over the course of the professional development program.

How Sonya Created Opportunities for Learner to Engage in Science Identity Work

Over the course of the professional development program, Sonya moved from prioritizing creating opportunities for learners to engage with the competence aspect of science identity, gaining content knowledge, to the recognition aspect of science identity, having the opportunity to recognize oneself and be recognized by others as a science person. This shift was largely influenced by Sonya's experiences facilitating with underrepresented students during field trip activities. While Sonya ended up including all four aspects of science identity into her facilitation practice, she consistently emphasized recognition and competence over performance and investment.

Entry

Sonya came into the professional development program primarily concerned with how to engage learners in the competence aspect of science identity during facilitation. She also incorporated performance and investment into her ideas about facilitation; however, they were secondary to competence. When I first asked her about informal science institution, the first thing she chose to talk about was performance. I asked what she thought the primary role of such an institution was, and she said:

> I think the primary purpose is to give mostly students an opportunity to be hands-on and explorative of science topics rather than learning from the textbook. It's more hands-on, visual learning than just reading something and trying to comprehend it, especially younger people. It's easier hands-on to see what their experiment is telling them to do rather than someone reading it. (Sonya, Entry Interview)

Sonya identified hands-on experimentation as one of the primary benefits of learning science in an informal setting, wanting learners to have the opportunity to participate in science rather than merely read about it (performance).

Next, when I asked Sonya what she considered to be the ideal takeaway for the learner after experiencing an informal science institution, she focused on the competence element of science identity. She responded, "I think a better understanding of the content or how the world works or a new way to look at the world" (Sonya, Entry Interview). Sonya wanted learners to come away with more knowledge about the world (competence) to help shape their view of the world. She further supported this emphasis on competence when I asked whether she thought it was important for informal educators in these spaces to have the relevant content knowledge. She replied:

> I think it's very important to have science knowledge because, yes, we may be showing them one thing, but then a lot of people are curious when they come into museums and they might start going asking more questions related to the topic or not related. If they're coming to the museum, they want to learn, so you want to be able to answer the questions to your best ability, your best knowledge, so I think it's very important. (Sonya, Entry Interview)

Sonya expected informal educators to use their content knowledge when interacting with learners, so she felt having content knowledge was an important quality for an educator to have. For her, being able to answer learners' questions was important.

Lastly, Sonya mentioned investment alongside competence when talking about what prior experiences or background she had that she believed would help her facilitate exhibits at the Museum of Physical Sciences. She reflected:

> I think understanding the technology behind how the exhibits work, or if the exhibit is trying to represent how electricity works, knowing the fundamentals [of] how electricity works and how that affects the specific exhibit or other exhibits in the museum as well and how that applies to daily life and stuff, because people will be like, "Oh, how do I see this in my daily life?" and you be like, "Oh actually, XYZ" type of thing. (Sonya, Entry Interview)

She felt her background knowledge on certain science topics would benefit her in the role of informal educator. Additionally, she mentioned wanting to connect her knowledge to everyday life to illustrate for learners how the science topics they could learn about in the museum would be relevant to them. This aspect of her proposed facilitation highlights the investment aspect of science identity, a way to create buy-in for learners to the exhibit experience.

About a month after this interview took place, Sonya wrote a blog post that talked about her ideas about what learning meant, and here she incorporated the competence and investment aspects of facilitation into her writing. She reflected:

> My initial idea of learning is to expand one's knowledge of new or previously learned topics…We learn by doing, and we hopefully learn from our mistakes,

> and I think the former is very applicable to the essence of the Museum of Physical Sciences. It is a hands-on experience with little guidance or instruction to allow people to learn through play and exploration. I think learning through exploration is a good way to create new ideas or build on ideas learned in school…There is no correct way to learn but as long as there is growth, exploration, and an expansion of knowledge then learning has happened. (Sonya, Nov 1, 2020, Blog Post)

Sonya first equated learning with expanding one's knowledge (competence) and building on topics that were possibly introduced in school. Second, she emphasized that the essence of the Museum of Physical Sciences was playful exploration (investment). She implied that the manner of learning in the museum was positive and fun. Although Sonya mentioned performance and investment as significant parts of facilitation in her initial ideas about facilitation, she cared the most about providing opportunities to learners to engage with the competence aspect of science identity, to expand their science knowledge.

Fall

By the fall interview, about two months from the start of the program, Sonya had incorporated recognition into her facilitation practice along with the three aspects of science identity already mentioned in the entry interview, supporting that all four aspects were important parts of facilitation. First, Sonya touched on recognition when I asked her what she thought made for good facilitation. She said in good facilitation:

> The visitor, learner, has the opportunity to ask questions themselves and come to conclusions on their own rather than a facilitator simply just telling them, asking them a question and them answering their own question type of situation, because

> I think in facilitation, you want the visitor to be learning, and because you already know the answer, probably, you want them to get to the answer on their own. (Sonya, Fall Interview)

This attention to providing learners the opportunity to see themselves as capable of engaging in science and finding their own answers (recognition) is in sharp contrast to Sonya's statements in the entry interview, in which she focused on knowledge transfer from her to the learner as the primary way to expand their learnings.

Next, Sonya talked about wanting to engage learners in scientific practices (performance). I asked her whether there were any strategies she used with learners. She said:

> I think a lot of open-ended questions like, "What do you notice?" or "What causes it to do this?" And then, a lot of the times, they will try to come up with multiple different answers, and then I'll say, "OK, well why don't we test these multiple different things that you said and see which one works out the best?" (Sonya, Fall Interview)

Sonya recalled leading learners to test their ideas and narrow their hypotheses down to figure out which of their ideas was the correct one. She provided learners with opportunities to engage with performance and behave as scientists would.

Then, we moved onto talking about a specific facilitation experience Sonya had at an exhibit where learners could construct roller coasters with rubber tracks and roll a ball down the track, and in this experience, she talked about incorporating, or at least wanting to incorporate, all four aspects of science identity into her facilitation. Two boys, brothers, were at the exhibit, and she guessed they were about seven and 12 years old.

The boys were looking at a video of someone else constructing a track at the exhibit. Their goal was to build a track that had three loops. She remembered:

> I asked them how many loops do they think that they can make, and they said the last time they were at the museum, they could only get two loops, and it was impossible to get past two loops. So, I asked them, "Well, you noticed that the people in the video made multiple loops. How do you think they did that?" And the older brother was like, "I don't know, it's impossible." Then he just kind of walked off, but then the younger brother was like, "I don't know, but I wanna try to make a third loop." So, I said, "OK, well let's first make two working loops," and so he made the track of the first two working loops. And I said, "So, what do you think you need to do to make it work on the third loop?" And he said, "Maybe make it steep," so he made a steep incline to make the third loop, and it just kind of jumped off. And so, I said, "Well, what do you notice in the videos? What do you notice the people who have multiple loops that they're doing?" And he said that, "The loops were kind of smaller, and they were more close together," so he moved his track up a little bit and made a smaller loop, and then it didn't work again. And I said, "So, what is causing the ball to not go through the loop?" And he said that he didn't think the ball had enough speed to go down into the third loop, so I said, "Is it any of our other previous loops? How can we change that?" And so, he decided to make the other loops smaller, so the ball didn't have to go as big of a loop beforehand. And then, he got it to go through the third loop, so that was pretty cool, he was really excited. (Sonya, Fall Interview)

Sonya led this boy through making observations about the track in the video (performance) and then testing and adjusting his track (performance) until he reached his goal of having the ball run successfully through three loops.

When I asked Sonya further about this encounter, she explained how this incorporated recognition and investment as well. I asked her what her goal was in this interaction, and she responded, "The goal was to get them to do a third loop because they said it was impossible, so I wanted to be like, 'It's not impossible. You can do it, but how do we get to that point?'" (Sonya, Fall Interview). She kept the boy's goal at the forefront of the interaction, facilitating an interaction that kept him interested (investment) long enough to engage with scientific practices (performance). Furthermore, Sonya wanted to convey that his goal was achievable and that he was fully capable of reaching it (recognition).

When I asked about what he took away from the interaction, Sonya returned to the performance aspect of the facilitation. She said he took away that:

> You have to test things out. It may seem impossible, but if you try different things out and observe what other people had done, because I told him to…use what he saw on the video and apply it to his own track. (Sonya, Fall Interview)

She felt his main takeaway from this facilitation was related to testing things out and making observations (performance).

When I asked her whether there was anything she wished she would have changed about this facilitation encounter, she introduced the competence aspect. She thought about the older brother of the boy she had interacted with and said she wished she could have gotten:

> Them to do it together, because I noticed that the younger one wanted to do it with his older brother, and so I think maybe asking the older brother more questions, more specific questions, that maybe he would know, like momentum or something like that, to get him to want to do it himself, too, to keep him engaged. I think if I could have done that, that would have been a lot better, but yeah. I think it was mostly just getting him to stay engaged and want to test out his theories. (Sonya, Fall Interview)

In reflecting on this experience, Sonya recognized she could have incorporated content knowledge (competence) that maybe tapped into the older brother's prior knowledge would have created a greater interest in the activity (investment) that would have led him to engage in experimentation (performance) alongside his younger brother. In this instance, Sonya would have liked to use the competence and investment aspects of science identity to lead to an opportunity to engage him in the performance aspect.

When I asked Sonya why she considered this anecdote an instance of good facilitation, she attributed it to her incorporation of recognition. She explained:

> They succeeded in doing what they came there to do, and I didn't give them any answers, and I didn't touch the track either…I was kind of standing off and asking him questions and seeing if he could do that based off of the questions that I was asking him, if he could come to his conclusions and make his own track from that. (Sonya, Fall Interview)

She was proud of the way she did not give him any answers but instead led the learner to discover on his own how he could reach his goal. She provided space for the learner to feel capable of answering his own questions (recognition).

At the end of the interview, she reiterated the importance of recognition as well as investment. I asked her what advice she would give to new informal educators at the museum, and she said:

> I think the best for facilitation is definitely asking open-ended questions and wanting to know what a person's goal is at an exhibit, like if they have no clue what the exhibit is, just asking them questions trying to get them to try things out, try different aspects of the exhibit. But, let's say there's someone who's already been to that exhibit before, asking them how they can expand on their last visit to the exhibit…Sometimes, you want to show them how to do something, but I think it's important to take a step back and use your words more rather than you being hands-on with it and showing them like do this. You say, "Oh, why don't we try this and see what happens," rather than just saying, "Do this," or, "I can show you how to do this," giving them the opportunity to do it themselves. (Sonya, Fall Interview)

Sonya valued creating an interaction in which the learner was in control of their own learning both as it related to the recognition, or their autonomy to lead their exploration, and investment, or their interest in the experience, parts of science identity. She thought it was important for learners to try out things on their own and come up with their own ideas for exploration, with informal educators offering suggestions but not instructions. Additionally, she felt it fell to the informal educator to find something at an exhibit that would interest the learner and keep them invested in the experience, whether it was a goal that already had in mind, or it was a suggestion based on the learner's previous experiences with the exhibit. At this point in the program, Sonya talked the most about

the recognition element in her interactions with learners, that giving them space to learn on their own rather than being given answers was one of the most important aspects of being an informal educator. She also talked about performance and investment but to lesser degrees, and only briefly about competence.

Summer

In the summer interview, about nine months into the program, Sonya had returned to her earlier notions of facilitation, focusing primarily on competence and secondarily on recognition and performance, only mentioning investment indirectly in this interview. When I asked Sonya what she thought made for good facilitation, she said, "I think what makes a good facilitation encounter is that if someone leaves the encounter with more information than they came in with" (Sonya, Summer Interview). I asked Sonya to elaborate on what she meant by wanting the learner to come away with more "information." She explained it meant for example:

> Learning how a pipe can make a sound, or if you hit a specific pipe of a specific length, it will make a difference and then when that's longer or shorter, or how sound waves were hitting a whisper dish, or even that the whisper dish is similar to a satellite, whether you know how a satellite works or not. (Sonya, Summer Interview)

The hallmark of good facilitation for Sonya was coming away with more information about a science topic or phenomenon (competence).

She offered two examples of facilitation that supported this view of facilitation as driven by competence. In the first example, she described a young boy playing at the

exhibit where people can build and race cars, and I asked what her main goal in this interaction was. She explained that she had observed him changing things on his car:

> So, I wanted to know where his head was at, why he was changing things, if he even understood, like, what he was doing to change the cars because he was like very determined to come in first. So, I think I just wanted to like help him get to understand, you know, how the track and the specific car that he had, because he had a long car, would help him win the race. (Sonya, Summer Interview)

Beyond changing variables and running tests with different types of cars (performance), Sonya wanted this learner to understand the reasoning behind why some cars were faster than others (competence), why changing certain variables had an effect. She was focused on expanding his content knowledge related to the experiments he was already running.

In the second example, Sonya described interacting with multiple children at a solar panel exhibit, in which a solar panel powers a wheel to turn producing noise. Again, her goal for this interaction was to convey information. She said:

> I wanted at least someone to say that it was solar panels, but they were also like first graders, so I don't know how much they knew about solar panels. And, I think in the beginning, I wanted to get to them to get to that, but by the third student, I knew that they didn't really know what solar panels was, so that's why I told her… I think [my goal] was more how the panel itself worked, like if you cover the panel, it stops, but if you open the panel, it goes. If you cover part of the panel, it slows down but doesn't completely stop. (Sonya, Summer Interview).

Her main goal for this group of learners was for them to get to a better understanding of what a solar panel was and how it impacted the behavior of the exhibit (competence). For

both interactions that she considered good examples of facilitation, her main efforts went towards engaging learners with the competence aspect of science identity.

Towards the end of the interview, I asked Sonya whether helping learners see themselves as capable of engaging with science was a part of her facilitation, as it had been her main focus in her fall interview, and she had yet to mentioned it in this interview. She replied that it was still important to her, especially in the context of facilitating with children from lower-income schools who do not have access to many resources for hands-on science learning. She said:

> Over the past like six weeks, I've been working with underrepresented students, like specifically going to the schools, and then they come to the museum on Fridays. So, I think when I go to the school specifically, my goal there is to get them more familiar with the engineering process and how to test ideas and try new things out, and then I hope that they apply it when they come to the museum on Friday, and I usually say, "Remember when we built our ramps? It didn't work out for us, but we tried something new. How can we do that here?" or getting them even more comfortable in a science background or trying out new ideas, especially because that's stuff that we did in their field trips at their schools where they were most comfortable…I think for the outreach students, it's the most important thing. (Sonya, Summer Interview)

Sonya felt the recognition aspect of science identity was the most important thing to incorporate into facilitation with underrepresented populations. Sonya acknowledged that underrepresented populations may not have comfortability in a science museum, so getting them feeling capable (recognition) of engaging in scientific practices

(performance) in their own classrooms laid the groundwork for future explorations at the museum. Thus, she linked recognition and performance in this instance as vital aspects of facilitation but prioritized the recognition aspect.

I then asked whether Sonya thought learners were receptive to her efforts to create a comfortable space in which to engage with science, and she incorporated recognition and investment into her response. She said:

> I definitely do think they are a lot more receptive to it because I'll notice that they'll go and try things out on their own, or they'll go show their friend who might be like, "I don't know what to do." Then, they'll start showing their friends like, "Oh, this is what you do," or, "Maybe we could try doing this." I've also had a number of students actually come back to the museum later with their parents, on a later date to try different things that they couldn't do on their field trips. And, I don't want to say that I single-handedly did that, but I feel like they're more comfortable. They're comfortable enough to say to their parents, "Hey, I think I want to do this. Can you take me here?" (Sonya, Summer Interview)

In Sonya's experiences with underrepresented school populations, she felt giving students the opportunity to see themselves in a science setting and doing science on their own (recognition) was the most important thing she could do as the educator in that situation. She recognized that building their confidence in themselves in this way opened the door to engage with other aspects of science identity such as investment, by way of wanting to come back to the museum and keep exploring their curiosities.

Sonya's views on facilitation nearing the end of the program were a combination of her initial ideas and the ideas she voiced in the fall interview, prioritizing either

recognition or competence depending on the situation. She demonstrated that in her everyday interactions on the museum floor, she cared about providing content knowledge and leading learners to expand their understanding of phenomena (competence). However, in talking about her experiences with underrepresented populations specifically, she acknowledged that guiding learners to feel capable of engaging with science was the most important (recognition). She still incorporated investment and performance into her views on facilitation as well, but competence and recognition stood out in this interview.

Exit

By the end of the program, Sonya had moved her views on facilitation to emphasize recognition even more; however, all four aspects of science identity played a role in her facilitation. When I asked Sonya what she hoped learners' general takeaways after being in the Museum of Physical Sciences would be, she emphasized their investment, saying:

> Learning something new in any capacity is the big takeaway, or they came in wanting to explore, or maybe they didn't even come in wanting to explore it, but then leaving with the mindset of, "Oh, I want to try new things," or, "I want to learn more about X." (Sonya, Exit Interview)

This response is similar to ones she gave previously, which focused on competence, and while this response, too, focused on learning something new and adding to one's scientific understanding, Sonya did not emphasize the knowledge gains themselves (competence) in this interview but rather the mindset of curiosity and exploration (investment) new knowledge could inspire in the learner, thus putting more emphasis on

engaging learners in the investment aspect of science identity. Instead of talking about the learner leaving with a certain amount of new knowledge, Sonya focused on cultivating an explorative mindset through the process of gaining new knowledge.

Sonya nonetheless still valued competence as a significant part of facilitation. When I asked her whether she felt having content knowledge was important for informal educators, she responded:

> At first, I didn't really think it was all that important, but now, I feel like it is a little bit more important in understanding how the exhibits work and the science behind them just because you have varying levels of guest interaction, and I feel like if you understand the most amount of science knowledge about that exhibit, you can dial it back, depending on what education or exploration level that people are at, but I feel like if you have no knowledge on it, it's a little bit harder to help people who might be a little bit more familiar in the sciences get to an even greater level of exploration. (Sonya, Exit Interview)

Sonya had valued competence in facilitation in the form of informal educators' possession of content knowledge from the start of the program, and by the end, she expressed that she felt even more strongly about that aspect of facilitation than she had originally. She viewed having content knowledge and engaging learners in the competence aspect of science identity as important because it could deepen a learner's engagement at an exhibit if the educator knows more about the relevant phenomenon.

When talking more generally about the role of a facilitator, Sonya focused on the importance of engaging learners in the recognition aspect of science identity. She explained:

> I feel like in the beginning [of the program], you would think of a facilitator as more of a docent, that's the one that's there explaining information to you about a specific thing or exhibit, but I feel like now more it's someone that's there to help you more, rather than give you information. They help you get to that point of information on your own. (Sonya, Exit Interview)

Sonya felt an informal educator should lead learners to their own answers and not just give them information when they had questions. She valued giving learners space to see themselves as science people (recognition).

When I asked her how she handled interactions with learners when she did not know the answer to one of their questions, Sonya explained that she tried to engage the learner in the performance aspect of science identity. She said she would be transparent with the learner about not knowing the answer, and then, she would say, "'Maybe we can figure it out together,' if it's something about a specific exhibit that is a testable question" (Sonya, Exit Interview). Sonya's first response to a learner's question was to try to find a way to test their question or idea (performance) to get to an answer.

In talking about the advice she would give to other informal educators, Sonya returned to the importance of recognition. She said:

> Let [learners] come to the answer on their own but guide them through. As a facilitator, you're more like a guide, not a teacher. And so, I think it's guiding people to get to an answer, rather than as a teacher [who] would tell you the answer to something. (Sonya, Exit Interview)

She believed informal educators were supposed to guide learners to answers and allow them to explore on their own. She further reiterated the importance of recognition and

also of investment at the end of the interview when talking about the value of informal education spaces. She talked more about working with underrepresented populations on field trips and said:

> It's the fact that they now have this outlet or this resource that is given to them. It changes their perspective of who they are, and in the beginning of some classes, some students would be like, "I don't know what to do," or, "I can't do this," or, "I'm not creative." They'll doubt themselves. And then, by the end of it, they've created all these awesome, really cool things, and then, they're excited to go to the museum, and they don't want the field trip to end, so I think seeing that with my own eyes, me being the facilitator, that bridge between the museum and the students, I realized how important it was in the end for me. (Sonya, Exit Interview)

Sonya highly valued creating opportunities for students to engage with the recognition aspect of science identity because she observed that helping them see themselves as science people also fostered a sense of excitement around science learning (investment). By the end of the program, Sonya focused the most on recognition. Investment and competence were still prominent features of her facilitation, while performance played a minor role, comparatively.

Summary

Sonya consistently prioritized competence and/or recognition as valuable ways to engage learners in science identity work throughout the professional development program. She began the program by viewing her role as facilitator to be primarily about conveying content knowledge to expand a learner's understanding of the world, giving

the most emphasis to those learning opportunities that engaged learners in the competence aspect of science identity. However, as she participated in the program, Sonya came to see recognition as the most important way to engage learners in science, allowing for them to gain confidence in their abilities to be active participants in their science learning. Nearing the end of the program, competence and recognition were equally important to Sonya, prioritizing one or the other depending on the learner. She believed competence was the most important feature of facilitation unless she was interacting with underrepresented populations who did not have access to many science education resources. In those instances, Sonya thought helping them feel capable of engaging with science and of conducting explorations to answer their questions was the most important thing she could do as an informal educator. By the end of the program, however, she had expanded this view to all learners, prioritizing recognition across facilitation experiences. She still valued incorporating opportunities for learners to engage with the competence element of science identity, but it became a secondary goal.

Competence showed up in Sonya's early and midpoint definitions of science person as well, but by the end of the program, Sonya attributed being a science person largely to one's investment in science. While investment was not the top priority in facilitation, Sonya explained how sufficient attention to recognition could lead to participation in the other three aspects of science identity, including investment. Thus, both in her conception of a science person and in her views about how best to create science learning opportunities, competence became less essential over time, being replaced by investment and recognition, respectively.

Table 22 contains a summary of which aspects of science identity Leah most valued as components of facilitation and creating opportunities for learners to engage with a science identity and prominently featured at various points throughout the professional development program.

Chapter V: Discussion

Comparative Science Identities (Research Question 1)

I began this paper by asking two big research questions. The first asked how informal educators' identities as science people changed during participation in an informal science education professional development program. This question was addressed in three parts, attending to educators' general definition of "science person," their self-concept of being a science person, and their displays of being a science person. Table 26 summarizes which aspects of science identity were most prominent at three points (beginning, middle, and end) of the year-long program, taking into consideration all three of these sub-parts of the first research question. From this table, it is clear that competence (science content knowledge) was among the most important aspects at the beginning of the program—focused on by three of the four participants, but it had lost importance by the end of the program. Instead, the participants focused on investment (enjoying or being motivated in science) and performance (talking about and doing science) as important aspects of science identity. As will be discussed later, recognition (seeing oneself and being seen by others as a science person) did not play a significant role in participants' discussions about how their conception of a science person changed over the course of the program. However, recognition did feature prominently in discussion on facilitation as depicted in Table 28. I explored recognition more explicitly in the second sub-question of the first research question, regarding how educators' recognition of themselves and/or by others as being a science person changed over the course of the program, so while they spoke of recognition in terms of how they saw

themselves as science people, recognition as an aspect of identity did not factor into their general constructions of what the term "science person" meant.

Therefore, for the first half of the findings, which focus primarily on participants' conceptions of "science person" as a generalized term and not necessarily as it relates to themselves, only competence, performance, and investment were discussed as necessary components of possessing a science identity. While participants described times in which they or other people recognized themselves as science people, no one mentioned needing recognition as a requirement of taking on that identity. Table 27 summarizes how participants' construction of "science person," including how they defined the term and how they identified with the term, changed over the course of the entire program.

Table 26

Aspects of Science Identity Emphasized the Most by Each Participant

Participant	Entry	Midpoint	Exit
Stephanie	Competence + investment	Performance	Investment
Madison	Investment	Investment + performance	Performance
Leah	Performance + competence	Performance	Performance
Sonya	Competence	Competence + performance	Investment

Table 27

Each Participant's Construction of Self as a "Science Person" Over the Course of the Program

Participant	Description
Stephanie	Overall, Stephanie moved from a focus on competence to performance to investment in her conception of "science person." For the most part, Stephanie refused to recognize herself as a science person despite being recognized by others in this way and demonstrating engagement in the other three aspects of science identity. She expressed not feeling invested enough in science to claim it as part of her identity.
Madison	Madison shifted from a focus on competence and investment to performance. Performance gave her a more solid basis for her science identity, as opposed to competence, and she felt, given the year-long program, she had sufficient time to develop this aspect of her science identity.
Leah	From the beginning, Leah emphasized performance as one of the primary facets of being a science person. This only increased over the course of the program. While she always felt confident in recognizing herself as a science person, she felt the program greatly improved the performance aspect with regards to being able to better communicate with other about science.
Sonya	Overall, Sonya paid little attention to performance even after being introduced to it in the program. She differed from the other participants in this way because she only highlighted performance as an important aspect of being a science person temporarily in the middle of the program. She ended up giving the most weight to investment in deciding who could be a science person and in defining herself as a science person. She claimed being in the program had increased her investment in science through seeing the benefits of informal science learning to learners.

As depicted in Table 26, most participants emphasized competence in their conceptions of "science person" at the beginning of the professional development program. This makes sense because this is the most heavily emphasized aspect of science identity in formal education. They all thought that being a science person entailed having

some degree of content knowledge. Madison was the only exception, placing the most importance on investment.

By the midpoint of the program, the participants had been introduced to scientific practices and the idea that these practices would be the primary way in which they would engage visitors in science on the museum floor. It followed that they would all emphasize performance and ways of behaving like a scientist as a key part of their definition of a science person, as this was a heavy focus of the program. While Leah was the only one who had also emphasized performance in the entry interview, by the midpoint interview, Leah and Stephanie both prioritized performance over all other aspects of science identity, and Madison and Sonya equally valued performance alongside investment and competence, respectively.

By the end of the program, some of the participants remained firm in their description of performance as the primary factor in defining a science person, while others had decided investment was the most important facet of being a science person. In terms of performance as the most important, Leah had always emphasized performance, but it became even more important to her by the end of the program while Madison had a more gradual shift moving from investment to investment plus performance and then to performance as the most important aspects of being a science person. In terms of investment as the most important, neither Stephanie nor Sonya had prioritized investment prior to the exit interview, but they both ended up feeling this was the most important facet of being a science person.

Although most of the participants started out the program talking about how competence was the most defining feature of a science person, none of them felt that way

by the end of the program. This reflected a shift from their conception of science identity as rooted in formal education to a conception that was more inclusive. They recognized that participating in science in this way, in an informal education setting, allowed for more entry points to assume a science identity, making it easier for more people to engage in science identity work. For example, Madison acknowledged that her own sense of science identity had benefitted from being the program and learning about engaging in scientific practices as a way to be a science person because her identity as a science person was no longer dependent on the specific context, on whether she possessed sufficient knowledge about the relevant science topic; it just mattered that she brought a scientific mindset and employed scientific practices in each situation. Due to this change in viewpoint, she felt more confident in her identity as a science person by the end of the program than she did at the beginning. For Madison and for others in this study, participating in this professional development program had a positive effect on their own science identity.

Regardless of how they ended up defining "science person," whether primarily by the person's performance of or investment in science, all the participants demonstrated a change over the course of the program. Although most of them entered the program recognizing themselves as science people, they came away from the program feeling more confident in this identity as a result of expanding or shifting their definitions of who could be a science person.

Comparative Facilitation of Science Identity (Research Question 2)

The second question I asked was: How did informal educators create or aim to create opportunities for museum visitors to be science people? Table 28 shows how each

of the participant's views on facilitation changed over the course of the professional development program. While they each had a unique pathway from their views on facilitation at the beginning of the program to their views at the end of the program, all four participants heavily and consistently emphasized investment and/or recognition as the most important pieces of science identity with which to engage learners. In this way, the findings for this research questions were much more consistent among participants than they were for the first research question regarding a generalized concept of science identity. Table 29 describes how participants' views on how to engage learners in different aspects of science identity changed over the course of the program.

Table 28

Aspects of Science Identity Madison Most Emphasized in Facilitation

Participant	Entry	Fall	Midpoint	Summer	Exit
Stephanie	Investment	Performance	Investment + recognition	Investment + recognition	Recognition
Madison	Investment	Performance	Investment	Recognition	Recognition
Leah	Investment	Investment	Investment + recognition	Investment	Investment + recognition
Sonya	Competence	Recognition	-	Competence + recognition	Recognition

Note. - means no relevant data collected

Table 29

Each Participant's View on Science Identity within Facilitation Over the Course of the Program

Participant	Description
Stephanie	Stephanie consistently prioritized investment throughout the program. At the beginning of the program, she emphasized competence alongside investment. She briefly prioritized performance when the concept of engaging learners in scientific practices was introduced, but she ultimately decided recognition was the most important aspect of science identity to engage learners in although investment was a close second.
Madison	Madison shifted from focusing on investment to recognition with a brief emphasis on performance when scientific practices were first introduced. Over time she also placed less value on competence and more value on performance. For Madison, even though recognition ended up being the main priority, she expressed how she viewed each aspect of science identity as intertwined pieces of facilitation.
Leah	Leah was consistent in her views on facilitation, prioritizing investment and/or recognition throughout the entire program. By the end of the program, she equally emphasized investment and recognition as the most important aspects of facilitation. In her view, investment led to recognition which in turn lead to learners committing sufficient time to science learning experiences to engage with competence and performance. In this way, all four aspects were linked.
Sonya	Sonya was likewise consistent in her views on facilitation, prioritizing competence and/or recognition throughout the program. She started out the program valuing competence the most but ended up valuing recognition the most, particularly once she realized how important this component was to underrepresented populations whom she interacted with on school field trips.

While participants' conceptions of science identity followed different trajectories, participants' views on the incorporation of science identity into facilitation were more consistent and similar to one another. All the participants ended up valuing recognition as part of facilitation the most by the end of the program although Leah gave equal weight

to recognition and investment. Three of the four participants entered the program prioritizing investment over the other aspects of science identity as a key component of facilitation. Sonya was the exception, placing the most importance on competence. Stephanie and Madison emphasized performance in their fall interviews shortly after being introduced to scientific practices in the professional development program, but they too returned to a focus on investment and/or recognition by the midpoint interview. Even though the main focus of the professional development program was to teach informal educators how to engage learners in the performance aspect of science identity through scientific practices, informal educators did not prioritize this aspect, opting instead to engage learners primarily in the recognition component of science identity because they viewed getting learners to see themselves as capable of engaging with science as the gateway to engaging in other aspects of science identity, including performance.

Being in the professional development program may have inspired participants to incorporate recognition, or opportunities for learners to recognize themselves and be recognized by others as science people, into their facilitation when they had not even considered it before, or perhaps they had considered it, but experiences in the program led them to be more explicit about its importance and to place greater importance on it. For example, Sonya had not considered recognition an important part of facilitation previously but since working with students from marginalized groups on field trips, she had come to see just how important it was to support all learners to see themselves as capable within science. In contrast, Leah mentioned having always believed learners should be allowed to discover their own answers and lead their own learning, thus expressing a belief that creating space for learners to see themselves as science people is

an educator's responsibility, but the program helped her learn how to better accomplish that.

Both Madison and Leah discussed the intertwined and interconnected nature of the various components of science identity within facilitation. They viewed recognition as setting the foundation to engage with the investment, competence, and performance aspects of science identity because without feeling capable within a science context, learners may become frustrated, negatively impacting the investment aspect, and want to give up before they even give themselves a chance to engage with competence and performance. Across the board, participants ended the program feeling recognition was the first step to building a science identity.

Discrepancies between Participants' Conception of "Science Person" and Their View of Facilitation

While competence, performance, and investment featured prominently in participants' constructions of "science person," the aspects that were most prominent themes in their view of facilitation included recognition and investment. This discrepancy in emphases on different aspects of science identity can be partially explained because assuming an identity for oneself is categorically different from acting as a facilitator for another person to assume an identity. In Stephanie's case, she did not feel comfortable assigning the label of "science person" to herself but, nonetheless, had confidence in her ability to put on the science person hat and support others in their efforts to build a science identity.

One reason a focus on investment in particular makes sense is because a common theme among participants was describing informal science institutions, such as science

museums, as places where learners can explore in a judgement-free zone and make learning fun. If these qualities were viewed as core elements of the informal learning experience, it follows that many participants would speak to the importance of making learners' experiences positive ones. Especially when put in contrast to traditional classroom learning that entails a pre-determined agenda and curriculum, learners gain the opportunity to follow their own curiosities and not worry about being graded on their explorations. Falk and Dierking (2000) supported that this is one of the key responsibilities of informal educators, to create a positive experience for the learner by personalizing the experience to their interests. This emphasis to create a positive and personalized experience relates back to the idea of investment and creating buy-in for the learner to go deeper with the experience, which can lead to more opportunities to engage with other aspects of being a science person that many participants talked about. Participants prioritizing investment in their facilitation practice aligns with recommendations from the literature on informal education.

Additionally, even though performance was cited as the main hallmark of a science person by two of the four participants, participants felt they had to first address the recognition aspect, or creating space for learners to recognize themselves as science people through being allowed to lead their own discovery and come to their own conclusions, which can be a potential means to reach engagement in performance. Participants commonly viewed making space for learners to recognize themselves and/or be recognized as science people (recognition) as a way to create opportunities to generate interest in or a positive attitude towards the learning experience (investment), opportunities to expand learners' science content knowledge (competence), and

opportunities to behave like science people through engaging in scientific practices and interacting with others in the science community (performance). In the abstract, general sense of "science person," participants may have valued performance over the other components of science identity as the defining characteristic of what makes for a science person, but as informal science educators they felt they had responsibilities to first create space for learners to recognize themselves as belonging in a science context (recognition) and create buy-in from the learner to continue the experience through, for example, the affective aspect and making sure they were enjoying the experience or connecting the learning experience to something relevant in their personal lives (investment). Only once these two aspects of science identity were engaged with did educators feel they could engage learners meaningfully in all four aspects of science identity.

Lastly, informal science institutions provide the opportunities for learners to recognize themselves as science people because the interactions between them and the informal educators are inherently social, and recognition requires both seeing oneself in a certain way and being seen by others in the community that way. In this way, when informal educators treat learners as if they are science people, learners receive that recognition, and it creates an environment in which learners can more easily recognize themselves in this way too. As Falk and Storksdieck (2005) explained, one of the main contexts within a museum space is sociocultural. Therefore, it follows that the participants in this study emphasized recognition, the only component of science identity that necessarily involves interactions between people. Just as one of the core aspects of museum learning is making it fun and positive, lending itself to the investment aspect of science identity, another core aspect of museum learning that it is social, lending itself the

recognition aspect of science identity. Moreover, informal educators are often viewed by museum visitors as the experts in the space, which puts these informal educators in a good position to give recognition because their opinion carries weight to a lot of people.

When considering the key qualities of informal learning institutions, regardless of the specific topics taught or exhibits presented therein, striving to make learners' experiences positive and to help learners see they have the tools to lead their own explorations and seek out their own answers should be constants across informal educators' facilitation practices. Thus, participants consistently focusing on investment and recognition as the most important parts of facilitation fits within the context of informal learning.

Implications

Implications for Theory

This study added to Carlone and Johnson's (2007) framework for science identity. While they defined science identity by three qualities—competence, performance, and recognition—I defined it using an additional fourth element: investment. This was a necessary addition to the framework, as it emerged from the data consistently and frequently among participants when I asked them how they would define "science person." Many participants felt a necessary part of being a science person, and sometimes the most important part, was an interest or some other motivation for engaging in science—a sense of investment in the experience. Furthermore, this element of science identity featured prominently in their views on facilitation as well, expressing that guiding the visitor to feel interested in or at least positive about the science learning experience was an essential step to then engage them in other aspects of science identity

such as competence (content knowledge) and performance (talking about and doing science). Many participants thought engaging with the investment aspect of being a science person was a good way to ensure visitors engaged with all aspects of being a science person because it allowed for the time and space to have a more holistic science learning experience.

Considering investment to be an essential part of being a science person has implications for both science education and research. Educators can think of investment as a way to create entry points for learners to access science. Educators can recognize that connecting science topics to a learner's personal life and interests is valuable as a starting point for developing all facets of a person's science identity because through investment, learners may be more motivated to build their knowledge and practice doing science. Thus, investment may add a layer of meaning to the science learning experience. Likewise for researchers, considering investment to be part of science identity is valuable because it gives us another lens through which to analyze science learning in informal as well as formal spaces. Particularly, for learners who may struggle with the way in which science is presented in a traditional classroom with a heavy emphasis on gaining content knowledge quickly and easily and on performing ways of talking about and doing science, investment may play a critical role in validating their potential for being a science person and open up the possibility of assuming that identity to more people.

Implication for Museums and Other Informal Education Institutions

Recognizing visitors as science people is an important component of facilitation in any educator-visitor interaction. For example, Madison saw value in giving learners the opportunities to see themselves as science people when she worked with young

children who were particularly shy or unsure of themselves in the space. She acknowledged that because facilitation is so learner-dependent, recognition can be even more important in circumstances where a learner's personality or disposition makes them more reluctant to actively participate in their learning, and informal educators have the capability of easing the experience for them.

Moreover, recognizing visitors as science people can be particularly valuable for learners in historically marginalized groups, which Sonya and Leah supported with their experiences during the program. Museums are spaces that have historically been exclusive to those in upper socio-economic classes, so today there still exists the need to make museum learning more equitable and more accessible (Falk & Dierking, 2000). If museums take on this responsibility to be a resource to all members of their communities, having informal educators who understand how to interact meaningfully with diverse populations is essential. Sonya, especially, viewed that the way to accomplish more equitable learning was through helping learners see themselves as capable of engaging with and as belonging within science spaces. While helping visitors feel recognized as science people is an important part of interacting with all visitors, it can be especially meaningful for people whose identities may make recognition of themselves and by others as science people more difficult to achieve.

Implications for Informal Science Education Professional Development Programs

One crucial quality of this professional development program was its timeline, lasting for an entire year. Madison and Stephanie mentioned time being a factor in how their conception of themselves as science people evolved, that having time to sit with ideas about informal science learning had important implications for how they came to

view themselves and others within a science space. The identities of most participants continued to change up to the end of the program. Their views on science identity changed between the entry and the midpoint interviews, and their views shifted yet again between the midpoint and the exit interviews. This would support that participating in the professional development program for the entire year was impactful. However, even though sufficient time is necessary for identity work to be meaningfully engaged in, identifying how long is sufficient for a professional development program is hard, and perhaps a shorter duration would have had similar impacts, or merely the experience of facilitating on the floor of the museum would have provided enough opportunities for identity development without a professional development program at all. Future research could explore the effects on the science identity development of informal educators participating in a shorter professional development program to see if similar changes occur. This would be especially useful given the nature of informal science institutions in that they often lack the funding and resources to provide extensive training for their staff, let alone training that includes expertise to more closely resemble professional development that offers opportunities to reflect on their practice and consider the theoretical underpinnings of their work rather than instructing them only about the practical and logistical aspects of their roles.

Though providing these professional learning opportunities to staff is often challenging, I argue it is worthwhile. Other research supports this claim as well, particularly Reflecting on Practice (Martin et al., 2019; Tran & Halverson, 2021; Tran et al., 2013). Tran and colleagues implemented Reflecting on Practice as a way to be more intentional about the professional development needs of informal educators. They found

that participation in the Reflecting on Practice professional development program resulted in positive outcomes, such as participants' change in behavior with learners (e.g., asking more open-ended questions), participants' change thinking (e.g., having more intention behind their facilitation choices), and participants' sharing of knowledge and practice with each other more frequently and thoughtfully. Similar to Tran and colleagues, I found that participation in a professional development program coincided with my participants' changes in facilitation as well (Tables 16, 17). Further, in my analysis I offer another benefit of engaging in such a program—participants, for the most part, expanded and deepened their sense of themselves, as well as their view of other people, as a science person over the course of their participation in the program, not necessarily related to facilitation. Participants in this study had the opportunity to grow and change not only as informal educators but as individuals with their own science identities. This view of how professional development programs can be beneficial for informal educators recognizes them as persons, too, who will each interpret and incorporate their professional development experiences into their facilitation practice in their own unique ways.

Therefore, efforts need to be made to provide informal educators the time and space to be reflective about their practice. Often participants' shifting views of themselves as science people and what constitutes a science person were reflected in their views on facilitation and how they believed they should interact with learners. As their definitions of "science person" broadened, participants facilitated experiences with learners that became more inclusive and that increasingly prioritized the recognition aspect of science identity. While I cannot say whether changing science identities

influenced changes in facilitation or vice versa, I can confidently say that participants' engagement with science identity in this study and their practice of facilitation with learners to engage with a science identity were linked. Madison, for example, described feeling more confident in herself as a science person when she supported children in the museum to see themselves in that way because, as she described, the more she told children they were capable of engaging with science, the more she believed she too was capable of engaging with science. Thus, just as classroom teachers' identities may be reflected in their teaching practice (Avraamidou, 2014a; Katz et al., 2011; Moore, 2008; Rivera Maulucci, 2013), the same was true in this study of informal educators' identities and their facilitation practice. If informal science institutions aim to reach a broad and diverse audience, in order to serve all members of their communities, investing in the professional learning of their educators is one way to support that goal because the ways in which they grow as individuals and educators will come through in their interactions with learners.

The important takeaways from this study for other institutions hoping to implement more professional learning for informal educators were providing sufficient time and multiple opportunities for informal educators to grow. Participants benefited from returning to ideas about science identity and facilitation multiple times over the course of the program, integrating what they were learning during professional development with their own experience on the museum floor and their own perspectives on learning as a whole. If short on time and resources, however, institutions may be able to impart professional learning to their staff over a shorter period of time or periodically, like a few times a year, and, over time, they may see changes and growth in educators'

facilitation practice. Perhaps the professional development itself may not need to last very long, but educators still need time to reflect on those learnings and incorporate them into their facilitation practice as they gain more experience and insight into how they can best support learners. Furthermore, participants expressed that having varied activities in which to practice and reflect on what they had learned in the program helped them refine their facilitation, as the more situations and factors they took into consideration, the more they felt sure about themselves as science educators and the more they solidified their views on facilitation.

Limitations

This study's limitations include the types of data collected and the research context. This was limited, in part, due to restrictions on in person interactions due to COVID-19 protocols put in place by both the museum and the university. Due to the COVID-19 pandemic participants had limited time on the floor, so making connections between the time they spent as a facilitator and the outcomes is difficult to generalize.

With regards to the types of data analyzed in this paper, collecting interviews and written artifacts were helpful for gaining insight into participants' perspectives and reflections throughout the program. However, in terms of their recounting of facilitation experiences, I relied on participants' interpretation and self-report of the events because I did not always have direct observations of their interactions with learners. While some of the experiences they discussed in interviews were video-recorded, the video was limited in ways visible and audible, necessitating that the participants narrate some of the events. While I feel confident that interviews and written reflections together were sufficient for answering the first research question about how participants' science identity (both their

definition of it and their place within that definition) changed over time, I think the second research question about how their views on science identity within facilitation changed could have been even more supported through observation data. Nonetheless, the data provided evidence of their views on facilitation and the intentionality behind their facilitation choices, something that would not be easily deciphered in observation data. Thus, for the purposes of this paper, interview data made the most sense. In future iterations of this work, however, observation data could serve as confirmation or refutation of educators' claims about how they facilitate.

Furthermore, I observed changes in the self-reported science identity of the participants occurred over the course of the professional development program, but attributing specific parts of the program to these changes is difficult. While many participants expressed being in the program had a positive impact on their views of themselves as science people and had broadened their view of who could be a science person, they had a hard time specifying which aspects of the program had the biggest impact because they felt holistically, all the components—facilitating, reviewing facilitation with peers in the cohort, reflecting in writing about their experiences, receiving direct instruction, etc.—worked together to create a meaningful experience over that year. Therefore, I can argue that providing space for informal educators to engage with professional learning to develop their own identities as well as to reflect on how best to support learners in identity work, but I cannot speak to which specific assignments or activities within the professional development program of this study, if any, were most responsible for the growth and development of the participants.

With regards to the research context, although I applied a revised version of Carlone and Johnson's (2007) construction of science identity, including competence, performance, recognition, and investment, I acknowledge that the professional development program in which this study took place did not give equal attention to these four aspects. Performance in the form of scientific practices was the most emphasized piece of facilitation. Recognition was emphasized to a slightly lesser extent, encouraging participants to see everyone as capable of engaging with scientific practices. Investment was emphasized even less. That is, the professional development program did not explicitly focus on how to convey that museum learning should be enjoyable and positive experiences. Competence, gaining and possessing science content knowledge, was also only addressed in a limited way. This way of ranking the importance of different aspects of science identity were in line with the goals of the institution itself and with its views on how best to engage people in science in a hands-on setting with interactive exhibits. While this structure of the program stayed true to the institution, it did not give equal opportunity for participants to engage with all the aspects of science identity as described in the framework of this study.

This was not ideal for giving equal chances for participants to develop science identity around each of the four components, but I think the places where this bias came into play were explicated in my analysis of the findings. For one, participants were for the most part already familiar with the idea of competence playing a role in science identity because this the most emphasized aspect in formal education. Additionally, participants benefitted from being introduced to performance as a key element of science identity, helping them to broaden their conceptions of who could be a science person, and

while some participants highly valued performance once introduced to it, other participants prioritized performance only briefly and then incorporated it into their facilitation practice more holistically, choosing by the end of the program to emphasize other aspects of science identity in facilitation more. I think the timeframe of the program helped make up for its biasing of some science identity components over others. Given many months to become familiar with scientific practices and then consider how they would most like to engage learners in science, participants came to their own conclusions about what was important to them in facilitation, which may or may not have prioritized performance.

Future Research

This study supported that providing opportunities for informal educators to engage in science identity work had positive implications for their interactions with learners. Future research can be more comparative to further refine what professional learning opportunities should look like and which are the key elements that have the biggest impact while expending the least amount of resources. For example, a future study could compare informal educators in a professional development program and informal educators who work at the same institution but are not in a professional development program. This would be possible at the Museum of Physical Sciences, where not all staff go through the professional development program, but instead a shorter training session when they are first hired to learn the logistics of their job. In this way, researchers could explore to what extent the professional development impacts facilitation and science identity versus how these areas would be impacted through gaining facilitation experience alone. Additionally, future research could look at a

program that involves similar activities as the one focused on in this paper but only occurs over six months, or an even shorter time period, to see whether meaningful changes in facilitation and science identity happen sooner than the one-year mark, which would mean institutions could save on resources.

Conclusion

The participants' conception of science identity, their perception of their own science identity, and how they encouraged science identity of guests through facilitation changed over the course of the professional development program for the four participants in this paper. While they differed in their pathways of how to define "science person," participants had largely similar views on facilitation throughout the program. I observed that science identity development and views on facilitation were linked as participants described each influencing the other. As researchers, we can aim to better understand this relationship, particularly because informal educators are the most important agents in carrying out the mission of an informal learning institution. If institutions can more effectively and meaningfully train their staff by creating opportunities to engage in professional learning, they can more easily achieve their goals and better serve their visitors.

This study contributed to the gap in the literature for research on the science identity of informal educators, showing that in fact science identity of the individual educator does affect their facilitation with learners. Moreover, professional development programs are still rare in the informal education field, while they are commonplace in formal education. This paper described the benefits of investing in programs such as this for informal educators because ensuring science institutions meet their goals of engaging

learners in science and their responsibilities of serving their communities, including populations that have historically been excluded from such institutions and science more generally, is important for the betterment of society. Having more members of our communities that are capable of engaging with science and feel they belong in science creates a better-informed society who influence the choices and policies related to science that impact everyone.

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Appendix

Entry Interview Protocol

1. What science experiences have you had? (These can be related to education, jobs, recreational activities.)
2. a. What does it mean to you to be a science person?
   b. What qualities do you associate with a science person?
3. a. Would you describe yourself as a science person?
   b. Do you think you possess any of the qualities you just described?
   c. Do you think you possess any qualities that would hinder you from being a science person?
4. Can you think of a specific time you did or did not feel like a science person? Can you tell me about it?
5. Do you think anyone in your life has seen you as a science person? This can be a teacher, a family member, a friend, etc.
6. Have you seen science people either in your personal life or in the media that you identify with? (e.g., similar education backgrounds, gender, race, language, etc.)
7. What experiences have you had in informal science settings (e.g., museums, after-school programs, zoos/aquaria)?
8. What do you think is the primary role or purpose of informal science institutions like science centers, museums and zoos?

a. Probe if they don't understand the question: When someone comes to a science center, museum, or zoo, do you hope they leave with a better understanding of science, an interest in the world around them, a memory of a fun time, a connection to other visitors, a connection to their family or their community, opportunities to engage in science, or something else? If you think there are multiple goals, which is the most important to you?

9. How important do you think having content knowledge is for staff when interacting with visitors? For example, having science knowledge in a science museum.

a. How do you think you might answer a content question you don't know the answer to?

10. Think of an exhibit that you have seen at an informal science institution (museum, zoo) that you think is particularly "good" or effective (they can define "good/effective however they want -- good at conveying some science idea, fun, good at engaging people in conversation, etc).

a. Describe the exhibit.
b. What do you think made it effective?
c. If you were working at the museum/zoo that you described above and responsible for facilitating other visitors' experience with the exhibit you described, what would you do? And why?

i. What if the visitor was a very young child?
ii. What if the visitor was an adult who was an expert in the content?
iii. What if the visitor was a member of the museum who had seen the exhibit many times before?

11. What qualities, experiences, or background knowledge do you think you have that will help you when facilitating exhibits at the museum?
12. What do you hope you gain or learn through the professional development program?

Fall Interview Protocol

1. Could you please describe what you think makes a good facilitation encounter?

2. What strategies did you use in your interactions with visitors?

I would like to transition into reflecting about the facilitation experiences you wrote about in blog posts. Feel free to have those posts in front of you while we talk for reference. Just let me know which post you're referring to if possible.

3. Can you please describe in detail what is happening in the situation(s) you selected/wrote about?
4. Thinking about this (these) experience(s) do you think they were example(s) of good facilitation? Why or why not?

Possible Probing Questions

a. Why did you decide to take that course of action?
b. What did you see that made you respond in that way?
c. How did the visitors respond to these efforts?

5. What was your goal as a facilitator in this situation?
6. What do you think the visitor took away from this interaction?
7. Looking back at this experience, is there anything that you would change in your facilitation?
8. If you were to train someone who had never worked in an open-ended museum, what advice would you give them?

Midpoint Interview Protocol

1. Could you please describe what you think makes a good facilitation encounter?
2. What strategies mainly guide your day-to-day interaction with visitors?

I would like to transition into reflecting about the X minute video that you selected as being a good facilitation encounter. I have the video here for your reference if you need to pull up any specific moments while we talk, please feel free to. {have them share their screen to show video or pull up on box and share your screen}

3. Can you please describe in detail what is happening in the situation you selected?
4. Looking at this video clip, why did you identify these X minutes as being good facilitation?

Possible Probing Questions:

a. Why did you decide to take that course of action?
b. What did you see that made you respond in that way?
c. How did the visitors respond to these efforts?

5. What was your goal as a facilitator in this situation?
6. What do you think the visitor took away from this interaction?
7. Looking back at this experience, is there anything that you would change in your facilitation?
8. If you were to train someone who had never worked in an open-ended museum, what advice would you give them?

Summer Interview Protocol

1. Could you please describe what you think makes a good facilitation encounter?
2. What strategies mainly guide your day-to-day interaction with visitors?

I would like to transition into reflecting about the X minute video that you selected as being a good facilitation encounter. I have the video here for your reference if you need to pull up any specific moments while we talk, please feel free to. {have them share their screen to show video or pull up on box and share your screen}

3. Can you please describe in detail what is happening in the situation you selected?

4. Looking at this video clip, why did you identify these X minutes as being good facilitation?

Possible Probing Questions

a. Why did you decide to take that course of action?
b. What did you see that made you respond in that way?
c. How did the visitors respond to these efforts?
5. What was your goal as a facilitator in this situation?
6. What do you think the visitor took away from this interaction?
7. Looking back at this experience, is there anything that you would change in your facilitation?
8. What are your goals in general for visitors? What do you hope they take away? (probe about practices, content, recognition if not already mentioned)
9. If you were to train someone who had never worked in an open-ended museum, what advice would you give them?

Exit Interview Protocol

1. Could you please describe what you think makes a good facilitation encounter?
2. What strategies mainly guide your day-to-day interaction with visitors?

I would like to transition into reflecting about the X minute video that you selected as being a good facilitation encounter back in the Fall. I have the video here for your reference if you need to pull up any specific moments while we talk, please feel free to. {have them share their screen to show video or pull up on box and share your screen} I would like you to answer these questions from your perspective now after having had much more experience facilitating exhibits and participating in this program.

3. Can you please describe in detail what you now think is happening in the situation you selected?
   a. Please describe what your goals for the learner would be now.
   b. How would you facilitate this experience if you had the chance to do it again?
      i. What prompts would you use?
   ii. What would your initial goals be?
   c. If you were able to spend an extended time with the visitor(s) in the video you selected, what do you think you could accomplish with them?
   d. Thinking about the framework we introduced in class. For each question, think about specific prompts you might use.
      i. How could you maximize their use of a specific practice?
      ii. How could you optimize their engagement level?
      iii. How could you extend their experience to include other practices?
4. What do you think the role of a facilitator is in a space like the Museum of Physical Sciences?
5. During your time at the museum, you had training opportunities which included shadowing experienced Sparks, reflecting on video of your own facilitation, discussing facilitation with your peers, direct instruction, reading about research on informal education, remote facilitation, and conducting research on projects of your own interest. Which of these do you think contributed to your own learning and how?
6. If you were to train someone who had never worked in an open-ended museum like the Museum of Physical Sciences, what advice would you give them?

7. Is there anything else you'd like to share about your experience facilitating or with the professional development program?