Long-Term Impacts of a Museum School Experience on Science Identity

Catherine J. Scharon

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Committee:

Jessica J. Luke

Katie Davis

Mark A. Windschitl

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ABSTRACT

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Catherine J. Scharon

Chair of the Supervisory Committee:
Jessica J. Luke, Ph.D.
Museology

While museum schools have proliferated over the past quarter century, little research has examined the outcomes of these formal-informal partnerships. This study investigated the long-term impacts of a museum school experience on alumni of Raisbeck Aviation High School and the Museum of Flight (Seattle) and Science Leadership Academy and The Franklin Institute (Philadelphia) using science identity as a theoretical lens. In retrospective interviews, alumni reported having and enacting a science identity and attributed several important indicators to memorable experiences at the museums. Participants placed particular value on the museums' tangible learning experiences, real-world connections, and access to professional networks. These results support the learning value of intensive museum school partnerships and suggest potential directions for future research.

Keywords: Museum schools, museum-school partnerships, science identity, informal science education, project-based learning.

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CHAPTER 1: Introduction

Today's museums allocate immense proportions of their resources to student audiences. In the United States, museums and informal learning institutions spend more than two billion dollars per year on education, contributing more than eighteen million instructional hours to students and school programs (Center for the Future of Museums, 2014). Increasingly intensive partnerships known as "museum schools" are reshaping the way informal learning institutions reach these audiences. These veritable laboratories for museum-style pedagogy provide a best-case scenario for exploring the full potential of formal-informal collaborations. Research into the lasting student outcomes of these partnerships will allow us to better understand the range of possibilities for museum outreach and identify key strategies for engaging these student audiences.

Museum Schools: A Growing Trend

What exactly is a "Museum School"? Though they vary greatly in their organizational structures (King, 1998; Povis, 2011), museum schools are defined in this study as robust, formal school-museum partnerships that integrate museum curricula and object- or project-based learning into everyday instruction. Schools may work closely with a single museum, zoo, or science center, or they may partner with multiple informal learning institutions to create authentic experiences. Classes may take place in the museum, on the museum's campus, or off-site with frequent excursions; however, the partnerships must be sustained over the entire academic year.

Museum schools have proliferated over the past quarter century to include nearly fifty sites nationwide (NAMS, 2015; Povis, 2011; Sturgeon, 2010), with proposals to open new schools or add grade levels continuing through 2021 (Grand Rapids Public Museum School, 2015; Lowe, 2015). However, the museum school literature to date has focused on describing different models (Finnerty, 1996; King, 1998; Povis, 2011; SMM, 1996) and understanding the mechanisms for successful collaboration (Boekhoff, 2002; Klein et al., 2001). Work from the University of Southern California has characterized classroom instruction and professional development at the Alexander Science Center School in Los Angeles, but primarily from the perspective of formal education (Gargus, 2006; Heughins, 2006; Larson, 2006; Watkins, 2006).

Moreover, the American Alliance of Museums has identified museum schools as a priority for research through the newly established Ford W. Bell Fellowship for Museums and K-12 Education (Guiter, 2015). The consensus is that we need to better understand these proliferating institutions, with the implication that identifying successful strategies now could lead to the creation of new partnerships in the future (Center for the Future of Museums, 2014; Merritt, 2012).

STEM Education: Building a Science Identity

While the literature contains snapshots of existing museum-school collaborations, studies to date have generated little understanding of the lasting impacts these institutions have on the trajectories of students' lives and careers. At the high school level, several museum schools orient themselves around the fields of science, technology, engineering, and mathematics (STEM), widely regarded as key disciplines for national economic growth and innovation (PCAST, 2010). While the number of museum school students who go on to pursue advanced degrees and professions in STEM fields is one metric of success, the concept of *science identity* provides a broader framework for conceptualizing successful science learning (Carlone &

Johnson, 2007). Science identity depends not only on the cognitive knowledge imparted during formal education, but also a range of affective and behavioral components across a range of social contexts (Ascherbacher, Li, & Roth, 2010; Carlone & Johnson, 2007).

There are practical benefits to using science identity as a framework to assess STEM-oriented museum high schools as well. Science identity gels over time as it is "habitually accessed, performed, and recognized," (Carlone & Johnson, 2007); as a result, retrospective research offers useful methodologies for studying the social, emotional, and cognitive learning experiences that are intertwined in a museum school.

Purpose and Research Questions

The purpose of this research is to investigate the long-term impacts of a museum school experience on the formation of alumni's science identity:

1. To what extent do museum school alumni report having and enacting a science identity?
2. In what ways do alumni of museum schools attribute their science identity to the museum school experience? In particular, which resources or opportunities do alumni recall as having a lasting significance or connection to their current engagement with science?

Implications

This research will contribute to our nascent understanding of museum schools and the kinds of meaningful experiences they deliver. By delving into their long-term impacts on students, this study will inform educators and administrators on both sides of the museum-school equation in refining curricula and guiding the development of future partnerships.

CHAPTER 2: Literature Review

Following the first conference dedicated to the emerging museum school trend, Museum Magnet School coordinator Kelly Finnerty (1996) described these innovations as an opportunity to expand the very definition of museum education: "The message from the frontier of museum-school partnerships to museum educators is that it's not only what museums do but the way museums do it that has educational value for children and teachers" (p. 9). Despite Finnerty's optimism and the proliferation of museum schools in the since (Povis, 2011), the literature has made little progress towards substantiating such claims of educational value with evidence.

Much of the literature directly related to museum schools over the past quarter century has focused on defining the trend and documenting the range of collaborative models, with only a limited number of case studies addressing learning in these contexts. Interest in museum schools often hinges on the assumption that they deliver museums' educational promise; as a result, this study also borrows from the literature on museums' shifting educational priorities and the growing evidence base for object- and project-based learning.

This study is also informed by the literature on informal science learning and science identity. Research on STEM (science, technology, engineering, and mathematics) education recognizes cognitive elements of learning as well as social and emotional factors; science identity provides a framework for considering both the contents and inspirational impacts of learning experiences as they bloom over a lifetime. By situating this study adjacent to the established literature on effective science education, pathways for researching the effects of museum school practices will become clear. This literature review will first explore the museum school literature itself, followed by sections on the challenges of science learning and science identity, and concluding with connections between the two.

Museums and Schools: A Natural Affinity

The affinity between museums and formal education is well established, despite the relative novelty of museum schools. Scholar of museum education George Hein (2004) notes the significance of museums in John Dewey's influential educational philosophy as an exemplar of the connection between classroom and real-life experiences. In the 1920s, Dewey's Laboratory School at the University of Chicago made use of the campus museum and visited what was then the Field Columbian Museum "for an hour and a half every week" as "part of an extensive program of excursions to connect school life with the world outside" (Hein, 2004). Hein also notes parallel thinking in John Cotton Dana's progressive museum education, which sought to democratize museums for experiential learning. This connection between museums and formal education has persisted, as seen in an article by learning theorist and developmental psychologist Howard Gardner (1991) entitled "Making Schools More Like Museums."

Concurrently, the museum field of the late twentieth and early twenty-first centuries has positioned itself as directly educational through its own research and strategic communications. Building on the Commission on Museums for a New Century (1984), the American Alliance of Museums' report *Excellence in Equity* called on member institutions to embed educational purpose "unequivocally" in their mission (Hirzy, 1992). Noted museum scholar Stephen Weil (2002) characterized the operationalization of museum education as a transformation "From Being *about* Something to Being *for* Somebody" in *Making Museums Matter*, arguing that these institutions have long been shifting away from collections management towards more publicly oriented missions and programs. Similarly, Hilde Hein (2000) noted the role that education plays in museum marketing: "Education has become truly big business, and museums are more than ever in the position of competing, as well as collaborating, with other institutions" (p. 115).

Proliferation of Museum Schools

Though the Forth Worth Museum School's early childhood education program precedes most museum schools by several decades (Stetson & Stroud, 2014), the literature recognizes the contemporary museum school movement as originating around 1990 with the opening of Charles Drew Science Magnet School at the Buffalo Museum of Science (Klein et al., 2001) and the Museum Magnet School affiliated with Science Museum of Minnesota (Finnerty, 1996). Kira King's (1998) cross-case study of museum schools documents several other notable examples from this first wave of establishments, including the New York City Museum School and both elementary and middle grade level museum schools affiliated with the Smithsonian Institution.

Two conference sessions dedicated to museum schools reflect continued momentum throughout the decade. "Museum Schools: A National Symposium" was hosted in 1995 by the Science Museum of Minnesota, the Institute for Museum and Library Services, and the Association of Science-Technology Centers (Finnerty, 1996; Klein et al., 2001; Science Museum of Minnesota, 1995); in 1998, "Museum Schools and Student Success: A National Symposium" was hosted by SMM, IMLS, and the Smithsonian Institution (Klein et al., 2001). By the latter convening, King's (1998) research had identified eleven sites calling themselves museum schools, with eight others fulfilling her criteria for museum learning and organizational cooperation.

The early twenty-first century saw a second wave of proliferation, as documented in Kaleen Povis's (2011) museum school database project. Like King (1998), Povis (2011) included both self-identified museum schools and those with consistent partnership models, confirming the existence of at least thirty-two actives sites and four more in development. Povis's findings also note up to thirty more schools that have operated under a museum school model at some point in their history but had since closed, merged, or revised their practice, including the original Museum Magnet School in St. Paul (Weber, 2011). As of this study's publication, at least 45 sites are believed to be operating under a museum school model in the United States. (See Appendix A: Museum School Census for a listing, building on the work of Povis (2011) and the National Association of Museum Schools (2015)).

There is also evidence that the museum school trend continues to grow. The Grand Rapids Public Museum School's inaugural 6th grade class enrolled in 2015, with plans to add one grade per year as students progress through middle and high school (Grand Rapids Public Museum School, 2015). In Jefferson County, Kentucky, a proposal for a new K-5 Museum Magnet School in collaboration with the Frazier History Museum and Kentucky Science Center is currently under review (Lowe, 2015).

It is worth noting that museum schools are nearly exclusive to the United States, though several international programs use similar terminology to different effect. In 2008, Langley Academy in Berkshire, England became the UK's first and only self-identified museum school; however, Watermeyer's (2015) study on faculty implementation of "museum pedagogy" in the classroom suggests that while the school does mirror some museum practices, it does so without the degree of organizational collaboration seen in the American phenomenon.

Some parallels may be drawn between American museum schools and the Forest School movement in England and Wales, which aims to provide sustained, hands-on learning in outdoor environments; however, these schools also lack a partnership component (O'Brien & Murray, 2006). Finally, the term has been applied to a variety of school-museum partnerships in Canada, but these are typically conducted as week-long immersive field trips rather and not as integral parts of the curriculum at a school level (Kydd, 2004; Museum School London, 2015).

Defining the Museum School

Finnerty (1996) offers an intuitive working description of museum schools as "a new concept, a hybrid of mixed origins that bears resemblance to each parent institution but is unique in itself" (p. 6). However, the literature struggles to find a precise formula for these collaborations. Interestingly, even the newly formed National Association of Museum Schools does not define the scope of its membership, opting instead to use the language of "project-based learning and the museum model of learning" in its online presence (NAMS, 2015).

Though researchers have not agreed on a single, unified definition of museum schools, there are three major points of consensus. First, the literature is quick to acknowledge that diverse models for these school-museum partnerships can exist with regards to their logistics, such as number of partners and locations (Finnerty, 1996; King, 1998; Klein et al., 2001; Povis, 2011). Two major criteria follow: first, a strong organizational relationship between the school and museum parties; and secondly, a curriculum designed in partnership to make use of museum content and/or strategies (Borden, 2000; Kendrick, 2003; King, 1998; Klein et al., 2001).

Museum School Configurations

Researchers and museum educators have recognized several variables within the range of museum school models (Finnerty, 1996; Sturgeon, 2010; Povis, 2011). At an administrative level, some schools chose to partner with multiple cultural institutions while others align themselves closely with a single organization. The New York City Museum School is perhaps the earliest and most notable example of a school that works with a constellation of museums (King, 1998), but the model has been replicated more recently at sites including the Museum School at Avondale Estates in Georgia (Povis, 2011). Moreover, a number of museum schools include additional cross-sector partners, such as universities (Klein et al., 2001) or corporations. This corporate support may be philanthropic, as in the Henry Ford Academy (Heughins, 2006), or programmatic as in Cleveland's MC^2 STEM High School's partnerships with General Electric's Lighting headquarters at Nela Park (MC^2 STEM High School, 2015).

With respect to governance, museum schools are typically public, tax-funded institutions. Though a handful of museum schools are categorized as neighborhood schools, they more commonly operate as one of the following types:

- Magnet schools, featuring broad attendance boundaries but attracting students with a specialized curriculum and selective enrollment (Forester, 2007);
- Charter schools, with neighborhood attendance boundaries and special provisions for leeway with curricula and testing (Forester, 2007; Krapfel, 1998); or
- Alternative schools, fully embracing nontraditional curricula to meet the needs of a specific student audience (Povis, 2011).

Museum schools also vary in their spatial arrangement and proximity to the museum (Povis, 2011; Sturgeon, 2010). Classes may be convened entirely in museum-operated spaces, as in the case of Henry Ford Academy (Heughins, 2006) and the newly opened Grand Rapids Public Museum School (Grand Rapids Public Museum School, 2015). Other sites have a dedicated school space located on or adjacent to the museum campus, such as Raisbeck Aviation High School at the Museum of Flight near Seattle (Rogers & Keller, 2013). Others still occupy traditional school buildings off-site, with frequent excursions to one or more museum partner institutions, as with the Museum School at Avondale Estates (Merritt, Kelbaugh, & Rombauer, 2015; Povis, 2011).

Organizational Partnerships

Across the range of museum school configurations, the literature highlights authentic collaboration as a common thread critical to the success and very definition of a museum school. It is not enough for an initiative to simply share museum resources with student groups—as in the case of field trips or outreach programs. Rather, museum schools are a true "paradigm shift that requires new organizational structures," according to founding co-director of the New York City Museum School, Sonnet Takahisa (1998, p. 5). Takahisa also highlights accountability and responsibility as being the domain of both the museum and school partners; their relationship "implies a consistent, long-term commitment that, unlike other 'projects,' cannot simply be abandoned upon the completion of funding" (p. 5).

External researchers agree that a high level of shared commitment is a defining characteristic of museum schools. Naida Kendrick's (2003) thesis, "Building Viable Museum Schools" identifies "large scope" and "significant collaboration and curricular integration" as necessary criteria for museum schools (p. 6); similarly, Rebecca Borden (2000) refers to "long-term, cooperative relationships" (in Povis, 2011, p. 6). Lynette Larson's (2006) dissertation on science teaching in museum schools also highlights shared commitment and vision; she adds that the collaborative work carried out by teachers and museum educators serves as a positive model for students' own teamwork.

A small strand of research exists on the blending of school and museum culture, using lenses of organizational development and collective impact. Klein et al. (2001)'s analysis of the Compton-Drew Investigative Learning Center affiliated with the St. Louis Science Center uses program documentation and observations to find positive signs of "merging" cultures, including sustained engagement from both parties. Boekhoff's (2002) dissertation, written from the perspective of a founding teacher of the pseudonymous "School of Museum Studies," sheds a more critical light on the way staffing changes and new testing and reform measures can jeopardize support for the museum school model.

Though the results of these organizational studies are mixed, together they demonstrate the significant challenges of sustaining intensive museum-school partnerships. Though museums and schools naturally occupy complementary niches, collaborative museum schools represent a substantial paradigm shift. Kira King's (1998) dissertation distinguishes between one-sided projects with isolated results ("museums-in-schools" and "schools-in-museums") and true museum schools "requiring the re-definition of institutional boundaries" (p. 30). The result is not only a strong organizational partnership structure, but a cohesive museum school capable of systemic change over time.

Integrating Museum Learning

The final defining feature of a museum school is the weaving of museum content or practices into the educational strategies employed with students. This museum learning component is the natural outgrowth of a co-created curriculum and can be seen across each of the partnership models; however, the specific museum strategies adopted represent yet another variable. Many of the first wave museum schools, including the Museum Magnet School at the Science Museum of Minnesota, operate under "the premise that the exhibit development process used by museums and its attendant activities—collecting, research, observation, experimentation, interpretation, and presentation—will stimulate children's creativity and critical thinking and provide an interdisciplinary framework that can foster effective classroom learning" (Finnerty, 1996, p. 7).

King (1998) provides a broader definition for the work of a museum school: "to implement museum learning with at least one of the following three application activities: object creation, exhibit creation, and museum creation" (p. 196). In her dissertation, King finds evidence of constructivist learning approaches through "museum learning," a phrase borrowed from the New York City Museum School to describe any "project-enhanced learning that utilizes experience-oriented or object-oriented activities" (p. 196). This expanded definition includes internships and opportunities to engage with content experts or museum professionals, in addition to the collections or exhibit-based activities associated with informal institutions.

Collections-oriented approaches focus on authenticity and understanding through student engagement with artifacts or other "realia," such as manipulatives, models, and interactives (Larson, 2006). These kinds of object-based lessons have been shown to provoke especially long-lasting understanding in Paula Liken's (2009) research. Using quasi-experimental methods, a treatment group of students learned about the history of mining in the Southwest using museum artifacts; a control group used images of the same items. Despite having similar levels of recall the next day, when asked about the lesson two months later, students who used the real artifacts demonstrated significantly better understanding and memory.

Some museums schools—particularly those serving higher grade levels, like Science Leadership Academy at The Franklin Institute in Philadelphia—focus on the real-world aspect of completing internships or capstone projects and engaging with professionals (Lehmann & Chase, 2015). Proponents of "project-based learning" cite the approach as fostering deep understanding by simulating professional experiences; moreover, they are particularly fitting for museums as they make "students, teachers, and community members engage in collaborative activities to find solutions" (Krajcik & Blumenfeld, 2006, p. 318).

Kaleen Povis's (2011) thesis project reflects on the multiplicity of definitions and attempts to categorize manifestations of museum learning according to each institution's predominant mode. Povis's motivation stems from Michelle Phillips (2006) of the Exploratorium's Center for Informal Learning and Schools, who writes that "research reveals that conceiving of museum-schools as fitting a single model or being defined, based only on linear continua, fails to capture their multiple dimensions and complexity" (in Povis, 2011, p. 7). Povis identified four emergent categories for the museum processes adopted by schools (see Table 1). Although Povis matches compelling archetypes to each category, the effectiveness of this coding scheme in sorting all museum schools into singular categories is untested. Nevertheless, these categories demonstrate a broad range of activities under the umbrella of museum learning.

Table 1. Types of Museum Learning Exhibited in Museum Schools (Povis, 2011, p. 24-25)

Category	**Description**
Teaching Approach	Uses museum-style pedagogy, with an emphasis on object-based learning.
Thought Process	Uses museum practices as a model for learning, with an emphasis the exhibit process.
Topical	Uses the museum as a subject expert, with an emphasis on content alignment.
Thematic	Uses the museum as a topic of study, with an emphasis on organizational development.

State of the Museum School Literature

As noted above, the direct body of literature has been slow to move beyond the identification and description of museum school models; however, the need for research into these educational partnerships has been widely recognized. King's (1998) dissertation focuses on the need for external research, warning of potential bias in early literature derived almost exclusively from internal voices. King's concern is reflected in a 1998 issue of the *Journal of Museum Education* titled "The Classroom Connection: Museums as Catalysts for School Reform" (Dow, 1998). The journal features museum schools as a prominent theme, but relies heavily on narrative accounts by administrators and practitioners describing their home institutions' strategies (Finnerty et al., 1998; Klein, 1998; Krapfel, 1998; Takahisa, 1998).

In 2006, a series of dissertations from the University of Southern California's Rossier School of Education examined the Alexander Science Center School from educational leadership and instructional perspectives. Andrew Heughins (2006) traces years of negotiation on the part of the California Science Center, the Los Angeles Unified School District, and other private and public interests in the project's architecture, while Diane Watkins (2006) and Lynette Larson (2006) examine the implementation of science curricula as single case and cross-case studies, respectively. In each instance, findings indicate that the museum school structure represents a significant departure from the traditional model. Gerald Gargus (2006) frames the discussion in terms of teacher professional development needs, finding that faculty are acutely aware that they are being challenged to "incorporate hands-on, activity-based learning to teach science" in the new context of a museum school (p. 61).

The resulting picture of museum schools is largely incomplete, with claims that the literature is still in its infancy continuing through more contemporary research (Klein et al., 2001; Povis, 2011). Museum schools are increasingly promoted within the museum community as a promising educational solution to inspire learning, with Elizabeth Merritt of the Center for the Future of Museums leading the charge (Center for the Future of Museums, 2014; Merritt, 2012; Merritt, Kelbaugh, & Rombauer, 2015). Merritt's brand of "futurist" museum forecasting posits that informal partnerships have an important role to play in an "America… on the cusp of transformational change in the educational system" as school reform, funding crises, and the new technological economy challenge industrial paradigms. While Merritt's perspective is among the most visible through her work with the American Alliance of Museums, she is hardly alone in her enthusiasm. In an interview provided as part of Courtney Forester's (2007) thesis work on practitioner perspectives of school-museum cooperation, museum consultant and theorist Elaine Heumann Gurian is "enthusiastic about museum charter schools… as a great model for the future of public education" (p. 66). Other respected professionals have more tempered responses, but are positive nonetheless; museum and free-choice learning expert Lynn Dierking, for instance, frames museum schools as having potential for education, but not necessarily as a vehicle for policy change (Forester, 2007).

The recent calls for research through the American Alliance of Museums reflect the gaps in our knowledge about the efficacy of museum schools (Center for the Future of Museums, 2014; Guiter, 2015; Merritt, Kelbaugh, & Rombauer, 2015). Larson (2006) suggests that the application of student assessments, including "informal, practical, authentic, and formal" is a major area for potential improvement for museum school practice (p. 125). To that end, this study is positioned move the literature towards the consideration of museum school outcomes.

Challenges of Science Learning

A large body of educational research has shown that learning science is a complex endeavor. The Center for the Advancement of Informal Science Education (2010) describes the consensus of national research and policy agencies as finding that, "Scientific literacy is more than factual recall; it involves a rich array of conceptual understanding, ways of thinking, capacities to use scientific knowledge for personal and social purposes, and an understanding of the meaning and relevance of science to everyday life" (p. 11). At the same time, the President's Council of Advisors on Science and Technology (2010) has framed the national improvement of science education as relying on two complimentary goals: to "**prepare** students so they all have a strong foundation in STEM," and equally importantly to "**inspire** students so that all are motivated to learn STEM and many are excited about entering STEM fields" (p. 15).

The resulting portrait of science learning that invokes cognitive, social, and emotional dimensions poses significant challenges for measuring the impacts of science education. The concept of "science identity," however, offers a promising theoretical lens for assessing the impacts of formal and informal science education. In a longitudinal study funded by the National Science Foundation entitled "Is Science Me?," Ascherbacher, Li, and Roth (2010) followed up with young adults who showed interest in STEM fields as high school students to better understand "what invites diverse young people to appreciate, desire to learn, and develop a sense of themselves as someone who does science; how they perceive and pursue their science interests and career options; and why so many young people initially interested in science chose not to continue learning science or pursue careers involving science" (p. 565). This kind of inquiry into science identity over a prolonged period offers a compelling framework to "look beyond achievement and interest to understand how and why some students persist in and others opt out of science" (Carlone & Johnson, 2007, p.1190).

Defining Science Identity

The contemporary sense of "identity" as the conception of oneself or one's group membership stems from the psychological work of Erik Erikson (1968), but has branched to include both a structural understanding in the developmental tradition of Jean Piaget as well as a sociocultural understanding in the tradition of anthropology (Kroger, 2007). This study primarily employs a sociocultural understanding of identity and its measurable characteristics, which addresses "how identities are formed, constrained, and defined by context" (Kroger, 2007, p. 29). Individual identity can be viewed as the intersection of participation in different "communities of practice"; by observing and participating in these social environments, individuals acquire shared knowledge, competency, and belonging (Lave & Wenger, 1991; Wenger, 1998). As a result, an individual may have several different identities that are developed and expressed in different social contexts. Much has been written about cultural identifiers like race or ethnicity, but academic and professional identities like "environmental identity" and "science identity" have been gaining traction in informal learning contexts in recent years (Blatt, 2013; Stapleton, 2015).

In a study through the Center for the Advancement of Informal Science Education, Fraser and Ward (2009) found evidence for interest in the concept of science identity as an important area for research, but an incomplete understanding across the field. Of the 288 responses to an e-mail survey distributed through the CAISE mailing list, 46% of professionals indicated identity theory as an important area of study while 40% felt they needed more information to judge its value; only 3% indicated that they believed identity theory to be a fad.

While researchers and theorists have crafted several subtle variations on the definition of science identity, Stapleton (2015) summarizes how "like the general identity literature, science identity literature highlights the importance of practice, action, and or/performance in identity construction" (p. 96). This emphasis on the enactment of identity moves us towards an understanding of science learning as a process with observable indicators. Brickhouse and Potter (2001) conclude that active participation is critical to reinforcing a positive science identity, based on their study of the diverging paths of two African American girls who shared an initial interest in computer science at their urban high school. Science identity is socially reinforced by engaging in related activities, and can thus also be described as including a sense of self, belief in one's capabilities, and aspirations for practicing science (Aschbacher et al., 2010). Calabrese Barton, Tan & Rivet (2011) build on these definitions and emphasize the need to view "science practices" as including both the mastery of skills and the knowledge of when and how to deploy them in a social context.

Carlone & Johnson (2007) offer another useful modification, driven by data collected from successful women of color in the sciences: science identity encompasses the extent to which one reports having *competence* to be a scientist, active *performance* as a scientist, and *recognition* as a scientist. This formulation makes the important distinction that participation is socially embedded and that credibility changes across context and times. This recognition, however, is subject to interactions with other identities such as gender, race, ethnicity, or class. Nevertheless, Carlone & Johnson (2007) view this identity-driven understanding of science education as more equitable, promoting questions of participation and critical thinking rather than perpetuating "science as a finished body of knowledge" (p. 1189).

Science Identity in Museums

The ultimate conclusion of Carlone & Johnson's (2007) interviews with successful female scientists of color is that identity "arises out of the constraints and resources available in a local setting" (p. 1192). This vein of educational research on science identity resonates strongly with museums because it the kind of educational experiences that informal learning institutions can provide. Bell, Lewenstein, Shouse, and Feder's (2008) Strands of Science framework for the National Resource Council outlines six interwoven kinds of learning supported in informal learning environments: 1) developing interest in science, 2) understanding science knowledge, 3) engaging in scientific reasoning, 4) reflecting on science) 5) engaging in scientific practice, and 6) identifying with the scientific enterprise (pp. 43-47). While the first five strands recognize science as a complex process requiring knowledge, skills, and attitudes consistent with "science practices" as described above (Calabrese Barton, et al., 2011), the sixth strand explicitly describes informal learning as a potential driver of individuals' positive science identity "by helping them to identify and solidify their interests, commitments, and social networks, thereby providing access to scientific communities and careers" (Bell, et al., 2008, p. 46).

The potential of informal learning environments is recognized even in the science identity literature surrounding schools and formal learning. Ascherbacher, et al. (2010) identify access to experiential learning as key to encouraging young adults to follow through on their school age interests in STEM. Respected adult role models and mentors were found to enhance their science identities during school years, but students often faced "poor instruction, lackluster curriculum with few hands-on inquiry activities or meaningful projects," contributing to their "lost potential" as future STEM professionals (p. 570). Museum schools represent a possible solution to this gap by offering real-world projects and meaningful extracurricular activities as part of the normal curriculum.

Science identity research provides a foil for the exhibit and collection-oriented approaches of some museum schools in their description of successful identity-reinforcing behaviors. In longitudinal ethnographic case studies, Calabrese Barton, et al. (2011) find "hybrid spaces" that function as both classroom and social space to be particularly successful in engaging middle school girls in meaningful science learning at three public schools in New York City. In addition to providing evidence of the socially reinforcing aspects of science learning, Calabrese

Barton et al. (2011) indicate that the girls could strategically legitimize their participation as learners and credible content experts through the creation of "signature science artifacts" such as songs, displays, or collections. These artifacts represented a coalescing of both intellectual and social meaning and "bridged science and their world so that the perceived importance of science could help them to gain access to resources or to elevate the perceived value of their social status" (Calabrese Barton et al., 2011, p. 85).

These successful identity-supporting activities bear strong resemblance to the strategies of museum schools. The Center for the Advance of Informal Science Education (2010) identifies two main assets of museum-school collaborations for K-12 education: firstly, they present "direct, multi-modal experiences" that make use of tangible objects and sensory experiences, and secondly, they "can provide the sustained time, and developmental and pedagogical expertise" to scaffold learning beyond the immediate experience (p. 14).

Science Identity as a Framework for Assessing Informal Science Learning

The concept of science identity has distinct advantages as a framework for understanding the potential outcomes of a museum school experience. Because science identity considers the wide range of cognitive, social, and emotional learning aspects described above, informal science research projects like McCreedy and Dierking's (2013) *Cascading Influences* study favor this theoretical lens to understand the ways that meaningful experiences can create and reinforce identities over a lifetime of learning. McCreedy and Dierking's National Science Foundation-funded study examines the long-term impacts of out-of-school-time STEM experiences for girls and, like this study of museum schools, seeks to address a gap in the knowledge about the potential of informal learning programs over a span of several years.

Cascading Influences uses a kind of best-case approach to understanding the potential influences of these STEM programs by limiting itself to initiatives with documented effectiveness. Consistent with a science identity framework, however, the study considers a range of desirable outcomes with regard to STEM learning, including “interest, engagement, and participation in science communities, hobbies and careers” as well and positive attitudes about what science is and who can be a scientist (McCreedy & Dierking, 2013, p. 5). At the same time, science identity does not preclude more straightforward indicators of successful science education; in fact, “science identity offers an important predictor of participation and persistence in science careers” (Schon, 2015, p. 3). Contributing to the “pipeline” of advanced degrees and careers in STEM fields has been touted as a national priority (PCAST, 2010) and has leveraging value on the part of museums and schools in reporting outcomes. While STEM achievement is a relatively simple indicator, it is not without challenges; the “effect of science experience on career choice for children is a major Strand 6 outcome, but it is also very difficult to assess because the time frame involved is so long” (Bell et al., 2008, p. 76)

Science identity’s capacity to address outcomes over a longer time frame is a key asset for research in museums and informal learning institutions. In their contextual model of learning, Falk and Dierking (2000) assert that learning “does not respect institutional boundaries” and must be understood as an accumulation of experiences, reflections, and reinforcing events over time (p. 139). McCreedy and Dierking (2013) similarly conclude that “[m]emories of STEM experiences became critical resources in girls’ stories about their lives” and could be found in narrative arcs related to science careers and other milestones (p. 32). A recent longitudinal study of alumni from teen art museum programs similarly shows that in-depth engagement opportunities promote a sense of personal identity and knowledge (Linzer & Munley, 2015).

Summary

Further research into the outcomes of museum schools is needed to validate assumptions about these partnerships. While shifts in the museum field towards educational programming offer evidence of these institutions' contribution to learning, the literature specific to museum schools has been largely definitional. Although the range of museum-school partnerships vary, they are unified by strong organizational collaboration and the implementation of museum-style learning or museum-based projects. The literature on informal science education supports the need for the kind of experiential learning that museum schools seek to provide. Science identity literature provides a theoretical lens for examining the broad outcomes necessary for lasting, meaningful learning by focusing on a holistic range of affects like *competence, performance*, and *recognition* as scientist (Carlone & Johnson, 2007). As the museum field calls for more long-term and longitudinal research to evidence the learning value of these institutions, science identity provides a framework for assessing the educational experience that a museum school might impart on students and alumni.

CHAPTER 3: Methodology

This study was designed to advance the literature on museum schools towards the exploration of outcomes in these environments. The purpose of this research is to investigate the long-term impacts of a museum school experience on the formation of alumni's science identity. The following questions guided this research:

1. To what extent do museum school alumni report having and enacting a science identity?
2. In what ways do alumni of museum schools attribute their science identity to the museum school experience? In particular, which resources or opportunities do alumni recall as having a lasting significance or connection to their current engagement with science?

This chapter outlines the methodology for this research, including the rationale behind research site selection, alumni sampling procedure, data collection, data analysis, and limitations.

Research Sites

During the literature review process, the researcher compiled an updated list of institutions operating under museum school models based on previous work by Povis (2011) and the National Association of Museum Schools (2015). High schools were chosen as the target of this study design because they serve the adolescent demographic reflected in much of the identity development literature. Focusing on secondary education also removes the need to isolate shared primary or middle school experiences from subsequent education. Only museum schools that had been continuously operating for five years or more were considered for this study to ensure that cohorts of four-year graduates could be identified.

Ultimately, the two museum schools chosen for this research were Raisbeck Aviation High School (Tukwila, WA, near Seattle) and Science Leadership Academy (Philadelphia, PA).

Both museum schools serve grades 9 through 12 with project-based curricula including STEM and college preparatory coursework (Raisbeck Aviation High School, 2015b; Science Leadership Academy, 2015). Additionally, both sites are included in the National Association of Museum Schools' online directory (NAMS, 2015).

Raisbeck Aviation High School

Raisbeck Aviation High School (RAHS), established in 2004, describes itself as "the only aviation-themed college preparatory high school in the country to share resources with an aerospace museum" (Rogers & Keller, 2013). Though the school has always shared an affiliation with the Museum of Flight, it was renamed and rehoused in 2013 on the museum's "Air Park" campus adjacent to Boeing Field. Raisbeck Aviation High School is a public institution in the Highline School District, but its selective application process is open to students from the entire Puget Sound region (Raisbeck Aviation High School, 2015a). RAHS serves approximately 400 students per year in grades nine through twelve (Rogers & Keller, 2013) and has been recognized as a top-performing school at the state level (Raisbeck Aviation High School, 2015a).

The Museum of Flight has partnered with the school since its inception as a model for the Washington STEM Lighthouse Program, which supports smaller, specialized learning communities with STEM curricula and partnerships (Rogers & Keller, 2013). The museum's scope includes extensive collections and archives related to the history and design of air and spacecraft, as well as programs "that inspire an interest and understanding of science, technology, and the humanities" (Museum of Flight, 2015). Educational opportunities focus on the study and interpretation of aviation and aerospace history in addition to the science, technology, and engineering that makes flight possible.

Science Leadership Academy

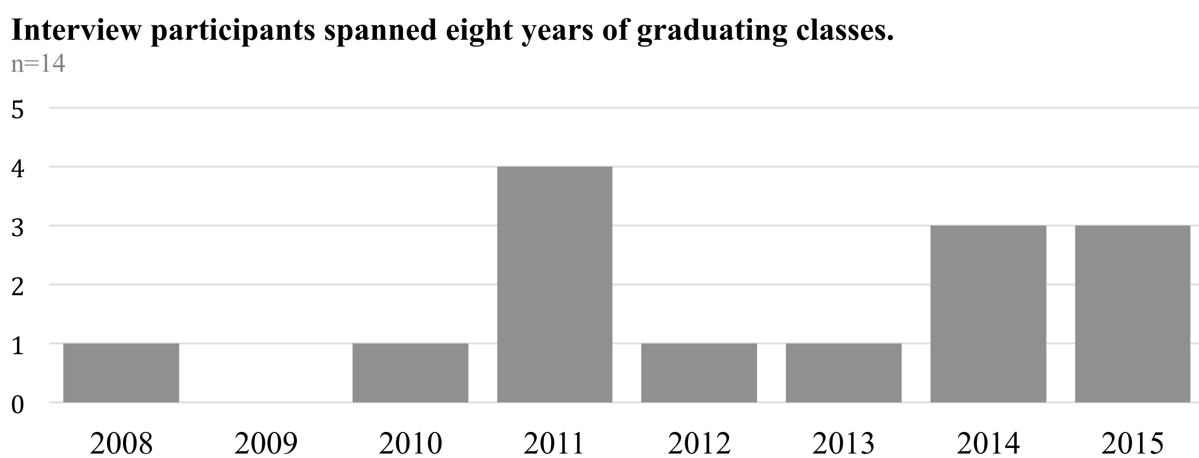
Founding principal Chris Lehmann and former teacher Zac Chase (2015) describe Science Leadership Academy (SLA), established in 2006, as developed "in partnership with The Franklin Institute and its commitment to inquiry-based science" and espousing the "core values of inquiry, research, collaboration, presentation, and reflection." Though the name Science Leadership Academy has been extended to a second school at the SLA: Beeber campus (Science Leadership Academy, 2016), this research focuses on the original Center City campus located three blocks from The Franklin Institute. Science Leadership Academy is a selective enrollment public magnet school within the School District of Philadelphia and serves approximately 450 students. SLA has been recognized at the national level and garnered attention from several prominent speakers, including Bill Gates (Gates, 2010) and President Barack Obama (White House, Office of the Press Secretary, 2012).

The Franklin Institute has been an integral partner throughout the development and operation of Science Leadership Academy. The museum bills itself as "one of the first museums in the nation to offer a hands-on approach to learning about the physical world" and continues today under a mission "to inspire a passion for learning about science and technology" (Franklin Institute, 2016). The Franklin Institute's STEM focused content features permanent and traveling exhibitions, educational programs for students and teachers, and is home to the Fels Planetarium.

Sampling

Under institutional review board approval from the University of Washington, 14 phone interviews were completed between March 23 and April 16, 2016, including 8 from Raisbeck Aviation High School and 6 from Science Leadership Academy. Interviews typically lasted for 25 to 45 minutes and were digitally recorded. Interview participants were ultimately recruited through the partner museums, whose staff e-mailed relevant contact lists known to include alumni. The museums distributed a message outlining the purpose of the study and establishing the criteria for participation: only alumni age 18 and older who had graduated from the museum school could participate, but no current involvement in science was required. Study participation was incentivized with a random prize drawing for one of two $25 gift cards. The researcher subsequently contacted interested participants to explain the study in detail, secure permission, and schedule telephone interviews. Of the 16 alumni who responded to the call for subjects, 14 agreed to participate. Participants were 64% male (n=9) and 36% female (n=5). The majority of participants (n=12) indicated that they were between 18 and 23 years old, while the remainder (n=2) were between 24 and 29 years old. Their graduation years appear in Figure 1, below.

Figure 1. Distribution of graduation years in interview sample.



Data Collection

Data were collected using an interview guide adapted from McCreedy & Dierking's (2013) *Cascading Influences: Long-Term Impacts of Informal STEM Experiences for Girls*. Whereas McCreedy & Dierking used an online questionnaire, this research employed a semi-structured phone interview format to allow for additional follow-up questions. The interview protocol broke questions into four sections (see Appendix B: Interview Guide). First, alumni participants were asked to describe their time at the museum school, including years of enrollment and the kinds of coursework and activities completed. In the second section, participants were asked to describe memorable experiences and takeaways from the museum school, both in general and with specific reference to the partner museum. In third section, alumni were asked about their educational and career trajectories and how they may or may not relate to science today. Finally, participants were asked a series of close-ended questions rating potential outcomes of the museum school experience and ranking potential influences that may have contributed to those impacts.

Data Analysis

Recorded interviews were transcribed and open-ended questions analyzed for emergent themes. A coding rubric was designed for each question and applied to each interview (see Appendix C: Coding Rubric). Where applicable, definitions of science and engineering-related degrees and careers were based on definitions published by the National Center for Education Statistics (2011) and the National Science Board (2016). Close-ended responses were coded and analyzed using Excel.

Limitations

Museum schools, by definition, blur the lines between institutions (Finnerty, 1996; King, 1998; Klein et al., 2001; Takahisa, 1998). As a result, efforts to identify resources as coming the museum partner rely on the differentiation of physical space and personnel at the risk of missing more subtle sharing of resources. This study includes questions about the potential influence of different program components in an effort to understand the most memorable points of collaboration and museum participation.

Each museum school offers a unique range of experiences and the resulting data cannot be generalized to describe all such institutions. Memory and learning are inherently personal and idiosyncratic (Falk & Dierking, 2000); while they may be derived in part from context, other factors such as prior knowledge and intersecting identities cannot be completely eliminated as potential influences. This study can be viewed as a best-case scenario to describe the potential range and outcomes of museum school experiences in an effort to address a gap in the literature.

Lastly, the sample for this research is self-selected and highlights the inherent challenges in conducting long-term research in free-choice learning environments. As Linzer & Munley's (2015) *Room to Rise* study on the alumni of teen art museum programs corroborates, reconnecting with alumni can be an arduous process. In this study, attempts to reach alumni via the school administration faced procedural hurdles; museum partners proved to have greater flexibility, but their constituencies were limited to alumni who had maintained some involvement with the museum or had current contact information on file. Study participants often worked at the museum during and/or after their high school experiences and brought those perspectives to questions about the museum's value to the school; however, the nature of questions focused on individual experiences, and memories both positive and negative.

CHAPTER 4: Results & Discussion

This chapter summarizes the results and themes from the collected data, organized according to the study's two major research questions and preceded by a description of the range of museum school experiences undertaken. Data were analyzed according to emergent themes detailed in Appendix C: Coding Rubric.

Participants' Descriptions of Museum School

Motivations for Attending

Alumni reported a variety of motivations for enrolling at Raisbeck Aviation High School (RAHS) and Science Leadership Academy (SLA). Nearly every participant (n=13) indicated a positive desire to attend the museum school, with the remaining respondent (n=1) stating that despite having wanted to go somewhere other than RAHS, "I'm ultimately glad that I ended up going there, in the end." Half of participants (n=7) chose to apply to their respective museum school because it aligned to their interests in STEM or aviation fields. Several alumni (n=5) also cited their respective schools' academic reputations—not for science specifically, but as one student put it, as "good for college and getting ready, the studious part of the program, the academics. They train you well to get good test scores, and get ready for the real world, and prepare you for the future." For a handful of SLA alumni in particular (n=3), the school's philosophy and project-based style were attractive features. As one participant explained, "their principles about learning… and their ideas about critical thinking and project-based learning were what really excited me about SLA."

Practical concerns also factored into some alumni's decisions to attend the museum school. Three (n=3) participants had preferences regarding the size, location, and/or organizational structure of the two public application-based schools, including one interviewee who felt that having “400 students instead of what’s often a thousand or more at a high school” cultivated a “really small community where the teachers come to know everyone.” Closer social connections were mentioned by a couple of participants (n=2) with friends or family members who had attended the school. The remaining participant (n=1) described Science Leadership Academy’s one-to-one laptop policy (Lehmann & Chase, 2015) as the main motivation.

Coursework

Participating alumni were asked to describe the range of coursework and activities that they engaged in while enrolled at the museum school. Both sites offer a degree of customization through elective courses, extracurricular activities, and internships; as a result, participants had varying expectations and degrees of participation in museum-based activities.

All but one participant (n=13) described their school as offering a typical high school curriculum with distribution requirements including sciences, mathematics, humanities, and social studies. The majority of alumni (n=12) also highlighted the school’s emphasis on aviation-related or STEM-related coursework, including electives in topics like robotics, computer programming, and aerospace engineering. When asked to recall favorite courses or subjects, most (n=9) cited a STEM- or aviation-themed area of study. However, interest and current engagement in science were not criteria for participating in the study, and a few alumni (n=3) chose humanities or social science courses such as AP English, creative writing, or journalism while the remainder (n=2) could not identify a favorite.

Extracurricular Activities

Participants were also involved in a variety of extracurricular activities in school, museum, and external contexts. The majority (n=11) of alumni reported being involved with the partner museum in a formalized way during their high school career. Within that subset of alumni, seven (n=7) worked at the partner institution as an intern or paid employee while six (n=6) participated in a teen volunteer program, including two (n=2) respondents who shifted between the two roles over time. Volunteer experiences (namely, the Museum of Flight's Museum Apprentice Program) were typically described as focusing on guest engagement projects. As one participant described, "I did… what they call Discovery Carts. Researched a topic, made some demo stuff, and then on the First Free Thursdays went and presented it to the public." Internships and employment, meanwhile, gave participants experience with a specific department or staff person: "the counselor found an internship for me at The Franklin Institute, working with the Vice President of Operations. And I worked one-on-one with that specific individual every Wednesday, from twelve to four in the afternoon and it was an amazing experience."

Interviewees also indicated widespread participation in activities related to STEM-learning and career readiness. More than half of participants (n=8) were involved in one or more STEM-related clubs after school, including robotics competitions, Science Olympiad, or student groups devoted to topics like technology or ecology. The two (n=2) responses highlighting robotics are significant in they suggest greater involvement with the museum partner; a participant from SLA specifically described robotics as being "in joint with The Franklin Institute," while a student from RAHS noted that the robotics instructor was also on staff at the Museum of Flight.

Participants also commonly mentioned career development opportunities beyond the scope of the museum partnership. Several alumni (n=5) recalled meeting with mentors, either through an organized group or on an individual basis. Three (n=3) alumni of RAHS specifically referenced the Airlines Career Club, which included excursions to local aviation facilities and brought in a mentor from Alaska Airlines: "He was a captain and would tell us all about his experiences, give us advice on how we can transition into college and becoming a pilot." Interview participants from both RAHS and SLA (n=5) also described internship opportunities at local corporations or, in one instance, a university-based media lab. Three (n=3) participants reported taking college-level courses through other initiatives or partnerships. Alumni also reported taking part in a number of non-academic extracurricular activities, including organized sports or physical activities like cheerleading) (n=6), planning student events (n=3), or miscellaneous opportunities (n=5).

Question 1: To what extent do alumni report having and enacting a science identity?

This research question employs Carlone & Johnson's (2007) understanding of science identity as having three dimensions: *competence*, *performance*, and *recognition*. Together, these concepts serve as an organizational framework for the data below; however, it is worth noting that Carlone & Jonson (2007) illustrate the dimensions as overlapping circles, which are together mediated by social contexts and other racial, ethnic, and gender identities.

Competence

Competence describes one’s knowledge, skills, and deeper understanding of science content, and as a dimension of science identity “may be less publicly visible than performance” (Carlone & Johnson, 2007, p. 1191). Interview participants were asked a series of close-ended questions rating the extent to which the museum school experience increased their capacities on a scale from one to six, with instructions to choose one “if you think you did not change at all in this way” and to choose six “if you think you changed in this way ‘a lot.’”

When asked to rate how the museum school “increased my knowledge of science” (Figure 2), alumni all agreed that they had gained considerable knowledge and assigned scores with a median of 5.5 (n=14). Alumni provided a wider range of responses when asked to rate the extent to which the museum school “increased my confidence in doing science” (Figure 3) with a median score of 5.0 (n=14).

Figure 2. To what extent did being enrolled in the museum school increase your knowledge of science? Responses on a scale from 1 (no change) to 6 (changed a lot).

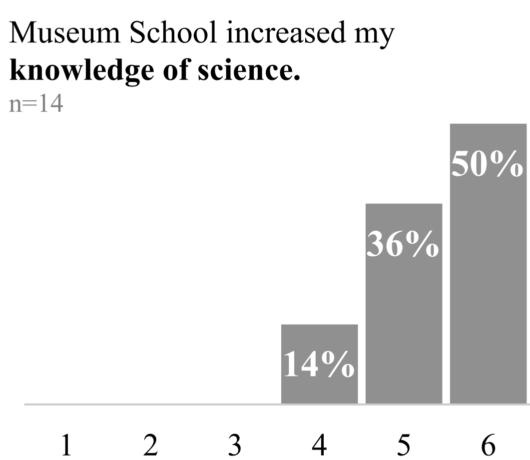
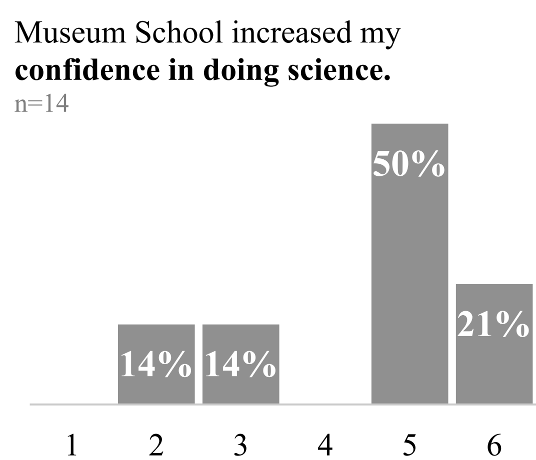


Figure 3. To what extent did being enrolled in the museum school increase your confidence in doing science? Responses on a scale from 1 (no change) to 6 (changed a lot).



Performance

Performance of science identity entails using the tools and language of science in ways that are perceptible to others in a social context (Carlone & Johnson, 2007). As Carlone & Johnson note, interview methods do not fully capture the extent to which performance is deployed in a real-world setting; however, the data below reflect aspirations and intent to engage in scientific arena where they might be called upon to perform.

In close-ended questioning, participants were asked to indicate the extent to which the museum school "increased my desire to go to college" using the same scale of one to six (Figure 4). Alumni responses were mixed, with a median value of 4.5 (n=14). Several respondents (n=5) assigned scores despite indicating that their answer was complicated by a pre-existing intent to attend college. As one participant noted, "I guess, in my mind, I was going to find a way to go to college either way. So I guess maybe still, it helped encourage me to pursue what I was interested in or kind of refine what I was interested in." In contrast, one participant (n=1) reported a negative impact: "I don't really think I was impacted in that kind of way. I think it was the opposite, that's the problem."

Alumni were also asked to rate the extent to which the museum school "increased my desire to have a career in science" on a scale from one to six (Figure 5). Again, responses were mixed with a median score of 4.5 (n=14). Only one participant reported that it was challenging to assign a value to the museum school's impact on their career aspirations due to pre-existing interests, stating, "I went in to the school and everything with that in mind, kind of having a good idea of what I wanted to do or where I wanted to go. And it definitely supported that." In contrast, another participant mentioned that the school "steered me away from pursuing science" and towards a degree in business after struggling with math and physics courses.

Figure 4. To what extent did being enrolled in the museum school increase your desire to go to college? Responses on a scale from 1 (no change) to 6 (changed a lot).

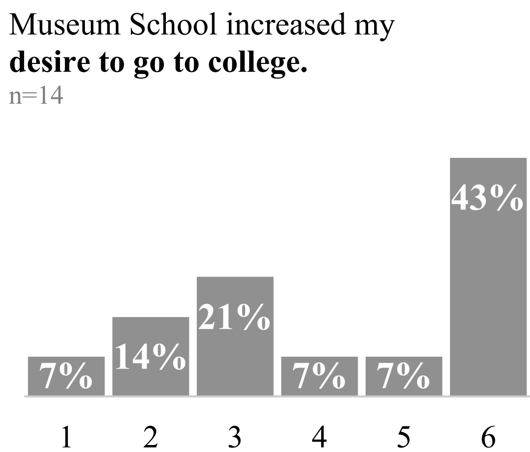
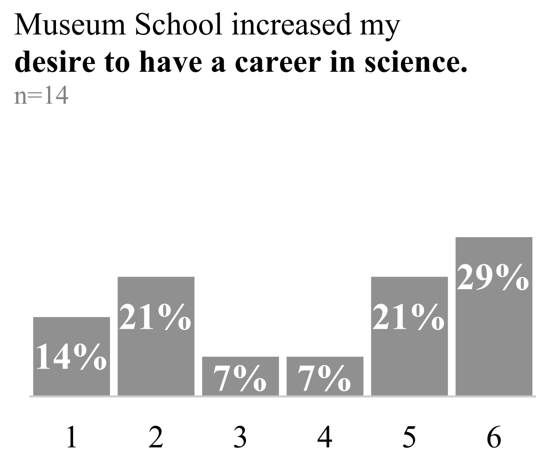
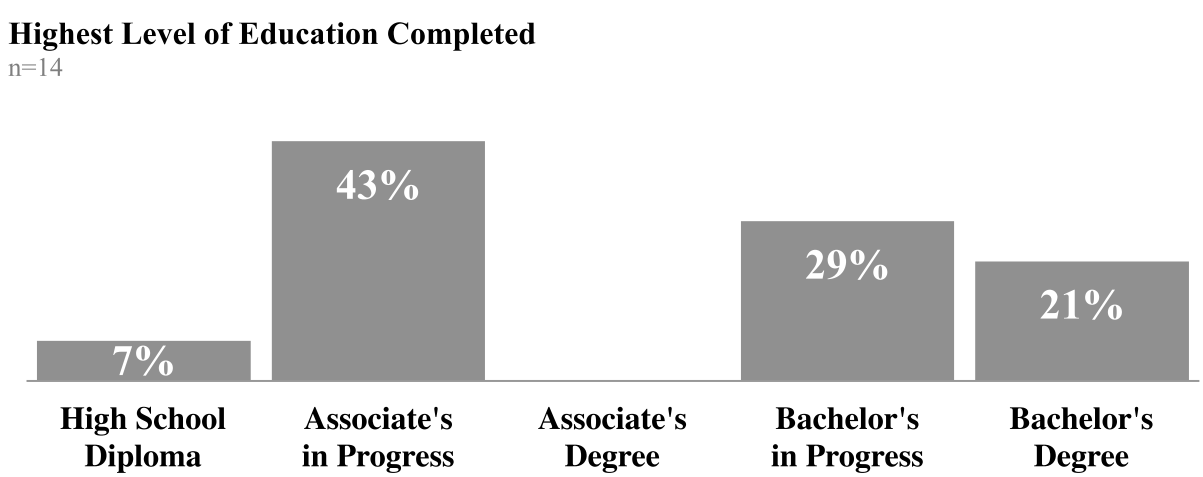


Figure 5. To what extent did being enrolled in the museum school increase your desire to have a career in science? Responses on a scale from 1 (no change) to 6 (changed a lot).



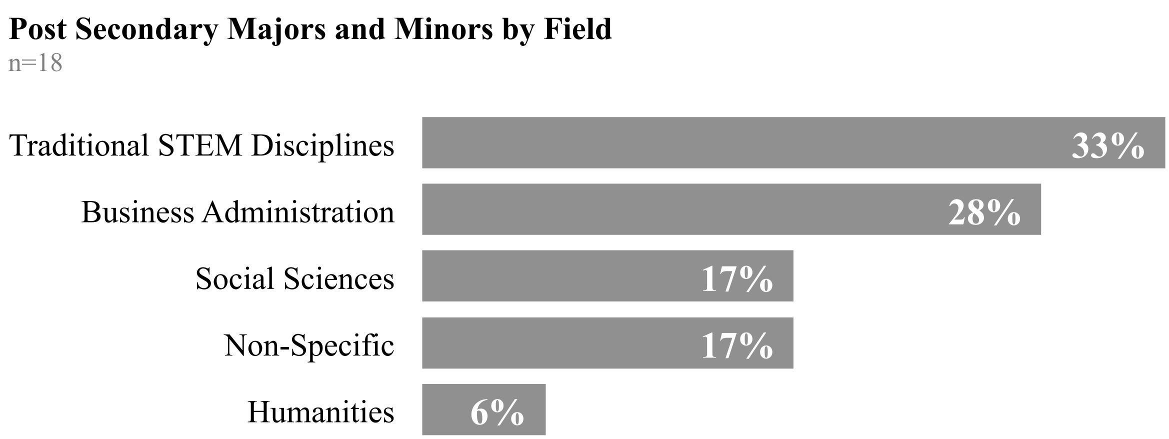
Participants were also asked to indicate whether they were enrolled in or had ever attended post-secondary school (Figure 6). All but one participant (n=13) had attended at least some two- or four-year college, with the other (n=1) indicating intent to enroll in autumn 2016. To date, less than a quarter of alumni (n=3) have completed a higher degree; however, this is likely due in part to the proportion of recent high school graduates in the sample (see Figure 2).

Figure 6. Degrees started or earned by interview participants.



Alumni who went on to attend or complete college coursework after the museum school reported a total of eighteen different majors and minors (Figure 7). While the United States federal government does not maintain an official list of STEM program areas, tables identifying subcategories of STEM degrees by the National Center for Education Statistics (2011) and Science & Engineering Indicators by the National Science Board (2016) were consulted to code participants' specializations. One-third of degrees (n=6) were in traditional STEM disciplines including aerospace engineering (n=3), computer and information sciences (n=2), and mathematics (n=1). Some degrees reported in other fields intersect with STEM disciplines in their practical applications, such as aviation management (n=1) and economics (n=1).

Figure 7. What specialization(s) or major course(s) of study have you focused on, if any?



Several alumni indicated that they were making plans or weighing options for further post-secondary education. At the undergraduate level, participants indicated interest in pursing degrees in neurobiology (n=1), business (n=1), and unmanned aircraft systems operation (n=1); at the graduate level, participants indicated interest in pursuing degrees in one or more of science leadership (n=1), digital humanities (n=1), business (n=1), or aeronautics (n=1).

Nearly all participants (n=13) reported being employed on at least a part-time basis, many of whom also said they were currently enrolled as post-secondary students (n=9). A majority of the participants have returned to work at their respective partner museum in an education, guest services, or administrative roll, including two (n=2) in full-time positions and six (n=6) in part-time or seasonal positions. Of the eight alumni working in a museum context, six (n=6) felt their role was science related. Three participants (n=3) are currently working in STEM-related jobs outside of the museum context, one as a student transitioning to full-time IT infrastructure work (n=1), one in computer programming and design (n=1), and one working in data analysis (n=1).

When asked about their long-term employment goals, many participants (n=8) were unsure or shared a range of interests for future employment. Of those who were more certain about their goals (n=6), two alumni (n=2) indicated plans to become a pilot while others expressed interest in drone technology (n=1), computer science and network administration (n=1), logistics and supply chain management (n=1), and academic research and instruction in a non-STEM field (n=1). Several of the alumni still identifying long-term goals were interested in some form of science- or aviation- related entrepreneurship (n=3).

Recognition

The third dimension of science identity is recognition of one's competence and performance in science, both by oneself and by meaningful others (Carlone & Johnson). Because meaningful others often demonstrate the components of science identity themselves, this section presents data about connecting to those individuals as well as addressing perceptions directly.

When asked to rate the extent to which the museum school experience "increased my awareness of jobs or career choices in science or related fields," participants typically responded with high scores (Figure 8). Using the same scale from one to six as previous close-ended questions, alumni scores produced a median value of 5.5 (n=14). One participant elaborated on the rating by describing a talk given by Bill Gates to the students of Science Leadership Academy, describing the experience as “really interesting and surprising.” The participant went on to compare the visit to an annual “Meet the Scientist” event at The Franklin Institute where “they bring in a panel of scientists and the students can just come up and ask any question they have about their fields of work or anything that is related.”

Alumni also consistently rated the extent to which the museum school “increased my connections to people in science or related fields” highly (Figure 9). On a scale from one to six, the median value assigned for the connections question was 6.0 (n=14). One participant added that being employed at The Franklin Institute after graduating from Science Leadership Academy was evidence of this connection.

Figure 8. To what extent did being enrolled in the museum school increase your awareness of jobs or career choices in science or related fields? Responses on a scale from 1 (no change) to 6 (changed a lot).

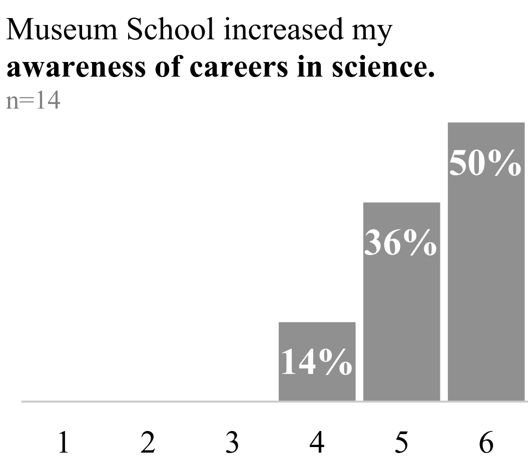
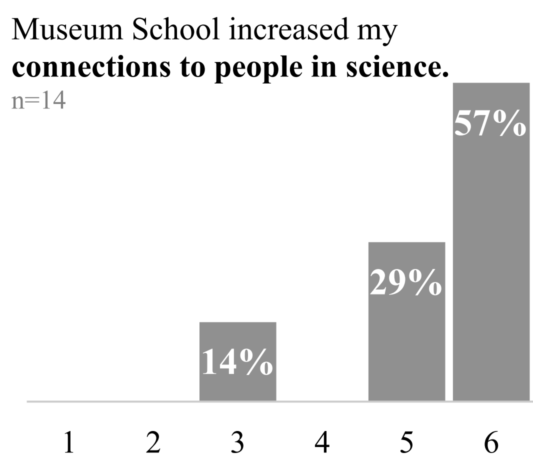


Figure 9. To what extent did being enrolled in the museum school increase your connections to people in science or related fields? Responses on a scale from 1 (no change) to 6 (changed a lot).



Finally, alumni were asked a pair of open-ended questions about their recognition point-blank: “Do you see yourself as a scientist?” and “Do you think others see you as a scientist?” A majority of participants (n=8) did not view themselves as scientists, while the remainder (n=6) did. In all but one case (n=13), the responses for self and others were the same. The remaining participant identified herself as a scientist because “the scientific method is something that I apply to my life on a daily basis,” but did not consider her work in information technology to be seen as science by others.

Among those who believed they were as scientists, most (n=4) described their recognition in a philosophical sense, though (n=3) also described more literal scientific participation. Philosophically speaking, one participant described others’ view by stating, “We’re all always trying to find something new, trying to find a new way to do something or see an idea, or someone has an idea and we all just experiment and play around with it.”

Of those who did not feel both aspects of recognition, (n=5) described their hesitation as including a lack of competence, while (n=7) included a lack of performance as a scientist. Two alumni (n=2) who cited a lack of competence viewed science as requiring greater skills. One participant did not see himself as a scientist “because I know that there are other more capable people than I am, and they can actually take the rigorous classes and they have a certain tenacity for those science classes that I don’t have.” Another was careful to draw the distinction between being a scientist and an engineer:

> A scientist I think of as someone who knows physics or chemistry, you know, along those lines. They’re not really builders. They’re more like teachers, and they help people with what they know. They’re like a wealth of information what the field is. And an engineer, for me, is someone who is more hands-on, and designs and tests, I mean, builds and tests the projects.

The lack of performance as a scientist did not always preclude a positive relationship with science. One alumna made the distinction of being a “science person” but not a “scientist.” From her own perspective, “I see myself as a social scientist, I don’t see myself as a scientist. I see myself as someone who’s very science literate.” Her recognition by others was bound by context: “I think at Aviation High School I was not viewed a as science person. I think at my small liberal arts college, with a lot of other social science majors and English majors, my friends here definitely view me as a science person.” For another participant, performance was linked to his emerging field of study incorporating data and technology: “It’s not quite there yet, though, it’s mostly just on the analytical level. But it definitely has a lot of room for growth. So, it’s possible, I could become a scientist in a sense in the future. But not quite at this moment.”

Question 2: In what ways do alumni attribute science identity to museum experiences?

This section examines the learning experiences of alumni participants according to three strands of questioning. First, the Memorable Experiences section reports data related to specific memories that have maintained some lasting power or significance in retrospect. The Museum Contribution section details the kinds of learning experiences that alumni reported having from the museum partner more broadly. Finally the Connecting Influences section looks at the way alumni considered different components of the museum-school relationship to impact different concepts related to the dimensions of science identity.

<u>Memorable Experiences</u>

To focus the interview and further explore the range of potentially meaningful activities within the museum school context, alumni participants were asked to reflect on positive and negative experiences from their enrollment. Because alumni answered by describing discrete memorable events (when possible), their qualitative responses were coded into exclusive categories describing the context.

When asked to recall “the highlight of your experience” at the museum school, participants responded by describing a variety of different school, museum, and extracurricular activities. Alumni from both schools (n=3) mentioned working at the partner museum as a volunteer, intern, or employee as their highlight. Another participant recalled presenting for museum visitors as a highlight:

> It would have to be interacting with the kids. Getting the opportunity to set a foundation for the skill that I could actually use after high school, I think that’s something in the memory that I can most likely recall. Every time I think about the school, it makes me think about the museum and how I taught the kids in the programs that I participated in.

Another participant described how museum collaboration became a recurring part of the high school experience: “Being able to work with the Chief Astronomer, definitely was one of my highlights. Especially since I was able to integrate it into my ILP [individualized learning plan]…. And it also turned into my capstone project.” Likewise, the third respondent went from doing a presentation at the museum to becoming a part-time employee:

> And so because of that, I started to have a much closer relationship with The Franklin. Because before that, you know, I had obviously gone there as a child, I had been to the exhibits and I loved The Franklin, so this was, I feel, a nice little turning point…. I was finally able to be a part of something that had been so big in my childhood that now I was able to start giving back to the community and the group of people that all made it a thing.

Some participants (n=3) viewed external internships or professional networking opportunities as highlights made possible by the museum school. Of those alumni, two respondents (n=2) specifically called out the Airline Career Experience Club at RAHS and internship experiences that followed. The other respondent (n=1) attributed the opportunities to the school more broadly, stating, "I think the highlight for me was really the career center and how well versed they are in what they do. I got the chance to go through Aviation High School, so many different events and to be involved in so many cool projects… outside of that school."

A few participants (n=3) considered the school environment to be a highlight in and of itself, with a couple (n=2) even going to so far as to describe it as "home." One interviewee described how wanting "to stay after school not only to get work done, but to socialize, and complete those extracurricular activities, to have Internet access and be part of that science environment more than twelve hours a day is an amazing feeling." Participants who focused on specific clubs (n=3) also highlighted a social component to the experiences. For one respondent, the highlight was simply "working with friends on the robotics team." Another recalled connecting to students and faculty through a book club, while the third described a technology repair club.

Specific projects or presentations stood out to the remaining alumni (n=2) as highlights and moments of personal achievement. One participant described organizing an Earth Day assembly, which stood out as a unique opportunity in retrospect: "Now that I've been at college and I've kind of talked about some things that I've done, I think there aren't a lot of schools where I could have gone to the vice principal" and been given that chance. The other participant recalled achievements more broadly, describing putting hard work into a project and presenting to the class "as real highlights."

Alumni were also asked to recall "the low point of your experience" at the museum school. A majority of respondents (n=8) focused on academic challenges in difficult classes or in managing a heavy overall workload. One participant recalled pressure to perform in upper level STEM courses, calling them the "low point, and not necessarily specifically about teaching styles but that it was a very difficult place to be in a classroom where students are very competitive, right? So not understanding, the classes move faster….” The same participant went on to describe dropping an advanced placement calculus course knowing “that I wasn’t going to go on and do hard science professionally, and not major in them in college” but still struggling with “the mindset that being good at math and science” was important. Another participant described the challenge of adapting to greater academic independence:

> I was used to the college preparatory environment, but I really wasn’t used to a 21st century college preparatory environment. So it really was like, here’s college, right? You know, all your information is online, solve this, here’s your teacher, you can call, text any time. You don’t do the work, we care, but we’re not going to hassle you, you’re an adult.

Of the remaining alumni, two participants (n=2) described the transition to college as being especially difficult. For one participant, the challenge derived from the application process and the “pressure to apply to college and get accepted to college and actually go to a four-year university, and that wasn’t really the right path for me, but I didn’t know it at the time.” The other participant realized the low point only after starting college and experiencing the “shock” of “having to take tests again” after a project-based curriculum. Additionally, two participants (n=2) could not identify a low point, while the remainder (n=2) cited miscellaneous or personal low points.

Narrowing the discussion to focus on experiences that might reinforce science identity more directly, alumni were asked to talk about “the most memorable moment when you felt excited by science.” Participants overwhelmingly described hands-on learning experiences (n=12). Half of the hands-on learning experiences (n=6) were classroom-based; for instance, one participant recalled studying sound in physics class and a project to “actually built a working, full-sized guitar. And that was amazing.”

Multiple RAHS alumni (n=3) described presenting their work to professionals in the field as a memorable and meaningful part of the project. One graduate recalled her group of four or five young women developing and presenting a proposal on how to fix an environmental challenge at nearby Seattle-Tacoma International Airport. After heir project was chosen as the winner, she recalled:

> We got to go to the airport during the summer and tour the airport. We went out onto the tarmac, we made our presentation to people who were executives at the airport. That was a really amazing thing…. I think because what I enjoyed was the people, the social aspect of it, I didn't see it as a science thing that I did, but looking back it totally was the best science moment I had.

Another participant shared a similar experience with the same project when discussing how the museum school increased connections to people in science, mentioning how "presenting the findings was cool because you got instant feedback from people who actually wanted to help you and were interested in the industry." A third participant called the opportunity to present a heat shield design to "actual, real engineers… inspiring as a freshman."

Not all hands-on opportunities occurred in classroom settings. Several of the hands-on experiences occurred as part of student clubs or competitions (n=4). One participant recalled starting work with a robotics group at The Franklin Institute:

> …my very first project when I was there was to build a 'BattleBot,' namely, a 30-pound robot that hit really, really hard. And so I got really, really excited about that, and it was probably the first real big project that I had ever really worked on, that I got to work with my hands.

The remaining hands-on experiences (n=2) were related to biological dissections, one as part of a biochemistry class and the other during one of SLA's recurring trips to The Franklin Institute. Of those respondents who did not cite experiential learning, one (n=1) remembered making an important breakthrough independently about the relationship between concepts in a physics class and a mathematics class; one (n=1) could not identify a specific memory.

Alumni were also asked about negative experiences and described memorable moments when they "felt discouraged by science." Responses were largely related to school science or mathematics coursework rather than extracurricular experiences. A majority of alumni (n=9) described academic challenges in specific courses or in managing a difficult workload; several (n=4) elaborated by connecting their memorable experience to shifting away from STEM-related educational trajectories or career aspirations. For one participant, physics was especially discouraging: "The teacher was decent, below average, and it was a really hard topic to understand and really, I guess, impaired my inspiration, maturation to learn or continue science." Another student reported struggling with chemistry and physics both for lack of interest in pursuing a science or engineering career and because the courses "didn't really catch my attention, or pique my interest in it." One participant shared that sense of frustration, despite maintaining career interests in aviation management down the line; chemistry was challenging where science was "usually pretty easy for me. But that and astronomy were the two classes where I really had to try, and it actually kind of turned me away from doing it."

Other alumni (n=3) felt discouraged by science when they compared themselves to talented peers. One participant reported being acutely aware of how difficult it would be in the future to get accepted into a selective college engineering program and described feeling "at risk." Another graduate called the most discouraging moment, "When I first saw how good my mentor [computer] programmer was. Yeah, mentoring can be intimidating in the science field." The third participant shared a detailed story about a classmate who exceled in robotics class:

> One of the girls in it, she's very smart, I think she's going into a science field now. But she kind of took control of the group, and I wasn't very confident in my ability to design a robot and do things like that because I wasn't familiar with it. And so she kind of took over and suggested that maybe I do small jobs that didn't really impact the design and actually drive the robot or any of the things that were actually involved in the process. And so I kind of ended up sorting parts, for part of that class instead of actually contributing to the design of the robot. And that was partially my fault for not standing up for myself. That was definitely one of the times that was most discouraging, having my fear confirmed that I wasn't smart enough or good enough to participate.

Museum Contribution

As noted in the participants' description of the museum school, several of the interviewed alumni participated in specific museum programs, internships, or jobs. However, the physical and organizational proximity between the museum and school partners also allows for a wider range of opportunities for student learning. This section describes the qualitative interview data related to understanding the museum-based experiences participants had and exploring why they mattered to alumni.

Before explicitly delving into the lasting impacts of the museum collaboration, alumni were asked if they remembered spending time at the partner museum as part of the school experience and what memories they had. Drawing on those responses and relevant activities mentioned elsewhere, types of museum participation were coded with multiple categories permitted. As in the previous description of participation, several alumni reported having a job or internship at the museum (n=7) and/or taking part in a volunteer program (n=6). The Museum of Flight's Museum Apprentice Program accounted for the volunteering responses, though a few participants (n=4) were unsure whether the program could be considered part of the school experience. When discussing influences in a later question, one participant described the program as not being "specific to Aviation High School, but a lot of the high school students are

Aviation High School kids, and there's a real connection." Another participant also described the program with a degree of distance:

> The counselor had internship and volunteer opportunities and a friend of mine, I think she was more involved in the museum, found out about a Museum Apprentice Program, so she got me interested in that… and then I went back and actually started working at the summer camp the next summer. So, not so much direct relation with the school or schoolwork, but I did find out about through the school.

Class excursions or field trips were also widely reported museum experiences, though the distribution represents programmatic differences between the two museum schools. Several alumni from Raisbeck Aviation High School (n=6) recalled taking field trips on an occasional basis—one or more per year and as part of a specific class. One participant recalled going for a class about historical and creative writing and connected it to her continued academic interests:

> We had a field trip to the Museum of Flight and we kind of wandered around, and it was very self-directed, where we could experience the museum as part of understanding writing and understanding history, but than also looking through the museum. Then we would choose someone who we wanted to write a report on. I ended up choosing to write my report on a woman who was featured in the World War II Women in Aviation exhibit, in the Personal Courage wing. I still very clearly remember looking at that exhibit, and… it was one of the first big papers that we wrote, and I'm no in a very writing-intensive college career…

Alumni from Science Leadership Academy unanimously mentioned field trips to The Franklin Institute as part of their experience (n=6), but in the form of recurring Wednesday afternoon trips as part of the freshman year experience. As one participant described, "We did so many things! Sometimes we would have a specific activity to do that they had created for us in one of the exhibits, sometimes we'd be an initial audience for a new presentation or a workshop…. And we got to see some exhibits, visiting exhibits, those were really cool."

In addition to having different collaboration models, proximity was mentioned as a factor by some RAHS alumni (n=3) whose enrollment spanned both the school's previous location in

Des Moines, Washington and the move to its current building on the Museum of Flight campus in 2013. As one participant recalled, visits were limited to field trips in the old location; "once we moved into the new building, it was more accessible and we'd go over there more often, trying to observe if there's a new exhibit or trying to do a research project there as well." Another participant described the increased field trips after the move as "kind of fun," describing how the they "would walk over to the museum to find stuff we were learning about. My English class would do that too, and I think that made a much bigger difference. It was more personal, the attraction of what we were learning."

Special events at the museum also stood out to alumni (n=4), both at The Franklin Institute (n=1) and the Museum of Flight in the form of the Pathfinder Gala (n=3). A few alumni (n=4) also mentioned visiting the museum on their own time. One participant emphasized that free access to The Franklin Institute was especially powerful in allowing his family to visit the museum as well:

> … the King Tut exhibit—we were one of the first to see it, which was so cool. We were able to bring our families, we got IMAX passes. All that contributed to the partnership that The Franklin Institute had with Science Leadership Academy…. It made the experience so much more worthwhile. I was able to bring my cousins to IMAX shows, to go into the planetarium and see the shows and the sky. That experience was worthwhile not only to myself but to my family.

Alumni were then asked to elaborate on the effects of their museum-related experiences with the prompt, "Do you think you learned anything at the museum specifically? What did you learn?" Nearly all participants (n=13) agreed and described evidence of learning; the remainder (n=1) was "sure" he had learned but could not think of specific instances. Examples of learning were spread across four emergent categories: content knowledge, interest and engagement, career skills and habits, and professional networking.

Nearly half of alumni (n=6) reported gaining content knowledge related to STEM or aviation from spending time with museum exhibits, programs, and staff. For instance, one graduate recalled going on SLA's recurring trips to The Franklin Institute: "For a few weeks, I remember a physical science kind of section that we did. I remember some things about the weather that I really didn't understand before." Similarly, a participant from RAHS reported, "I do recall multiple times coming over [to the Museum of Flight] and being able to refer to exhibits in papers when I'm talking about his or her plane, or history and periods in aviation. I was definitely utilizing it."

Interest and engagement responses (n=4) described the museum as reinforcing and deepening the learning from the school context rather than introducing new knowledge. As one participant described, "There were things that I did learn at the museum, nothing really new and striking to me, but just enhancing my learning. You know, enhancing my knowledge of aviation, the history of it." Others framed the museum experience in comparison to the limitations of a traditional school setting: "It definitely gives you a more in-depth and interactive learning experience when it comes to science. A lot more, I think, than a school setting can give you, since in a school setting… you follow these standards…. A museum doesn't have that restriction." Another participant described the museum as permitting "a wider variety of experiments because they had access to materials that we wouldn't normally be able to get a hold of" in a school, particularly one so newly established.

Several alumni (n=4) reported taking away professional skills and workplace habits as a result of their museum participation, including those related to "time management, public speaking, and problem solving," "customer service," "teamwork," and "responsibility." In addition, a few participants (n=3) focused on professional networking opportunities and learning to build relationships within an industry. The two RAHS respondents discussed the Museum of Flight's Pathfinder Gala as a form of educational experience:

> I learned a lot about networking with professionals in the aviation industry, people who own the businesses around, people who have been in the industry for many years, and just understanding their experiences and their career paths, or the inspiration that they had, and the business contacts that I could network with, and just the whole experience in general, I learned a lot specifically there.

Not only did alumni feel that they had learned from the partner institutions, when asked to explain whether "the museum component matters" to the museum school experience they unanimously said yes (n=14). Many responses about the value of the museum partnership aligned to the kinds of learning experiences the museum engendered. Interest and engagement the most common value, mentioned by half of all alumni (n=7) using descriptors like "interactive," "personal," and "memorable." One SLA graduate described The Franklin Institute as "a good place for a student to go and get interested about sciences or anything STEM or really motivated to do anything in a science field." A participant from RAHS also described the Museum of Flight as a source of motivation:

> You'd be sitting in the classroom and you'd look outside and there's all of this history and there all… these physical objects that you can see, tangibly. So if anything, it's really motivating to keep doing what you're doing, and it gives you that idea of a purpose of what you're studying, and the purpose of learning from what you're doing.

Another graduate described the museum as cultivating long-lasting learning:

> I think it's a huge difference what you can read in a book and what you can actually see… but when you can go to a museum and you can see the exhibit and you can listen to people who actually flew those planes in this museum… it kind of brings it to life and your remember it a lot more. I remember so much more from just what docents told me than I would learn reading the book….

Several participants (n=4) valued the museum for the unique content knowledge they gained from working with its exhibits and collections; the Museum of Flight's archive, in particular, stood out to RAHS graduates (n=2):

> …the Museum of Flight provides resources for the Aviation High School. They allow us to go over there whenever we want to… try to get information on our research, on our projects that we need to do. …Rather than going to the library, we'd go to the museum, you know? Which I found was really cool, versus going to a library.

This emphasis on the expanding available resources was shared by several Science Leadership Academy alumni (n=5), but in terms of leveraging the social capital of The Franklin Institute to realize the new school's vision. One graduate felt that the museum school relationship mattered "because not only does it allow students to go over to The Franklin… it also provides the school with a very powerful ally in terms of finding, getting help for some of the other pieces, components to the school…." Another participant stated that in The Franklin Institute was "a selling point" for the new school:

> It afforded us better connection to the outside world. So it made some of our relationships with other museums happen. It allowed us to do things that ordinarily a first year high school would not be able to do. And so the relationship with The Franklin Institute, I guess in summarization, basically help us expand our aspirations.

In addition to these institutional scale connections, alumni from both schools (n=3) valued the museum as a forum for networking as an individual. As one participant reported, "The biggest thing for me in going to Aviation and that being tied to the museum is all the opportunities to meet people in the industry and speak with them and be able to develop those relationships with those people. And the cool thing about museums is they know everybody."

For some alumni, connecting to the museum itself was of significant value. Two participants (n=2) referred to the museum as a place to cultivate professional skills; "I know for the majority of the kids… start their volunteer and internship program, pretty much start the foundation of their career at the Museum of Flight." In addition, two alumni (n=2) acknowledge that the museum inspired them to continue working in that environment: "I guess it probably helped lead me to working here, kind of as an informal setting."

Finally, alumni were asked to think in terms of the museum school's lasting significance and how it had "contributed to who you are today." For a majority of participants (n=8), the museum school clarified educational or career goals in an important way. For some (n=4), the experience reinforced a path towards STEM- or aviation-related careers, at least through their transition to college. As one alumna stated:

> When I went to college, the classes were easy and I knew what I wanted to do because I think that museum emphasis really helped me figure out what I wanted to do. So when I got to college, I knew what classes I wanted to take, I looked up all of them. And also the science background really helped, I remember in my aerodynamics class now… it's not too difficult because much of it was stuff we talked about in high school already.

Several alumni (n=4) reported that the museum school clarified goals that did not align to STEM careers, though they each framed the outcome as positive. One participant became certain "that I was good with math, not certainly so with science, so it kind of steered me to the right direction and not down the STEM path anymore. So I think it helps people figure out what they want to do in life." Another reported still having related life goals, if not professional ones:

> I was able to really understand if I want to go into aviation as a career, and the different ways I can do that, and the different career paths there are, even though currently I want to go into business and entrepreneurship now, after going to Aviation I realized I wanted to do that instead. I still want to get my pilot's license in the future.

One participant even reported having an interest in informal education reinforced by the museum school experience, shifting from volunteer and seasonal roles and then "becoming a part-time and eventually full-time educator. So I guess it definitely kept me around the education environment, more so… more so than just going to high school and then going to college and then going out into the field."

A number of alumni credited the museum school with cultivating transferable skills for a variety of professional contexts. Confidence was the most commonly reported gain (n=5), with one graduate describing the museum and school as making "sure that I was steady on my feet, was really confident, could speak in front of a room, was used to giving presentations… or interacting with people who were professionals, who were coming in as mentors." A few alumni (n=3) characterized the experience as making them adept learners. "At SLA," one participant described, "they kind of teach you how to learn, teach you critical thinking, teach you how to question things, and I would be a completely different person without that." Additionally, some participants (n=2) felt well-prepared for the future because of the museum school: "They make you make your resumes so you can get ready for job interviews or internships, you make business cards, and once you get to sophomore and junior years you can apply for internships, and through the four years too, they get you ready for college."

Connecting Influences

In order to explore the specific ways that the museum might contribute to science identity, alumni were asked to rank potential influences that contributed to the outcomes explored in the first research question. Influences were ranked in descending order across six science identity-related concepts: *knowledge* of science; *confidence* in doing science; desire to go to *college*; desire to have a *career* in science or related fields; *awareness* of jobs or career choices in science or related fields; and *connections* to people in science or related fields. A list of potential influences was provided in advance, along with the option to list other factors or choose none if the impact was not felt or attributable. The prompted influences consisted of: teachers and classroom time; museum exhibits or artifacts; projects or internships; engaging museum visitors; friends or family; and other organized youth activities. The aggregated results can be found in Tables 2 and 3. For weighted rankings, each first place ranking was assigned three points; second place, two points; third place, one point.

Teachers and classroom time consistently ranked among the most frequently and most highly rated influences, particularly for increasing knowledge of science. Projects and internships were also considered to be influential, particularly for connections to people in science, awareness of careers in science, and knowledge of science. Friends and family were commonly cited as second- or third-most influential, most powerfully in alumni's desire to go to college. Museum exhibits and artifacts were listed as influences for cultivating awareness of science-related careers and a desire to pursue them. Tables 4, 5, and 6 on the following page break down total responses into first, second, and third place rankings.

Table 2. Influential Factors by Total Number of Top Rankings
n=14

	Teachers/ Classroom	Museum Exhibits	Projects/ Internship	Engaging Visitors	Friends/ Family	Organized Activities	Other	None
Knowledge	13	3	12	0	8	3	1	2
Confidence	13	3	8	2	7	3	3	3
College	8	1	4	1	10	2	3	13
Career	9	6	8	3	6	2	2	5
Awareness	10	7	9	4	2	1	5	4
Connections	10	3	10	3	4	0	6	4

Table 3. Influential Factors by Total Weighted Rankings
n=14, weighted cumulative maximum of 42

	Teachers/ Classroom	Museum Exhibits	Projects/ Internship	Engaging Visitors	Friends/ Family	Organized Activities	Other	None
Knowledge	34	4	27	0	10	5	2	2
Confidence	28	6	16	6	14	7	4	3
College	21	3	8	2	20	3	4	23
Career	24	12	16	6	11	3	5	6
Awareness	21	16	21	6	4	1	11	4
Connections	24	4	24	4	7	0	13	5

Table 4. Influential Factors by Number of 1st Place Rankings
n=14

	Teachers/ Classroom	Museum Exhibits	Projects/ Internship	Engaging Visitors	Friends/ Family	Organized Activities	Other	None
Knowledge	9	0	4	0	0	1	0	0
Confidence	5	0	3	2	2	2	0	0
College	5	1	1	0	4	0	0	3
Career	7	1	2	1	2	0	1	0
Awareness	5	3	3	1	0	0	2	0
Connections	5	0	5	0	1	0	3	0

Table 5. Influential Factors by Number of 2nd Place Rankings
n=14

	Teachers/ Classroom	Museum Exhibits	Projects/ Internship	Engaging Visitors	Friends/ Family	Organized Activities	Other	None
Knowledge	3	1	7	0	2	0	1	0
Confidence	5	3	2	0	3	0	1	0
College	3	0	2	1	2	1	1	4
Career	1	4	4	1	1	1	1	1
Awareness	1	3	6	0	2	0	2	0
Connections	4	1	4	1	1	0	1	1

Table 6. Influential Factors by Number of 3rd Place Rankings
n=14

	Teachers/ Classroom	Museum Exhibits	Projects/ Internship	Engaging Visitors	Friends/ Family	Organized Activities	Other	None
Knowledge	1	2	1	0	6	2	0	2
Confidence	3	0	3	0	2	1	2	3
College	0	0	1	0	4	1	2	6
Career	1	1	2	1	3	1	0	4
Awareness	4	1	0	3	0	1	1	4
Connections	1	2	1	2	2	0	2	3

Projects and internships were consistently ranked among the top two influences, especially in connection to knowledge of science, awareness of careers in science, and connections to people in science. Because each participant's range of project and internship experiences included different school, museum, and external contexts, alumni were asked to clarify the kinds of opportunities they were recalling and qualitative responses were coded. In total, museum opportunities represented approximately 31% of the project and internship responses (n=16); school projects 25% of responses (n=13); a mix of school and museum opportunities, 27% (n=14); and outside internships, 16% (n=8). Although school projects were the most commonly cited for increasing knowledge of science (n=5), museum opportunities (n=3) and a mix of school and museum opportunities (n=3) were also common responses. Museums-based opportunities were the most commonly cited projects and internships for the statements about desire to have a career in science (n=3) and connections to people in science (n=3).

Emergent coding was also applied to responses of organized youth activities and other. In all but one instance (n=9), the other activity was a STEM-related club such as a robotics team, Science Olympiad, or ecology club. In the other influences category, alumni often listed networking or mentorship opportunities (n=16). However, several participants (n=5) also cited the school culture as a whole supporting and influencing them, particularly in the desire to go to college (n=3).

These fourteen interviews with alumni of STEM museum high schools show that participants reported having many of the indicators related to science identity and attributed several lasting impacts to the museum components of their educational experiences. Discussion and implications of these findings follow in the next chapter.

CHAPTER 5: Conclusions & Implications

Museum schools are an under-researched phenomenon with the potential to inform the field about the long-term student impacts of intensive formal-informal partnerships. This study contributes to our understanding of what museum school experiences can achieve and points to the specific opportunities that resonate with graduates for years to follow. By conducting interviews with fourteen alumni from two STEM museum high schools, this study assessed the extent to which participants have and enact a science identity and the ways in which they attribute it to museum experiences.

Conclusions

Having multiple channels for museum participation blurs institutional boundaries. The majority of interviewed alumni reported participating in a variety of museum-related opportunities above and beyond mere field trips. While class-related visits to the museum were memorable events, most alumni also had extracurricular participation within their larger educational ecosystems. Alumni recalled volunteer opportunities and internships in detail and consistently described them as significant learning experiences. Participants were not always clear which opportunities had been facilitated by the museum school directly, but recognized the partnership as enhancing their awareness of available museum resources. This blurring of lines reflects the crosspollination of leadership, resources, and opportunities between the two institutions. These results support the consensus in the literature that museum schools derive power from true collaboration (King, 1998; Klein et al., 2001; Takahisa, 1998) and can be thought of as a “hybrid of mixed origins” that is greater than the sum of its parts (Finnerty, 1996, p. 6).

Alumni have positive elements of science identity, even when they are not pursuing further science education or careers. Using Carlone & Johnson's (2007) three-pronged model of science identity, alumni reported having strong *competence* and *recognition* in doing science, while *performance* as a scientist was less consistent. Participant responses indicated that the museum school had been most effective in increasing their knowledge of and confidence in doing science, and in increasing awareness of careers in science and connections to the people working in science. Responses were understandably mixed in considering the museum school's impact on their desire to go to college or pursue a career in science, given the significance of external factors. Nevertheless, a third of participants reported continuing on to STEM fields in higher education with many more operating in STEM-adjacent realms of business and social science, supporting assertions that participation in relevant activities reinforce science identity (Brickhouse & Potter, 2001) and "solidify… interests, commitments, and social networks" (Bell et al., 2008, p. 46).

Though fewer than half of the participants reported recognizing themselves or feeling recognized as scientists, negative responses were nuanced and reflected the wide range of desirable outcomes in informal science (McCreedy & Dierking, 2013). Several participants drew careful distinctions between science, engineering, and technology; others described having a positive view of themselves as scientifically literate or having a scientific mindset despite growing apart from STEM professionally. Their responses demonstrate a rich understanding of "science practices" as including both the mastery of relevant skills and the knowledge of contexts in which they are to be deployed (Calabrese Barton, Tan, & Riven, 2011). In short, alumni presented a view of themselves as having an enduring participation in science within specific social contexts—the very definition of science identity (Carlone & Johnson, 2007).

Moreover, alumni attribute identity-reinforcing experiences to the museums. Notably, the indicators that alumni reported as increasing the most while at the museum school were the same ones they said had been most influenced by hands-on experiences. Teachers and classroom time were unsurprisingly the greatest educational influence, particularly for increasing participants' competence. Projects and internships, however, were a strong second and third choice across categories and in weighted comparisons, scoring as highly as traditional instruction for increasing awareness of science-related careers and connections to people in science. Taken alone, this finding is perhaps more of a tacit endorsement of project-based learning (Krajic & Blumenfeld, 2006) than of museum learning; however participants clearly valued the museum in their open-ended responses.

Interviewed alumni unanimously agreed that the museum relationship mattered to the school and that the overall museum school experience had contributed to who they are today. Several participants remarked that museum collections and programs had fostered highly memorable, lasting learning experiences. Content knowledge emerged as a recurring theme in questions about the museum's learning value and contribution to the school, including references to specific museum exhibits and archival resources. Several alumni also reported using the museum as a place to visit and learn as part of classwork or independent study outside the field trip context. Inspiration and engagement themes also emerged in participants' description of learning at the partner museum, describing it as more "personal," "real," and without the "restrictions" of a traditional school environment.

Participants also valued the museum for its social capital, facilitating both individual connections to professional networks and institutional connections to greater resources. In addition to providing volunteer, internship, and employment opportunities that alumni recognized as cultivating professional skills, many alumni saw the museum as a place to meet professional scientists and engineers. Though the specific opportunities ranged from juried presentations to career mentoring to formal galas, museums were consistently recognized as the vehicle for these encounters because, as one alumnus put it, “they know everybody.”

Participants identifiy a wide variety of cognitive, social, and emotional learning outcomes from the museum experience consistent with positive youth development frameworks. The “5Cs” model for youth-oriented programs (Lerner, et al., 2005) and the extended “6Cs” model by King et al. (2005) have been used to explore a full range of learning outcomes, in much the same way that science identity incorporates wider experiences. The outcomes identified by participants in this study are closely aligned to the findings of Luke, Stein, Kessler, & Dierking’s (2007) study of current participants and alumni of museum programs, including one at The Franklin Institute. In both studies, participants widely reported increasing their *competence* in cognitive, academic, and vocational realms of understanding; *confidence* in their own abilities, and *connections* to peers, adults, and the community. Luke and colleagues also found that *character* as an outcome was “more often related to developing a sense of identity and values than fitting into predefined standards” (p. 429), mirroring the consolidating of educational interests and career trajectories that museum school alumni reported in this study. *Caring* or *compassion* were also less emphasized in the museum-related programs. Perhaps most telling, however, is the parallel between the tempered responses about performing as a scientist and King et al.’s (2005) sixth “C” of *contribution*, which follows only when the other constructs have been achieved.

Science identity, while a useful as a conceptual framework, requires clarity of language and dynamic tools to fully understand potential long-term impacts. One of the assets of an identity-driven approach is its focus on holistic, lifelong learning. However, because career trajectory is such a prominent indicator of salience in science identity, recognition and performance-related responses reflect a professional understanding of the word “scientist.” Some participants interpreted the term literally and were careful to distinguish engineering and technology from science research; others employed a more cultural definition of being a “science person.” This study employed the word “scientist” to mirror *Cascading Influences* (McCreedy & Dierking, 2013), which similarly “revealed continued tensions in the ways [participants] think about what counts as science, complicating their relationship to and identification with, science” (p. 32). Delving into these tensions presents a rich opportunity for research and may be useful in identifying specific outcomes for science participation beyond professional opportunities.

Additional methods beyond retrospective interviews may also provide a more complete understanding of the way science identity is formed and expressed across time and settings. This study’s retrospective interviews relied heavily on memorable highlights, which reflected the interplay between competence, performance, and recognition in moments of success. The fluidity of each dimension across social contexts, however, is lost in these static data. Carlone and Johnson (2007) focus their study on recognition because performance is the most situationally emergent dimension of science identity, and museum school alumni research echoes the challenges of assessing practice through participants’ recollections and aspirations. Aligning McCreedy & Dierking (2013) indicators to Carlone & Johnson’s (2007) performance dimension proved particularly challenging, and could have been bolstered by integrating additional observational or longitudinal data as a way of understanding changes in behavior across contexts.

Implications for Further Research

Additional research has the potential to inform practitioner audiences and the field alike, with ramifications for both museums and schools. For the sites involved in this research, findings support institutional assertions about the museum's contribution and pinpoint the activities that resonate most strongly with alumni for years after graduation. Though the specific activities offered at other museum high schools may vary, participants' emphasis on social capital and pre-professional experiences can be generalized to a variety of programs and disciplines. These alumni perspectives also reflect the myriad opportunities that museums provide in and out of school time and serve as evidence of authentic student engagement in the museum school.

Replication of this study across larger samples, different schools, or wider grade levels could increase our understanding of the ways museum schools can effectively use informal learning strategies to foster meaningful educational experiences in and adjacent to formal schooling. Applying other theoretical lenses related to academic or professional identities could yield findings about other types of museum school and contribute to the broader literature about museum education. A quasi-experimental design comparing museum schools and project-based curricula without a set partner institution represents another avenue for research.

Demonstrating the value of museum school learning in this and future studies has policy implications as well. While this research has focused on museum schools as an extreme form of partnership, recognizing the value of school-museum collaboration has the potential to expand educational capacity and bring inspirational learning experiences to a broader audience. Students of magnet and charter schools have been the main beneficiaries of these initiatives to date, but museums have the potential to promote more equitable education by extending opportunities for in-depth collaboration to neighborhood schools.

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APPENDICES

Appendix A: Museum School Census

School Name	City	State	Zip	Est.	Grades	Location
Flagstaff Arts and Leadership Academy	Flagstaff	AZ	86001	1996	7-12	Off-Site
Carrillo Magnet School	Tucson	AZ	85701		K-5	Off-Site
Arroyo Seco Museum Science Magnet School	Los Angeles	CA	90042	1998	K-8	Off-Site
Dr. Theodore T. Alexander California Science Center School	Los Angeles	CA	90007	2004	K-5	Adjacent
Zoo Magnet Center	Los Angeles	CA	90027	1981	9-12	Adjacent
Chyrsalis Charter School	Palo Cedro	CA	96073	1996	K-8	Off-Site
The Museum School	San Diego	CA	92103	1998	K-8	Off-Site
Interdistrict Discovery Magnet School	Bridgeport	CT	06606	2011	PreK-8	Museum Campus
Fred D. Wish Museum School	Hartford	CT	06120		PreK-8	Off-Site
L. W. Beecher Museum School of Arts and Sciences Interdistrict Magnet	New Haven	CT	06516	2007	PreK-8	Off-Site
CREC Museum Academy	Windsor	CT	06095		PreK-5	Off-Site
Robert Brent Museum Magnet Elementary School	Washington	DC	20003	1996	PreK-6	Off-Site
Stuart-Hobson Middle School	Washington	DC	20002	1997	6-8	Off-Site
Ortega Elementary Museum Magnet School	Jacksonville	FL	32210	2010	K-5	Off-Site
Palm Beach Maritime Academy	Lantana	FL	33462	1999	K-8	Off-Site
Miami Children's Museum Charter School	Miami	FL	33132	2006	K-5	Museum
Shenandoah Middle School Museums Magnet	Miami	FL	33145	2005	6-8	Off-Site
Southside Elementary Magnet School	Miami	FL	33130	2005	PreK-3	Off-Site
Miami Springs Middle School	Miami Springs	FL	33166		6-8	Off-Site
The Museum School at Avondale Estates	Avondale Estates	GA	30002	2010	K-8	Off-Site
Talcott Fine Arts and Museum Academy	Chicago	IL	60622	2005	PreK-8	Off-Site
Henry Ford Academy	Dearborn	MI	48121	1997	9-12	Museum Campus
Grand Rapids Public Museum School	Grand Rapids	MI	49504	2015	6-12	Museum
School for Environmental Studies	Apple Valley	MN	55124	1994	11-12	Adjacent
Farnsworth Aerospace	St. Paul	MN	55106		PreK-8	Off-Site

School Name	City	State	Zip	Est.	Grades	Location
Compton-Drew Middle School	St. Louis	MO	63110	1996	6-8	Adjacent
Brooks Museums Magnet Elementary School	Raleigh	NC	27609	2002	K-5	Off-Site
Exploris Middle School	Raleigh	NC	27603	1997	K-8	Off-Site
Moore Square Museums Magnet Middle School	Raleigh	NC	27601	2002	6-8	Off-Site
The Museum School (PS 333)	Bronx	NY	10459		PreK-5	Off-Site
Dr. Charles R. Drew Science Magnet School	Buffalo	NY	14211	1990	3-8	Museum Campus
Museum Magnet School (PS 191)	New York	NY	10023	2011	PreK-8	Off-Site
New York City Museum School (#414)	New York	NY	10011	1995	9-12	Off-Site
Genesee Community Charter School	Rochester	NY	14211	2001	K-6	Museum Campus
Museum School 25	Yonkers	NY	10701	2001	PreK-6	Off-Site
Silverton Paideia Academy	Cincinnati	OH	45236	2009	PreK-6	Off-Site
MC^2 STEM High School	Cleveland	OH	44104	2008	9-12	Museum
Science Leadership Academy	Philadelphia	PA	19103	2006	9-12	Adjacent
Normal Park Museum Magnet School	Chattanooga	TN	37405	2002	K-8	Off-Site
John Early Museum Magnet School	Nashville	TN	37208	2011	6-8	Off-Site
Robert Churchwell Museum Magnet Elementary School	Nashville	TN	37208	2010	PreK-5	Off-Site
Uplift Luna Preparatory School	Dallas	TX	75202	2010	K-12	Off-Site
Fort Worth Museum School	Fort Worth	TX	76107	1949	PreK-K	Museum
Hunter Woods Elementary for the Arts and Sciences	Reston	VA	20191	1999	K-6	Off-Site
Raisbeck Aviation High School	Tukwila	WA	98108	2004	9-12	Museum Campus

Previous listings by Povis (2011), NAMS (2015), and Sturgeon (2010) included the following schools, which have temporarily or permanently ceased operating under a museum school model: Museum School for the Visual Arts (Tucson, AZ); Fitchburg Museum School (Fitchburg, MA); Elias Brookings Expeditionary Learning Museum Magnet School (Springfield, MA); Museum Magnet School (St. Paul, MN); and the Magnet School of Museum Studies at PS/IS 104 (Brooklyn, NY).

Appendix B: Interview Guide

Long-Term Impacts of Museum School Experiences on Alumni's Science Identity
Interview Guide

Catherine Scharon // Phone: 216-408-6878 // E-mail: cscharon@uw.edu
Thesis Advisor: Dr. Jessica Luke, Museology Graduate Program, University of Washington
Phone: 206-685-3496 / E-mail: jjluke@uw.edu

Consent Script
I am asking you to participate in a research study that is part of my Master's Thesis at the University of Washington. The purpose of this research is to examine the long-term impacts of a museum school experience on the formation of science identity. You do not need to be working in science or have even enjoyed your time in school to take part in this study.

Your participation is voluntary and you may discontinue participation at any time. Refusal to participate will involve no penalty or loss of benefits. I am audio recording this interview, but only I will listen to the recording. Your name will not be identified and while I may quote you, that quote will not be attributed to you. If you have any questions now or in the future, you may ask me or my advisor using the contact information I have shared with you. Do you have any questions? Do you agree to participate in this interview?

Introduction
Thank you for taking the time to talk with me today. Before we begin, I'd like to make sure we're on the same page with our terminology. For the purposes of this interview, I'm interested in your "museum school" experience both in terms of classroom time at [School Name] as well as any activities you may have participated in at [Museum Name] during or after school. At times, I may ask you to specify whether a program made use of a museum space or museum staff time as opposed to a classroom space or teacher time, but I will try to be clear about the distinction.

The goal of this interview is to understand the impact that attending a museum school has had on the way you think about, feel about, or use science today. I will ask you questions in four sections, each consisting of about 4 to 10 questions. First, I will ask a few questions about your time and participation at [museum school]. In the second section, I will ask about any memorable experiences you had during your time at [museum school]. The third section is about the role of science in your life today. Finally, I will ask a few questions about the way your [museum school] experiences could connect to your life today.

If there are any questions you'd like to skip, or if you would like a break at any point, please let me know. Do you have any questions before we get started?

Let's begin!

1: Background and Educational Experience

My first few questions are about the nature of your time at [Museum School] and the range of experiences you may have had there.

1. What years were you enrolled at [Museum School]?

2. How old are you now? 18-23 | 24-29 | 31-35 | 36-40 | older than 40

3. What kinds of courses did you take at [Museum School]?
   Probes: Did you have a favorite class? A least favorite class?

4. What kinds of programs or activities did you participate in at [Museum School], either during or after school time?
   Probes: Did you have a favorite activity? A least favorite activity? Did it happen at the school, at the museum, or somewhere else?

5. What made you choose to attend [Museum School]?
   Probes: How did you hear about the school? How did you decide to apply? Did you family play a role in your decision? Did you want to attend this school?

2: Memorable Experiences

Now I'm going to ask you to reflect on some of the memorable experiences from your time at [Museum School].

1. What was the highlight of your experience at [Museum School]?

2. What was the low point of your experience at [Museum School]?

3. Can you describe the most memorable moment when you were excited by science?

4. Can you describe the most memorable moment when you were discouraged by science?

5. Do you remember spending time at the [Museum] specifically? What specific memories do you have about that?

6. Do you think you learned anything at the [Museum] specifically? What did you learn?

7. Why do you think the museum component matters?
   Probes: What did it add to your experience? If you had gone to another STEM high school that without any attachment to [Museum], are there activities or opportunities you would have missed? Why are those significant?

8. How has [Museum School] contributed to who you are today?

3: Current Engagement with Science
Now I'd like to ask you some questions about the way you do or do not relate to science today.

1. I'd like ask you about any school you've attended since your time at [Museum School]. Have you ever attended or are you currently enrolled in college? Graduate school? Certificate or associate's program? Please indicate any degrees you've started or earned.

2. What specialization(s) or major course(s) of study have you focused on, if any?

3. Are you currently employed? Would you describe yourself as working outside of a degree-related field? In a degree-related field? In a science-related field?

4. What is your long-term employment goal?
   Probes: Do you think you will remain in your current field? What other field would you consider? Do you think you will go back to school?

5. Do you see yourself as a scientist? Why or why not?

6. Do you think others see you as a scientist? Why or why not?

4: Program Impacts
Lastly, I'm going to ask you about the potential influence that [Museum School] may have had using some ranking and rating questions.

First, I'm going to read some statements; for each idea, tell me if participating in the program has impacted you in this way using a scale from 1 to 6. Choose 1 if you think you did not change at all in this way, choose from 2 to 5 depending on how much you changed, with larger numbers indicating bigger change. Choose 6 if you think you changed in this way "a lot."

1. Being enrolled at [Museum School] increased my knowledge of science.

2. Being enrolled at [Museum School] increased my confidence in doing science.

3. Being enrolled at [Museum School] increased my desire to go to college.

4. Being enrolled at [Museum School] increased my desire to have a career in science.

5. Being enrolled at [Museum School] increased my awareness of jobs or career choices in science or related fields.

6. Being enrolled at [Museum School] has increased my connections to people in science or related fields.

Now, I'm going to go back through each statement and provide you with a list of possible influences that might have contributed to that impact; please rank your top three responses with 1 being the most influential. If none of these contributed or you did not feel that impact, list "none."

7. The following helped increase my knowledge of science:
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Talking to museum visitors
    d. Projects or internships
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

8. The following helped increase my confidence in doing science.
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Projects or internships
    d. Talking to museum visitors
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

9. The following helped increase my desire to go to college.
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Projects or internships
    d. Talking to museum visitors
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

10. The following helped increase my desire to have a career in science.
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Projects or internships
    d. Talking to museum visitors
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

11. The following helped increase my awareness of jobs or career choices in science or related fields.
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Projects or internships
    d. Talking to museum visitors
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

12. The following helped increased my connections to people in science or related fields.
    a. Teachers and classroom time
    b. Museum exhibits or artifacts
    c. Projects or internships
    d. Talking to museum visitors
    e. Friends or family
    f. Organized youth activities
    g. Other
    h. None

Appendix C: Coding Rubric

Q1.3: What kinds of courses did you take at [museum school]? Did you have a favorite?

My school offered…	
Standard curriculum	"Standard," "normal," "regular," or "basic" required curriculum, including mathematics, sciences, humanities, and social studies. *I took the basic required courses, like English, math, and science.*
STEM electives	Advanced or alternative courses in aviation or STEM topics. *I know at the time everyone did ground school. There were a few kind of elective classes that were more, I guess, engineering-themed. There was a Flight by Design thing, something like that.*

*multiple codes allowed

My favorites were…	
STEM-related or aviation-related	Courses related to science, engineering, technology, or mathematics, including courses specifically related to aircraft design and history. *It's always been sciences and math, it switches between math and physics, but in the end it was computer science.*
Not STEM- related or aviation-related	Courses in the humanities, arts, or other non-science disciplines. *Yeah, my favorite subjects were the humanities, so AP Language or AP English.*
Can't recall/choose	Could not recall or choose a favorite. *No, not really. They were all very, I don't know. They were all really great classes.*

*single code allowed

Q1.4: What kinds of programs or activities did you participate in at [museum school], either during or after school time?

I participated in…	
Museum volunteer program	Museum education/training program outside of normal school hours and open to students from different high schools, such as the Museum of Flight's Museum Apprentice Program (MAP). *…I was involved in the Museum Apprenticeship Program at the Museum of Flight. …I did, I guess what they call Discovery Carts. Researched a topic, made some demo stuff, and then on the First Free Thursdays went and presented it to the public….*
Museum job or internship	Part-time professional experience at the partner museum, paid or unpaid, beyond or in addition to the normal volunteer opportunities. *…a robotics teacher at Aviation… got me my first job as an interpreter. Programs Interpreter at the museum. And then during my senior year, there was the Executive Administration Assistant at the Museum of Flight, and I was really curious about the business aspect of things so I got to volunteer under her, mostly doing bookkeeping and administration stuff.*
Outside internship	Internship at an organization other than the partner museum. *Being able to work at a private jet charter at my age—at that time I think was 17 years old. Most people if they even decide to go on that path don't get to do that until they're in their 20s.*
Career mentoring	Mentoring for a specific career path, such the Airlines Career Experience (ACE) Club at RAHS or one-on-one mentoring by other professionals. *…it's the Airlines Career Experience Club, we have a mentor come in from Alaska Airlines. He was a captain and would tell us all about his experiences, give us advice on how we can transition into college and becoming a pilot.*
Robotics club	Club for designing, building, and/or competing with robots, based at the school or the partner museum. *I did robotics in joint with The Franklin Institute, which was the biggest thing. …Robotics was my favorite because I was doing it since I was age 8.*

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I participated in…	
STEM club	School-based club in STEM field, e.g. ecology club, technology club, or Science Olympiad. *...it was the environmental science club at school…. We would put on assemblies and raise awareness about environmental issues.*
College-level course	Additional courses eligible for college credit, completed independently or through program like Washington Aerospace Scholars (WAS). *And then I did another year [at Drexel University] where I actually took some college courses in sociology and psychology.*
Student leadership	School organization devoted to school events or student orientation. *ASB is Associate Student Body. It's basically a team of students who run for the different positions, there's class positions and student body positions, and basically you set up all the events, the student dances, fundraises, and assemblies….*
Organized sports	Organized sports, including Ultimate Frisbee, cheerleading, or dance.
Miscellaneous	Miscellaneous groups, such as book club, band, or debate team.

*multiple codes allowed

Q1.5: What made you choose to attend [museum school]?

I chose it for…	
Subject matter interest	I wanted to go to a school that would further my existing interest in science, math, aviation, or other STEM-related field. *I guess it was just something I was interested in. They were just starting the school when I was getting ready to go to high school, so it sounded interesting. I'd always been around and interested in aviation.*
Academic reputation	I wanted to go to a school known for academics and matriculation. *And that's when I knew I wanted to go to Aviation not only for its science and aviation, but it's also good for college and getting ready, the studious part of the program, the academics.*
School philosophy	I wanted to attend a school that catered to my learning style. *I'm not a particularly good test taker, so when they said the magic words, that it's a project-based curriculum instead of being a test-based curriculum, that really hit a high note for me.*
School logistics	I wanted to go to a public school that met my ideal size or location. *I would say that the thing that influenced me more was the size of the school. So, the 400 students instead of what's often a thousand or more at a high school. And then the really small community where the teachers come to know everyone….*
Friends or family	I wanted to go to a school where people I knew attended/had attended. *…I knew more of the people going there and my brother went there, so at the time it was kind of like the lesser of two evils.*
Provided laptop	I wanted to go to a school that would provide me with a laptop. *Well, it was the only school in the city, honestly, that gave out laptops… as a form of learning, and at home I wasn't accustomed to the Internet or anything and I started thinking after hearing [the principal] speak at my school that being a connected user was very powerful.*

*multiple codes allowed

Q2.1: What was the highlight of your experience at [museum school]?

The highlight was…	
Working at museum	Spending time at the museum as a volunteer, intern, or employee. *It would have to be interacting with the kids. Getting the opportunity to set a foundation for the skills that I could actually use after high school, I think that's something in my memory that I can most likely recall. Every time I think about the school it makes me think about the museum and how I taught the kids in the programs that I participated in.*
Professional connections	Participating in an internship or excursion outside of the museum and networking with professionals in a field of interest. *…just going around getting that first-hand experience at places in the aviation/aerospace industry, so going to Boeing facilities, going to the Alaska Airlines hanger, going on the delivery flights.*
School community	Being a part of the overall school community and ethos. *…the Science Leadership Academy served as my second home… going downtown to a place of learning, and then wanting to stay after school not only to get work done, but to socialize, and complete those extracurricular activities, to have internet access and be part of that science environment more than 12 hours a day is an amazing feeling.*
Project or presentation	Completing projects and presentations during classroom time. *Every time we had a really big project, that I worked really hard on and I felt that I had really succeeded. We would do presentations to the class constantly, and I distinctly remember those being real highlights.*
Part of club or team	Participating and socializing as a member of a team or club including robotics team, book club, or technology club. *Probably just working with friends on the robotics team.*

*single code allowed

Q2.2: What was the low point of your experience at [museum school]?

The low point was…	
Academic challenge	Difficulty in specific courses and/or managing time and workload. *…staying up late, doing homework until like three in the morning. I mean, that's pretty normal, not exactly the highlight of the high school experience.*
College transition	Pressure related to educational trajectory or transition to college. *There was a lot of pressure to apply to college and get accepted to college and actually go to a four-year university, and that wasn't really the right path for me, but I didn't know it at the time.*
Miscellaneous	Other miscellaneous low points, such as personal challenges or growing pains from attending a newly organized school.
None	Cannot identify low point

*single code allowed

Q2.3: Can you describe the most memorable moment when you were excited by science?

I was excited by…	
Hands-on learning	Participating in a specific project or hands-on experience, either individually or in a group context.
Class project	Completing a specific project as part of a class assignment. *…in my physics class, we had a project where we had to create a musical instrument and calculate all of the, well, we were learning about sound. And I actually built a working, full-sized guitar. And that was amazing.*
Dissections	Participating in biological dissections, during class or at the museum. *One of the programs that I got the ability to do during that time [at The Franklin Institute] was the opportunity to dissect a bunch of animals, see the parts inside, getting to use anything that they had at the time. At the time, I still wanted to be a surgeon, so that was extremely cool to me. I had never worked with a scalpel before….*
Club or competition	Creating projects and/or performing well in competitions, including robotics club, Science Olympiad, or city and regional science fairs. *So I managed to get into the robotics group, and my very first project when I was there was to build a 'BattleBot.' Namely a 30-pound robot that hit really, really hard. And so I got really, really excited about that, and it was probably the first real big project that I had ever really worked on, that I got to work with my hands.*
Breakthrough concept	Sudden realization or connection through classroom content. *I remember one time in my pre-calculus class, we were going through math problems about how… if you launch something off a catapult how far it would travel, and then we were doing the same thing in our physics class at the same time and I just remember making that connection. That there's two different ways to solve this, one using more physics, one using more math… I just remember being really excited to figure that out.*
None	Cannot identify memorable moment

*single code allowed

Q2.4: Can you describe the most memorable moment when you wee discouraged by science?

I was discouraged by…	
Academic challenge	Difficulty in specific courses and/or managing time and workload. *…I was doing, I believe some physics work or maybe some biochemistry work, and just not understanding certain concepts and having to—even though I didn't mind doing it. Putting that extra time into trying to understand something really put a damper… really put my mind back into reality that I'm not so comfortable with this material, that I need to just really study hard.*
Peer comparisons	Feeling inadequate compared to peers who excelled in science or daunted by competitiveness of field. *When I first saw how good my mentor programmer was. Mentoring can be intimidating in the science fields.* *I felt like I was in this risk. …Engineering at Penn State was like, "We only accept 125 applicants."*
None	Cannot recall memorable moment. *I don't think so. Probably not, no. I mean, the environment there is definitely very positive.*

*single code allowed

Q2.5: Do you remember spending time at [museum] specifically? What specific memories do you have about that?

I was there for…	
Museum volunteer program	Museum education/training program outside of normal school hours and open to students from different high schools, such as the Museum of Flight's Museum Apprentice Program (MAP). *I was in the Museum Apprentice Program, so one time I left [school] a little early to go to the research library that they have there. …We found a log book of a pilot from World War II and in his log book he was detailing all the flights to Seattle….*
Museum job or Internship	Part-time professional experience at the partner museum, paid or unpaid, beyond or in addition to the normal volunteer opportunities. *…in my junior year I took a position… within The Franklin Institute. So you know, going to school plus juggling a job, I had amazing support from the school, it was really cool.*
Occasional field trips	One or more field trips per year, as part of a specific class. *So for that class, as part of the syllabus we were learning to write biography and writing about historical characters, so we had a field trip to the Museum of Flight and we kind of wandered around, and it was very self-directed, where we could experience the museum as part of understanding writing and understanding history, but then also looking through the museum. Then we would choose someone who we wanted to write a report on.*
Recurring field trips	Weekly recurring field trips as part of a year-long program. *In our freshman year at SLA, Wednesdays were spent at The Franklin. …Sometimes we would have a specific activity to do that they had created for us in one of the exhibits, sometimes we'd kind of be an initial audience for a new presentation or workshop….*
Special events	Spent time at the museum for special events or programs, such as museum gala or presenting senior projects to museum guests. *I know we had some involvement with the big gala, and helping run volunteer opportunities, helping run or being involved indifferent events that were going on during the year. Little flying things and stuff like that.*

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I was there for…	
Visiting on my own	Spent time at the museum outside of any organized museum or school program. *Along with the fact that we were not only able to have our admission to The Franklin free, but we were given passes to specific events, the King Tut exhibit, we were one of the first to see, which was so cool. …I was able to bring my cousins to IMAX shows, to go into the planetarium and see the shows about the stars and the sky. That experience was worthwhile not only to myself but to my family.*

*multiple codes allowed

Q2.6: Do you think you learned anything at [museum] specifically? What did you learn?

I learned…	
Content knowledge	I learned specific content related to STEM topics or aviation from spending time in museum exhibits and programs. *For a few weeks I remember a physical science kind of section that we did. I remember some things about weather that I really didn't understand before.* *…I do recall multiple times coming over there and being able to refer to exhibits in papers when I'm talking about his or her plane, or history and periods in aviation. I was definitely utilizing it.*
Interest & engagement	I had experiences that enhanced my school learning by making it more interactive, personal, or memorable. *…it definitely gives you a more in-depth and interactive learning experience when it comes to science. A lot more, I think, than a school setting can give you, since in a school setting… you follow these standards…. A museum doesn't have that restriction.* *…being at The Franklin allowed us to do a wider variety of experiments because they had access to materials that we wouldn't normally be able to get a hold of.*
Career skills & habits	I learned or practiced professional skills and habits like time management, presenting, customer service, or strong work ethic. *Definitely, the three things that I learned from the Museum of Flight would be time management, public speaking, and problem-solving.*
Professional networking	I had opportunities to connect with professionals. *And I learned a lot about networking with professionals in the aviation industry, people who own the businesses around, people who have been in the industry for many years, and just understanding their experiences and their career paths….*

*multiple codes allowed

Q2.7: Why do you think the museum component matters?

It mattered for…	
Content knowledge	I learned specific content related to STEM topics or aviation from spending time in museum exhibits and programs. *I think it does, because the Museum of Flight provides resources for the Aviation High School. They allow us to go over there whenever we want to… try to get information on our research, on our projects that we need to do. …Rather than going to the library, we'd go to the museum, you know?*
Interest & engagement	I had experiences that enhanced my school learning by making it more interactive, personal, or memorable. *It was more personal, the attraction of what we were learning. …I think it's a huge difference between what you can read in a book and what you can actually see… but when you can go to a museum and you can see the exhibit and you can listen to people who actually flew those planes… it kind of brings it to life and you remember it a lot more. I remember so much more from just what docents told me that I would learn reading the book my senior year.*
Professional networking	I had opportunities to connect with professionals. *The biggest thing for me in going to Aviation and that being tied to the museum is all the opportunities to meet people in the industry and speak with them and be able to have, to develop those relationships with those people. And the cool thing about museums is they know everybody.*
Career skills	Museum internships and jobs became first steps to employment and provided a venue to practice career skills. *Most definitely. I think I can speak for the majority of the Aviation High School population when I say that it's because of the Museum of Flight where we have the opportunity to actually go to a business environment and practice the skills that we're taught at Aviation High School…. I know the majority of the kids… start their volunteer and internship program, pretty much start the foundation of their career at the Museum of Flight.*

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It mattered for…	
Sparked interest in informal education	*So I think it is really important, it gives that connection to some sort of career field I didn't even really know existed before. I wouldn't have thought twice about the museum if I hadn't gone to Aviation and learned about it a lot.*
Institutional leverage	Cultivating relationships and networks to further institutional goals, resources, and access for current and future students. *…at least at the starting point, I know that having The Franklin Institute connected to the name of SLA was a selling point for a lot of parents who were still iffy about sending their kids to a completely new high school. But aside from advertisement, I would have to say that being connected to a museum definitely afforded… us better connection to the outside world. …And so the relationship with The Franklin Institute, I guess in summarization, basically helped us expand our aspirations.*

*multiple codes allowed

Q2.8 How has [museum school] contributed to who you are today?

It contributed by…	
Clarifying future goals	Helped clarify or solidify my educational or career trajectories.
Towards STEM	Facilitated my trajectory towards STEM- or aviation-related paths. *When I went to college, the classes were easy and I knew what I wanted to do because I think that museum emphasis really helped me figure out what I wanted to do. So when I got to college, I knew what classes I wanted to take, I looked up all of them.*
Away from STEM	Facilitated my trajectory away from STEM- or aviation-related paths. *…it impacted me in a way where I kind of wanted to know what I wanted to do, career-wise. I knew that I was good a math, not certainly so with science, so it steered me to the right direction and not down the STEM path anymore. So I think it helps people figure out what they want to do in life.*
Towards museums	Facilitated my trajectory towards informal education paths. *…that led to the path when I graduated, become a part-time and eventually full-time educator. So I guess it definitely kept me around the education environment, more so than any informal education environment, more so than just going to high school and then going to college and then going out into the field.*
Fostering confidence	Made me feel supported and confident in my own abilities. *I think it was more the community at Aviation High School that kind of made sure that I was steady on my feet, was really confident, could speak in front of a room, was used to giving presentations. And I think a lot of the times that I was practicing giving presentations or I was interacting with people who were professionals, who were coming in as mentors, or taking trips places, either to the Museum of Flight or to the airport, right?*

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It contributed by…	
Career readiness	Prepared me for networking and applying for jobs. *I was prepared for careers, you know. One of our classes spent a whole section on showing how to do resumes and cover letters. I've done that and gotten a great response from the jobs I've applied to because of that.*
Independent learning	Taught me how to be a self-directed learner and thinker. *At SLA, they kind of teach you how to learn, teach you critical thinking, teach you how to question things, and I would be a completely different person without that.*
Did not specify	Question not addressed.

*multiple codes allowed

Q3.5: Do you see yourself as being a scientist? Why or why not?

See self as scientist?	
Yes, I do.	*Hands down, yes. I am a nerd at heart, and I'm always going to be a nerd at heart. I'm not saying all scientists are nerds, but I love science. Science is one of those subjects where you're never satisfied with just one answer. …It's the scientific method throughout life. And all I try to do is just continue to embrace it in myself because I am definitely a scientist. I live, breathe, sleep in numbers. I think in numbers all the time. I watch documentaries on Netflix about the galaxies and different history and famous individuals in science, Nikola Tesla, all that. I love being informed, and that's what science gets me.* *I think I do. I think a scientist, the description of it for me, is to be creating or doing some sort of science and really, really enjoying it. …before scientist I would probably call myself an education, since that's for the most part what I'm doing at The Franklin, is creating educational content especially for astronomy, to teach other people and kids about not just my love for astronomy, but all the cool things that are going on in it.* *Oh, I absolutely see myself as a scientist. I feel like a scientist is just somebody who takes the tools they have in this day and age and makes something new with it or feel like they can interpret in any kind of way. They have the ability to break something down.* *In the broad, always-experimenting sort of way.* *Yes. …I would say a scientist in training. Because I'm not really certified, I'm not really someone who's a specialist in any specific area of study or called upon to ask engaging questions about the environment. But I am in an environment with a lot of scientists…. So I definitely get to see what industry I need to penetrate and how I can not only be a scientist, but once I become a scientist, I can give back.* *Yes, actually! I remember when I was interviewing for this job, actually, I brought up SLA because they have a lot of the same collaborative and critical thinking values and the scientific method is something that I apply to my life on a daily basis. It's kind of part of my viewpoint and how I look at things.*

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No, I do not.	*As a scientist? No, I don't think I could. Why? I would say that math… and chemistry was not my forte in high school and it's something that just really hasn't come easy to me, but I'm pretty grateful that I discovered that in high school, too, because I thought I wanted to be an engineer and I realized that I really did not enjoy those subjects. It just wasn't fun to me.* *I see myself as a social scientist, I don't see myself as a scientist. I see myself as someone who's very science literate.* *No, because I know that there are other more capable people than I am, and they can actually take the rigorous classes and they have a certain tenacity for those science classes that I don't have.* *Not really. Science has really never been my strong suit. I do really enjoy learning about science at school, learning about anything, really, I find interesting. I think there are science aspects to my life, but I consider myself much more of a teacher or an educator than a scientist.* *No, I don't think so. Ever since my childhood, I haven't really been exposed in a science related field. None of my family members have really been in that field, like engineering or science. It's just, I think I've grown up differently, grown up more business focused and aviation focused, more piloting than engineering.* *I don't really see myself as a scientist, I see myself as more of an engineer. Because I love working with my hands, I love working and building and testing, but as a scientist not so much. …A scientist I think of as someone who knows physics or chemistry, you know, along those lines. They're not really builders. They're more like teachers, and they help people with what they know, they're like a wealth of information what the field is. And an engineer, for me, is someone who is more hands on, and designs and tests, I mean, builds and tests the… projects.* *I don't see myself, I wouldn't call myself a scientist, I don't identify as such. …if I was into the continued research and development of problems and challenges that face our industry today, if I was actively involved in that, I might identify myself as more on the scientist side, but since I'm not, that's not really my goal right now… I identify myself as more of a student.* (continued on next page)

	In the traditional sense, I'm definitely not a scientist because my main field of work doesn't really cross over into the STEM categories. However, I would say that the work that I'm trying to do definitely starts to creep over into at least the basic understanding of what science is. Because I'm starting to do work in a field called digital humanities, which is basically analyzing topics and research and mainly stories through the use of technology… it's a very, very new field, it's still in its baby stages, it's not fully fleshed out yet, so the possibility of being a kind of science is there. It's not quite there yet, though, it's mostly just on the analytical level. But it definitely has a lot of room for growth. So, it's possible, I could become a scientist in a sense in the future. But not quite at this moment.

*single code allowed

Q3.6 Do you think others see you as a scientist? Why or why not?

Others see as scientist?	
Yes, they do	*We're all always trying to find something new, trying to find a new way to do something or see an idea, or someone has an idea and we all just experiment or play around with it.* *I think so. There's definitely a split. Some might view me as a scientist, others might be like, 'He's definitely engaged in business a lot, he's very serious.' But yeah."* *…I believe so many people would agree that I am a scientist, and that I'm always trying to figure out why, why something is, or what I can do to make it what I think it would be. And then if I'm wrong, I'm going back to the drawing board and see where I messed up, and then drawn a different conclusion.* *I think so, because I don't think schools especially do a good job explaining the difference between a scientist and an educator, because it can be kind of a fine line, but a scientist in my opinion would be someone who is either in the workforce doing some science research/building a product using and of the STEM fields, while an educator is someone… like at The Franklin, we're trying to create content that allows kids and people to be engaged, sort of open them up to the different fields of science.* *I do think that my friends see me as a scientist, they see in me that ability to break things down, be methodical with problems, and for that reason… it's a very logical and methodical approach.*

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Others see as scientist?	
No, they do not	*Not really, I don't think. A lot of my classes here [at college] are either business or they're grounds class for flying, so the only science-related classes I'm taking here has been aerodynamics, so far.* *I don't think so, I think they see me more as support, not a scientist per se.* *No, probably not. They see me as a camp counselor or an educator.* *I don't think they see me as a scientist. No, I mean, I don't think other people do. People who are close to me know that I'm more of an engineer since I like working with my hands.* *No, I don't think so.* *No, I've never heard it, so I'd say no. Not at least at this point.* *No. I'm not a scientist in profession or anything like that. I don't know, I think if they said, 'Is [name] a scientist?' they would say no, she's not a scientist, she doesn't do science for her job.'"* *You know what, I think at Aviation High School I was not viewed as a science person. I think at my small liberal arts college, with a lot of other social science majors and English majors, my friends here definitely view me as a science person.* *I would say before they ask me what my major is, they would think of me as a scientist. During the work that I do. But I would say aside from that, probably no.*

*single code allowed

Q4.7-4.12: I'm going to go back through each of the previous statements and provide you with a list of possible influences that might have contributed to that impact. Please rank your top three responses with 1 being the most influential. If none of these contributed or you did not feel that impact, list "none."

I was influenced by…	
Teachers/classroom time	Instructors, lessons, and coursework in traditional school spaces.
Museum exhibit/artifacts	Museum collections, archives, displays, and demonstrations.
Talking to visitors	Engaging museum guests as a volunteer, intern, or employee.
Projects or internships	Hands-on or experiential learning opportunities.
School	Projects were course assignments and occurred in a school context.
Museum	Projects were duties as a museum volunteer, intern, or employee.
Both	Project occurred in a mix of school and museum contexts.
Outside	Project or internship occurred outside school or museum context.
Friends or family	Interpersonal relationships and support of peers or relatives.
Organized activities	Other activities including sports and academic clubs.
STEM activity	E.g. robotics team, Science Olympiad, or ecology club.
Non-STEM activity	E.g. sports or music
Other	Other specific influence.
Networking	Individual mentor or professional networking opportunities.
School culture	Overall atmosphere and culture of the museum school.
None	None of these contributed or impact not felt.

*single code allowed