TEACHING AND LEARNING SCIENCE IN A MUSEUM: EXAMINING THE ROLE OF ATTITUDES TOWARD SCIENCE, KNOWLEDGE OF SCIENCE, AND PARTICIPATORY LEARNING IN AN ASTRONOMY INTERNSHIP FOR HIGH SCHOOL STUDENTS

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ABSTRACT

TEACHING AND LEARNING SCIENCE IN A MUSEUM: EXAMINING THE ROLE OF ATTITUDES TOWARD SCIENCE, KNOWLEDGE OF SCIENCE, AND PARTICIPATORY LEARNING IN AN ASTRONOMY INTERNSHIP FOR HIGH SCHOOL STUDENTS

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This thesis adds to the empirical research foundation of informal science education through an investigation of a museum-based astronomy internship for high school students, in the domains of attitudes toward science, knowledge of science, and participatory science learning. Results are presented as three studies, all using a qualitative methodology and including the methods of semi-structured interview, reflective journal, direct observation, audio recording, and artifact collection.

In the first study, four aspects of attitudes toward science were investigated. Results revealed that interns held mixed views of themselves as scientists, held positive attitudes toward science for four primary reasons, and provided twelve reasons for their pursuit of science activities outside of school. The internship also solidified interns' (largely science-related) careers aspirations.

In the second study, four aspects of scientific knowledge were investigated. After participation, the majority of interns believed teaching was part of the scientific enterprise. Interns also used at least six modes of scientific thought, only one of which was taught explicitly to them. The amount and depth of science content learned during the internship depended on interns' prior knowledge, and was learned during three

specific aspects of the internship. Finally, interns used numerous science concepts during the internship, the most frequent of which were closely related to the internship activities.

In the third study, six aspects of participatory science learning were investigated. Results across the six domains indicated that interns found teaching to be the most salient aspect, viewing it as an authentic practice and a path to science learning, as well as providing a sense of ownership in their practices. Also, interns created a unique community within the internship, combining aspects of the pre-established museum educators' community of practice and an internship-centered activity group.

Looking across the three studies, both teaching and social interactions were found to be underlying factors in many of the results and represent two important concepts to understand this type of internship experience. There is also evidence for the learning of both contextualized and transferable science knowledge in the internship, suggesting further research in this domain.

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I. INTRODUCTION

Go outside on any clear night, look up, and you will see stars (and maybe even a galaxy or two). With universal access to the sky, astronomy is one of those subjects that can excite and amaze us all. Astronomy topics are often in the popular media, and young children as well as adults find them interesting. Even complex concepts such as gravity and light hold sway over many parts of our everyday lives, and these connections seem to bring those faraway stars overhead ever closer. Personally, my passion for astronomy is rooted in the numerous topics that fall under its aegis, and is realized most completely through opportunities to convey my fascination to others. More directly, my interest lies in studying the ways in which young people's attitudes (feelings, behaviors, and thoughts toward) and knowledge of astronomy can be leveraged within informal settings to further develop their lifelong learning.

Building on my personal interests, I believe the importance of time spent outside of school must not be underestimated if the education of our nation's students is to be taken seriously. Children in the U. S. spend only a small percentage of their time in school (~12% by age 18; National Science Foundation, 2006c), and even less time in school science classes. As adults, few have direct exposure to science through formal educational institutions, and those who do are often found within the professional ranks of scientists. Couple the short duration of science schooling with the dismal reports of children's science knowledge arriving from all sectors (e.g., Grigg, Lauko, & Brockway, 2006; National Academy of Sciences, 2006), and the importance of science learning outside of school becomes readily apparent. The scope of this out-of-school learning is immense, varying from everyday experiences to highly organized programs. These experiences often fall under the term "informal learning" within the education literature, but definitions of informal learning are often contradictory and used interchangeably (Colley, Hodgkinson, & Malcom, 2003).

Regardless of the term used, the cumulative impact of informal learning experiences is increasingly recognized as critical to an understanding of learners' trajectories in science (National Research Council, 1996). Many national groups dedicated to science education have shown an increased awareness of informal learning, providing directions for research (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003), highlighting the importance of informal learning environments (National Science Teachers Association, 1998), and establishing groups dedicated to their study (e.g., American Educational Research Association Informal Learning Environments Research Special Interest Group). In addition, the National Science Foundation has established a program to fund development of informal science education projects, and there are an increasing number of journal articles being published on the topic. Despite a growing awareness of the impact of informal learning on an individual's development in science, few studies have looked at the specific effects of informal learning experiences on students (Fadigan & Hammrich, 2004).

Opportunities for self-directed science learning become increasingly prevalent as urbanization provides alternative venues for learning about science (such as museums) and modern communication such as television and digital media expand the range of tools available. Inherent in this attention to informal learning is the assumption that individuals gain a substantial amount of their knowledge and feelings about science from influences outside the science classroom. In the limited number of direct studies on the topic, this assumption has generally held. For example, in his study of 35 research scientists, Rowsey found that 78% said nothing in their formal middle and high school experiences influenced their decision to become a scientist (Rowsey, 1997); whereas, many scientists attribute their initial interest in science to an informal learning experience (COSMOS Corporation, 1998). Thus, it may be true that early informal science experiences play large roles in the development of scientists.

Beyond academia, there is a growing concern over the future of the nation's knowledge-based workforce, and in science-based professions especially (National Academy of Sciences, 2006). There is talk in many places of the importance in getting students, especially minority and female students, into the science "pipeline." One promising point of entry into this pipeline is through museums. Museums provide unique science experiences for kids, ones that may hook them into a science career or, even more likely, a lifelong interest in science. Museums are just one type of institution among many within informal education, and yet they remain an important nexus for science teaching and learning outside of schools; they often offer different types of learning experiences for individuals (both young and old), families, and other groups.

Internships are one possible mode of such informal learning experiences, and this study examines the various effects of a museum-based astronomy internship program on participating high-school interns. In this particular internship, the majority of interns' time and the focus of the program were devoted to teaching science to museum visitors using hands-on activity carts. The focus of this study specifically is to investigate the effects of the program on interns' attitudes toward science, knowledge of science, and the degree to which they engaged in participatory science learning.

In the second chapter, I review the literature on informal learning by simultaneously deconstructing and disentangling previous definitions of informal learning as a means to synthesize a new definition. Focusing on informal learning (as opposed to informal teaching) is appropriate because it encompasses all three of the specific constructs in this dissertation and it provides a lens with which to view the teaching aspect of the internship. I also review the scant literature on astronomy education to provide a meaningful context for the science content highlighted in this study. From the (relatively) broad landscapes of informal learning and astronomy education, I focus in on informal astronomy education and internships to further ground the work in these two fields, before discussing the conceptual framework I adopt for this study. From this foundation in the literature, I provide a context for the research by describing the internship program upon which it is based. This is followed by the final section of chapter two, where I introduce the research questions I seek to address with this study.

For the results section of this thesis, I present three studies that address distinct but related aspects of interns' experience during their summer internship. They are written in a condensed manuscript form suitable for publication in peer-reviewed journals. As such, each of the three studies comprises one chapter formatted in the style of the journal to which it will be submitted, followed by a Discussion Chapter containing a summation and discussion of the three studies as a composite.

II. REVIEW OF THE LITERATURE

Informal Learning

In education, the term “informal” first began to appear in the late 1960s when it was borrowed from anthropologists and researchers in international development. In this first conception, the term was used by museum and environmental educators to try and distinguish the learning they were involved in from the learning taking place in schools (Falk, 2001). In fact, defining informal learning by what it is not (learning within schools) became the status quo for educators in widely varying fields, from adult education, broadly to science education, specifically. Since its initial introduction into the field of education, informal learning has become an increasingly important research endeavor, with almost 150 studies on informal learning identified in a review article by Callahan (1999).

As mentioned previously, informal learning has most often been defined by what it is *not*, typically in contradistinction to formal learning (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; National Science Teachers Association, 1998; Rennie, Feher, Dierking, & Falk, 2003). In this pattern of thought, formal learning is learning that takes place within a school classroom. It often is led by a teacher, has tests or other assessments and occurs in a rigid setting (Knappenberger, 2002). According to this typical definition, informal learning is simply the opposite. Does this mean any learning outside of a school classroom is informal? If this is true, then is setting the only factor in classifying learning as formal or informal? I argue that setting is an essential, but not allinclusive, factor in determining the type of learning occurring, and as Dierking (1991) puts it, ‘‘learning is learning, and it is strongly influenced by setting, social interaction, and individual beliefs, knowledge, and attitudes’’ (Dierking, 1991, p. 4). Thus, learning entails much more than just location, involving a complex set of interactions and negotiations.

Science learning takes place both in and out of school and many instances of learning in out-of-school settings are characterized as “informal.” The catch-all phrase of “informal learning” is used frequently in education literature; however, it is poorly defined, with a plethora of terms used to describe this type of learning. Within the science education literature more specifically, most definitions of informal learning are based on one of the two domains of *context* or *control*. For example, *context*-based definitions include “out-of-school” (Rennie, Feher, Dierking, & Falk, 2003) or “outside the classroom” (National Science Teachers Association, 1998). These definitions are often considered to be socially situated, meaning that learning is viewed as a process of enculturation through interactions with others (Brown, Collins, & Duguid, 1989). In this domain, informal learning is a process that happens between people. In a related strand, definitions based on *control* place the locus of control for learning within the learner, and can therefore be termed “self-directed” (Knowles, 1975) or “free-choice” (Falk, 2001; Rennie, Feher, Dierking, & Falk, 2003). These conceptualizations are closely related to learners’ interests and needs, and are guided by the lens of social constructivism. Even though social constructivism does not treat learners as individuals, it is important to note that learners are likely to enter informal learning environments with expectations different from those for formal learning environments and also different from their peers or family. As such, characteristics of individual learners must be accounted for during any analysis of informal learning.

While these two domains provide an umbrella under which most definitions of informal learning fit, they do not necessarily define its boundaries. In many cases, science learning found within classrooms may have attributes similar to informal learning, as defined by both context and control. For example, talented teachers may be able to foster the type of interactions and student-centered situations usually indicative of out-of-school settings. Therefore, a more clearly specified definition of informal learning is needed beyond definitions that focus narrowly on the domains of context and control. An improved definition should include a more careful combination of terms that clearly sets apart informal learning from other organized ways of learning. In the following sections, I deconstruct and further detail definitions based on both context and control, embedded in a larger perspective of constructivism, in order to develop a practical and theoretically-grounded synthesis of what informal learning means.

Physical Context & Constructivism

Definitions of informal learning based on context are the most prevalent, due to the historical significance of setting and its relation to important learning theories. Specifically, the physical context of learning outside of school first brought the idea of informal learning into the educational realm in the late 1970s (Falk, 2001; Rennie & Johnston, 2004), when researchers and educators realized students were learning outside of school classrooms, whether on field trips to museums or in homes with their families. This type of learning was certainly free (at least in a physical sense) from the conventional forms of learning occurring within the confines of the formalized school system. This development becomes clearer if it is recast in light of the emerging learning theory of the time–constructivism.

Constructivism emerged at around the same time as the term “informal,” as a way to describe the dynamic way learners engage with their environment and draw on prior knowledge to construct new meanings from their experiences. It frequently has been cited as characteristic of learning experiences outside of school. Constructivism describes *how* people learn, in terms of building and incorporating new ideas into a framework of existing ideas. Thus, knowledge emerges as a personal construction of lived experiences. By acknowledging previous conceptions of learners, this theory radically changed the view of the learner as an empty slate upon which a teacher inscribes a body of knowledge, refuting a basic premise of behaviorism. Constructivism also recognizes the physical setting as an important factor in knowledge formation (Duit & Treagust, 1998). Even though setting is recognized as important for learning, definitions of informal learning based on physical context rarely differentiate beyond a simple in-school/out-of-school dichotomy. In science education in particular, early work in the field defined informal learning as “outside the classroom” (National Science Teachers Association, 1998, p. 17), with some groups even using situational terms to directly distinguish this type of learning. For example, both “out-of-school” (Rennie, Feher, Dierking, & Falk, 2003) and “museum” (Ansbacher, 1998) have been used to differentiate this type of learning from that occurring inside of school.

It is notable that a gap of roughly two decades exists between when educators adopted the term “informal” and the early work in science education cited above. This gap is due, not to a lack of work in the field, but to the fact that this was a developing field and researchers and educators were attempting to work through exactly what research and learning meant in various “informal” settings. In addition, much of the research occurring in museums (the center of informal learning research for many years) was atheoretical and not strongly based on established research methods (Ramey-Gassert, Walberg, & Walberg, 1994). On a basic level, the people at the forefront of the research in this field were more concerned with the process of conducting research than with defining a theoretical basis for their work. Also, much of the work served internal purposes within museums and was not published to the broader educational community (Ramey-Gassert, Walberg, & Walberg, 1994).

One important idea that arose out of museum research was object-centered learning. This idea, best articulated by Leinhardt and Crowley (2002), holds that objects are a unique representation of ideas and are therefore centrally important for learning in artifact-based museums (e.g., natural history museums). According to Leinhardt and Crowley, there are four important aspects of objects related to their physical nature. First, physical objects contain a form of information not possible to fully represent in two dimensional form (such as in a photograph or drawing). The resolution and density of this information can take many forms, and is closely linked to the physicality of objects. For example, comparing the magnetic properties of meteoritic samples is greatly enhanced by being able to feel the tug and snap of a magnet hitting an iron meteorite and to feel the lack of such a pull when placing the magnet over a stony meteorite.

Second, the scale of objects is often one of their most salient features. Human-scale objects may provide a sense of accessibility, whereas very large objects may provide a sense of awe. It is often the large-ness or small-ness that museums hope to present in their choice of objects within exhibits.

Third, objects often represent a unique sense of authenticity. Objects are authentic only in relation to a particular culture are therefore dependent on the background of the viewer. Thus, even everyday objects (e.g., marshmallows) may be authentic for particular people (Shuh, 1999).

Fourth, objects are often particularly valuable, either monetarily or otherwise. For example, providing museum visitors an opportunity to see and use an expensive scientific apparatus (such as an infrared camera) may be rewarding precisely because it is too expensive for a lay person to interact with in their everyday life.

Taken together, these four aspects of objects add another important dimension to the physical setting of informal learning and highlight the importance of considering physical factors in such learning.

Social Context & Situated Learning

Besides constructivist aspects of informal learning definitions that focus on physical context, there is also, to a lesser degree, an emphasis on the social context of learning. This refers to the type of interactions occurring during the course of a learning experience. Such interactions play a secondhand role in constructivism because the unit of analysis is the individual. Situated learning theory, on the other hand, attributes learning to the group instead of the individual and focuses on social aspects of learning. Situated learning describes learning as a process of enculturation through interactions with others (Brown, Collins, & Duguid, 1989). Through participation in a community, learners take on improvised roles similar to apprentices (Lave & Wenger, 1991). Thus, the particular interactions that constitute a community modify the type of learning that takes place. For example, Marsick and Watkins (2001) identify incidental learning as dependent on not only the location but the social interactions that occur in that location. They include incidental as a type of informal learning, a form where "people are not always conscious of" the learning taking place (Marsick & Watkins, 2001, p. 25). Their work was in adult education, so they were primarily concerned with learning that occurs in everyday situations. During everyday interactions, adults (and all learners for that matter) are learning through a dialectical exchange of ideas, forming communities of learning. Such communities are embedded in the everyday lives of people and "should be regarded and studied as meaningful learning environments" (Aittola, 1999, p. 1).

In addition to defining the interplay between social situation and learning, situated learning also describes the embedded nature of content knowledge. In formal schooling situations this tends to result in negative consequences, as the content knowledge taught to students is displaced from the place and people creating it. Informal learning environments, while still potentially being distant from the source of the content knowledge, generally allow participants to interact with science content more directly and make the content knowledge their own.

Control, Social Constructivism, & Critical Theory

If informal learning depends on physical and social context, then the type of learning that occurs is strongly based on who controls the situation. One way control is often categorized is by locating the locus of control either internally or externally to the learner. Internal locus of control means control of the context rests within the power of the learner, whereas external locus of control denotes control by an external party (individual, group, or institution). Another way to categorize locus of control is to describe control of the situation by the means or objectives of the learning. If only the former categorization (internal or external) is used, definitions of informal learning tend to focus on how voluntary the learning is. Definitions of "free-choice" (Falk, 2001; Rennie, Feher, Dierking, & Falk, 2003), "self-directed" (Knowles, 1975), and "lifelong" (Roth & Lee, 2003) learning are all based to some extent on internal or external locus of control. If the latter categorization (means or objectives) is added, definitions of informal learning take on different meanings, connecting back to the contextual focus of other definitions (as control of the means of learning is based in the physical and social context). Mocker and Spear (1982) take such a view of lifelong learning, organizing it into four categories based on a two-by-two matrix of the two locus of control categorizations, i.e. 1) Formal Learning: learners control neither the means nor the objectives of learning, 2) Nonformal learning: learners control the objectives but not the means of learning, 3) Informal learning: learners control the means but not the objectives of learning, and 4) Self-directed learning: learners control both the means and the objectives of learning. Thus, informal learning takes place when "learners control the means but not the objectives" of learning (Mocker & Spear, 1982, p. 4).

Definitions of informal learning based on control are connected to ideas of social constructivism and critical theory. Social constructivism pertains to the contextualized and socially constructed nature of learning, whereas critical theory is concerned with power structures and conflict in educational systems. Social constructivism describes locus of control as the center of the interaction in a learning situation, whereas critical theory describes it as the dominant or sanctioned paradigm in a learning situation. One vocal group in science education (led by John Falk and Lynn Dierking) concerned with this type of learning takes a stance guided mostly by social constructivism, viewing informal learning as voluntary and "learning that is primarily driven by the unique intrinsic needs and interests of the learner" (Falk, 2001, p. 7). For critical theory definitions, the focus falls on who is controlling learning and what this control entails for social and cultural paradigms. Burns (2001) defines informal learning in relation to whether learning processes are controlled by institutions within the western paradigm or by non-western "Indigenous knowledge" (Burns, 2001, p. 2). Similarly, work by Calabrese-Barton and Yang (2000) looks at science education outside of school in terms of the "culture of power" (Calabrese Barton & Yang, 2000, p. 873). Their use of critical theory to explore control-based definitions brings into question the intentions (explicit or implicit) of the controlling party. The manner in which these intentions affect informal learning is the subject of the next section.

Social Interactions as Commonality

One common thread through all these definitions and across the two domains is the recognition of social interactions as central to learning. Social interactions act as mediators for learning and are embedded within the historical and cultural frameworks of the learners (Lemke, 2001). This stance, articulated by sociocultural theory, allows the formation of a unified definition for informal learning, taking into account important aspects of the definitions explained above. In this unified view, and taking into account the important aspects of informal learning environments mentioned above, I adopt the following definition for informal learning: *informal learning begins with the motivations, needs, or interests of the individual and is socially constructed in everyday situations beyond the school classroom*. This definition, in addition to being grounded in sociocultural theory, ties in closely with the six facets of informal learning environments identified by the National Association for Research in Science Teaching's "Informal Science Education" Ad Hoc Committee (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003).

An example situation may help elucidate specific aspects of my informal learning definition. The setup is as follows: while demonstrating an activity to a visiting family, a question arises in the mind of an intern regarding the activity. The activity involves placing a marshmallow into a sealed container and then removing the air (subsequently expanding the marshmallow) and is used as an analog for the human body in space. The intern wonders about how spacesuits protect astronauts and devises an experiment to explore her question. She proposes the experiment to her fellow interns who immediately agree it is a worthwhile endeavor, and the group of peers begins the experiment using a zip-top plastic bag as a "spacesuit" for the marshmallow. They try removing the air several times and observe the outcome, concluding that their plastic-bag-spacesuit is no good because the marshmallow still expands when the air is removed. Focusing on the intern who devised the experiment, this example illustrates many of the important aspects of informal learning. In particular, the informal learning began with the individual intern's motivations to better understand spacesuits and the ways in which they protect the human body in space. From this starting point, social interactions played an essential role in the content and process of all interns' (including the individual one of our focus) learning; their learning was also mediated by the physical objects used during their learning experience (e.g., the air pump, marshmallow, and plastic bag) and was therefore linked to the out of school setting. In this process, the individual intern took their learning into their own hands and came to construct a common understanding about spacesuits with a group of peers. Thus, their informal learning about spacesuits started with their own motivations and was socially constructed in a setting beyond the school classroom.

Astronomy

As the oldest science, astronomy has enjoyed many years of its teaching and learning, going back at least as far as 300 B.C. to Alexandria (Crabb, 1928). In the early part of this country's history, astronomy was taught almost entirely in religiously-based colleges (Crabb, 1928) before filtering down to the high schools and academies. It was featured prominently in science classes during the nineteenth century mainly because it was seen as improving a student's "mental discipline" (Hall, 1900; Marché, 2002). However, around the turn of the twentieth century a number of factors conspired to force a drastic decline in the teaching of astronomy at all levels. Some of the most important factors were the emergence of developmental models for human cognition that argued against the "mental discipline" model, the removal of astronomy as an elective in secondary curricula by the National Education Association, the report issued by the Committee of Ten, and the emergence of laboratory teaching and the elective system in higher education (Marché, 2002). As the teaching of astronomy declined, so did the number of students enrolled in astronomy classes (Rorer, 1906). The drop in numbers helped to disperse the content into other science disciplines such as physics and earth science, with the result that most students would come to learn about the subject outside of school. Astronomy has lived on with great vigor in this domain, in outlets such as museums, amateur associations, and observatories.

For the purposes of this thesis, I define astronomy as the study of objects and phenomena outside the Earth's atmosphere. It began as a mostly descriptive field, for many centuries trying to predict and explain the motions of the Sun, Moon, planets, and stars. These descriptions were important for practical and spiritual purposes, such as navigation, agriculture, cartography, and keeping track of the dates of religious festivals; and they occurred wherever evidence of previous civilizations are found (e.g., the Incas in Peru, Chichen Itza of the Mayans in Central America, Chaco Canyon and Mesa Verde of the Anasazi in the American Southwest, Stonehenge in Great Britain, Pyramids of the ancient Egyptians in Egypt, etc.). While it may seem strange to admit, many of the important problems of antiquity are still an open topic of research today, such as predicting and charting the motions of planets and stars. Even though some of the research problems may be the same, the methods, tools, and scope of astronomy have changed a great deal since its inception.

Among the physical sciences astronomy is somewhat unique, as it relies almost entirely on information gathered from outside Earth and it studies phenomena with the broadest and deepest scope imaginable–that of the Universe. I see this as a boon, because it is unconstrained by knowledge produced in Earth-based laboratories and instead calls the natural laboratory of the universe its rightful domain. (It is important to note that other sciences are also "field-based" in this sense and there is also significant overlap between astronomy and other fields of physical science.) Beyond this distinction from its brethren in the physical sciences, astronomy is a unique human endeavor that significantly impacts our culture. First, and maybe most relevant for the purposes of this thesis, people are enthralled by astronomy. The sense of wonder and inspiration it invokes through images and pictures can deeply affect individuals as well as define cultural symbols (Stoeger, 1996). Second, astronomy opens people up to new perspectives outside their everyday experiences (Stoeger, 1996). It reveals ideas such as the (non)uniqueness of life in the Universe as well as the origin of Earth, the Solar System, and the Universe; and in so doing allows us to contemplate our place in the cosmos. And finally, astronomy is part of our cultural heritage and connects us to our intellectual and historical predecessors. For example, astronomy was part of the quadrivium (the most advanced level, taught after the trivium) taught in monastic schools in the ninth century (Crabb, 1928) and was an essential feature of ancient Greek natural philosophy. These intellectual roots to Western society and their ideas are brought forth continually in colleges and universities around the country.

In-school ("Formal") Astronomy Education

Before reviewing astronomy education as it is situated outside of school, I briefly discuss the plight of astronomy education within our nation's schools. Presently, I believe school astronomy is doubly faulted. First, practices in science classrooms are often divorced from the practices of scientists (Barab & Hay, 2001; Brown, Collins, & Duguid, 1989) and second, they are far removed from the everyday experiences of students (Costa, 1995; Roth, 1992). At the elementary and middle school levels, astronomy content consists primarily of topics from antiquity (what I call "basic" astronomy), including seasons, moon phases, and the motions of celestial objects (Palen & Proctor, 2006). The study of such objects and phenomena, while important for connecting to our cultural heritage, does little to reveal the connections to students' lives or the current nature of astronomy as a science (Pasachoff, 2002). Research done by most professional astronomers involves only tenuous connection to the diurnal and annual motions of the sun, moon, and planets and has shifted to the study of processes and compositions.

The situation in U.S. high schools for the teaching and learning of astronomy is little better than in the lower grades. In many cases, astronomy is taught as part of physics or Earth science or is simply not taught at all (as a glance at a random sample of state curricula will quickly reveal). I believe its rightful place in the high school curriculum is either within physics or as a standalone course (both of which occur at the college level), not as an addition to Earth science (which few states even teach). As there are no firm statistics or reports on the amount and content of astronomy teaching in our high schools, it is illuminating to use physics as a (very conservative) proxy for astronomy. This comparison is apt for the following reasons. Within the professional ranks of physics, astronomy makes up less than ten percent of faculty appointments (7%, Ivie, Guo, & Carr, 2005) and enrollments at the undergraduate and graduate level (6%, Mulvey & Nicholson, 2006). Similarly telling, astronomy makes up eleven to twelve percent of the total physical sciences research and development expenditures in the U.S. (National Science Foundation, 2006a). By these measures and in the highly intertwined nature of the two fields based on my academic experience (B.A. in Astronomy *and* Physics and a M.A. in Astrophysics), I believe we can safely substitute physics for astronomy to get a sense of the state of affairs. Doing so reveals the following points: less than a third of all high school graduates take physics (Neuschatz & McFarling, 2003), and the numbers of those studying physics continues to drop through college and into graduate school (Mulvey & Nicholson, 2006). This attrition from the physics “pipeline” reduces not only the number of professional physicists (astronomers included), but also the number of people in the general populace exposed to physics (and astronomy) concepts. Thus, we find the current state of physics education (and therefore also astronomy education) to be lacking in amount, if not in kind.

There is also some evidence that teachers of physics (and astronomy) in high school are unprepared to teach the content, as less than a fourth of all physics teachers majored in physics (Neuschatz & McFarling, 2003). Though of these same teachers, almost 99 percent report being “Very well prepared” or “Adequately prepared” to teach the content. From these two statistics, we are led to believe that most high school physics teachers are teaching content that, in the best situation, they learned in an introductory course in college and in the worst situation, learned in high school. It makes sense then, that at all pre-college levels astronomy content ends up being portrayed as a set of facts denuded of their explanations, historical development, and relationship to other concepts (Trumper, 2006).

I have purposely left out a thorough discussion of undergraduate and graduate study in astronomy, as combined they reach less than 200,000 students every year in their courses and degree programs (Mulvey & Nicholson, 2006). Even though this is a figurative drop in the bucket compared with the number of students reached by K-12 science education every year, such courses and degrees are the only route to becoming a practicing astronomer. Additionally, the number of undergraduate students taking introductory astronomy courses has outpaced enrollments in other introductory physics courses for many years (Mulvey & Nicholson, 2006), and may be the only experience students have in formal astronomy education. I admit that the picture this paints of pre-college astronomy education is a fairly dark one, but there are reasons for hope, found outside of school.

Informal Astronomy Education

Astronomy education in informal learning environments (informal astronomy education for short) occurs in diverse settings and across the lifespan. Institutions such as museums, planetaria, and observatories have some of the most developed programs in informal astronomy education and sometimes have strongly developed connections to professional astronomers. Their astronomy programs vary widely and may include a host of activities, exhibits, community partnerships, workshops, specialized resources, and shows. For example, on November 8, 2006, I watched a Webcast of the transit of Mercury from Kitt Peak Observatory in Arizona on the Exploratorium’s website. This experience brought together an observatory (Kitt Peak) and a museum (the Exploratorium) in a unique partnership to provide an exciting and educational experience for as many people as possible.

Community-based organizations (CBO’s) also host astronomy education events and may hold ties to astronomers or astronomy institutions. These organizations include amateur astronomy clubs, afterschool programs/clubs, scout groups, libraries, and public lectures. Amateur astronomers were once used extensively by professional astronomers to collect observational data (Rothenberg, 1981) and today form a large body (there are at least ten times more amateur than professional astronomers in the U.S.) of eager informal astronomy educators (Storksdieck, Dierking, Wadman, & Jones, 2002) who continue to collaborate with professional astronomers through groups such as the American Association of Variable Star Observers (AAVSO). Their eagerness to discuss astronomy, host “star parties” for the public to view the stars and planets through a telescope, and learn more about professional astronomy make them a useful but underutilized resource within informal astronomy education. Another realm that has not been tapped to its full potential is after-school programs and clubs. After-school programs serve many millions of students every year and are increasingly recognized and studied as places where science learning takes place. For example, a number of astronomy curricula have been developed in conjunction with the National Aeronautics and Space Administration (NASA) for use in after-school programs (Walker, McGlashan, Danly, Hamilton, & Fotiadis, 2005). Also, the newly formed Coalition for Science After School is trying to capitalize on the fun and exploratory nature of after-school programs to produce effective science programs. Libraries play a role similar to after-school programs in that they provide a resource to their community, which most often means stocking their shelves with astronomy books or activities, but can also entail hosting programs in their space. Public lectures, while not exactly an organization, bring scientists and their work into public forums and are often hosted by organizations, institutions, or companies. They are a natural way for those interested in a topic to find out information directly from the source–the scientists themselves. They are usually one-time events and vary greatly in quality and value.

Astronomy learning also takes place within homes, among family members, as well as with various media. The difficulties of studying people in their homes are immense and there are few published studies investigating science practices within family groups inside their homes. In the only peer-reviewed article on this topic, Korpan et al. (1997) found that television and reading provide two of the most frequent activities where science is encountered in the home (Korpan, Bisanz, Bisanz, Boehme, & Lynch, 1997), a trend that seems to be reflected in the adult population as well (National Science Foundation, 2006b). Science activities are not limited to television and reading however, and encompass a wide variety of media such as simple experiments and computers. Clearly there is some interest by families in learning about science at home, and informal astronomy programs have begun to tap into this desire (e.g., the Family Astro program by the Astronomical Society of the Pacific).

Based purely on the small number of astronomers in the U.S., it is rare for people in the general populace to interact frequently, if at all, with practicing astronomers. However, they may see or hear about the work of astronomers in media reports. Astronomy, more so than other sciences, benefits from and excels at producing media-worthy images; rendered more important because these images may be all the exposure to informal astronomy education an individual ever receives.

Internships

Internships for high school students are one frequently utilized but infrequently studied form of informal learning (McComas, 1993), creating opportunities for students to engage in practices outside the decontextualized learning found in schools (Brickhouse, 1994; Collins, Brown, & Newman, 1989). There are numerous types of experience encompassed by the term “internship,” including certain periods within medical school, pre-service teaching programs, and vocational education. Among this broad range of experiences, those within secondary science education are salient for this study. In this domain, internships follow in the apprenticeship tradition and are generally of two types: student-scientist partnership or summer research program (Sadler, Burgin, & McKinney, 2007). Student-scientist partnerships are not generally classified as internships, but they have a common basis with summer research programs in their focus on apprenticeship learning (Sadler, Burgin, & McKinney, 2007) and pertinent literature on these experiences will therefore be included. Generally, student-scientist partnerships place secondary students in contact with practicing scientists for the purpose of collaborating on an existing research project (Lawless & Rock, 1998). As the name suggests, they are designed as a partnership between students and scientists, in an arrangement that is theoretically beneficial to both parties; students get to be involved in authentic science research and data collection and scientists are able to garner a larger data set than would otherwise be possible (often from a larger and dispersed geographic region than the scientist usually works in). These partnerships are often mediated by specialized technology that allows an interface between students, teachers, and scientists. Some examples of exemplary programs are GLOBE (Means, 1998) and Forest Watch (Fougere, 1998).

Summer research programs are most often designed to provide authentic research experiences for secondary or college students, and attempt to allow students to participate as legitimate peripheral participants within working research laboratories or groups

(Sadler, Burgin, & McKinney, 2007). These experiences often include some initial training or introduction period, direct involvement with a scientist (faculty or graduate student) in their research, and some sort of final presentation of the student's research. Results of the peer-reviewed studies on summer research programs highlight the affect of such programs on students' nature of science views (Barab & Hay, 2001; Bell, Blair, Crawford, & Lederman, 2003; Bleicher, 1996; Charney et al., 2007; Cooley & Bassett, 1961; Richmond & Kurth, 1999), scientific content knowledge (Abraham, 2002; Bleicher, 1996; Charney et al., 2007; Cooley & Bassett, 1961), attitudes toward science (Abraham, 2002; Cooley & Bassett, 1961; Stake & Mares, 2001), and science career aspirations (Abraham, 2002; Cooley & Bassett, 1961; Davis, 1999; Stake & Mares, 2001).

As mentioned in the introduction, the central activity of the internship investigated in this thesis was teaching science—a focus that, along with its museum setting, sets it apart from other science internships. As such, it is important to make clear why literature on science internships (in previous and subsequent sections) was chosen to ground this work. There are three related domains that inform this decision: (1) teaching practices within museums, (2) learning science through teaching science, and (3) alignment of this internship with other science "internships" (including both student-scientist partnerships and summer research programs).

First, the literature on teaching within museum-based internships is scant; there is only one peer-reviewed study that explores teaching within a museum internship (Diamond, St. John, Cleary, & Librero, 1987). Even more broadly, there are few studies that explore teaching practices within museums (Tran, 2007), and existing studies focus mostly on the observable behaviors of museum educators during museum tours (Cox-

Peterson, Marsh, Kisiel, & Melber, 2003) and structured field trips (Tal & Morag, 2007). Some of the existing museum programs dedicated to teaching, such as the explainer programs at the New York Hall of Science (Gupta & Siegel, 2007) and Exploratorium, are well-studied internally (e.g., through evaluations) but results have not been published widely.

Second, teaching is viewed as a pathway to science learning in this study and the specific pedagogical techniques used by interns are therefore less important than an investigation of the learning that such teaching may afford interns. More specifically, this internship relied on the power of learning-through-teaching (especially with/to peers), which has been shown to increase learning and/or achievement in domains as varied as medical (Krych et al., 2005; Wong, Waldrep, & Smith, 2007) and nursing school (Secomb, 2008), landscape architecture courses (Wagner & Gansemer-Topf, 2005), and alcohol prevention programs (Padget, Bell, Shamblen, & Ringwalt, 2005). These examples stem from a long tradition of learning-through-teaching, which can be traced back at least as far as Aristotle, who said that "teaching is the highest form of understanding." More recently, Schön (1983) described how teachers learn through engaging in their everyday teaching practices, revealing the importance of reflection for learning. Teaching peers has also been found to clarify and solidify science concepts for students in their science classes (National Research Council, 2005). Taken together, these points suggest that teaching leads to a deeper and more complete understanding of concepts and therefore warrants further investigation.

Finally, aspects of both student-scientist partnerships and summer research programs (the two primary forms of internship within secondary-school science) align with the current internship. As with most summer research programs (Barab & Hay, 2001; Bell, Blair, Crawford, & Lederman, 2003; Charney et al., 2007; Davis, 1999; Etkina, Matilsky, & Lawrence, 2003; Markowitz, 2004; McComas, 1993; Richmond & Kurth, 1999; Stake & Mares, 2001), this internship began with an introductory period during which interns were introduced to their primary tasks, to each other, and to their working environment (the Museum in this case).

This internship was also similar to both summer research programs and student-scientist partnerships in that it provided an opportunity to engage in science as a legitimate peripheral participant. In the case of summer research programs and student-scientist partnerships, legitimate peripheral participation entails an engagement with scientists in a way that is meaningful for the scientist's work (legitimate participation) and supports the central activities of the scientist's work (peripheral participation). In the case of the current internship, students engaged in activities (teaching science to Museum visitors) that were meaningful for, and which supported and enhanced the already-existing activities of, the Museum educators. Thus, legitimate peripheral participation links the current internship to other secondary science internships (i.e., student-scientist partnerships and summer research programs) even though the central activities of these internships vary (from engaging in scientific research during a summer research program to teaching science in the current internship). In the broadest sense, legitimate peripheral participation entails an important, but not central, role in a community of practice and implies a movement towards the center of that community (Lave & Wenger, 1991). For example, as a graduate student progresses through their program and becomes more familiar with the practices of their field of study, their activities may shift from those entirely prescribed by their advisor (e.g., analyzing already collected data) to the creation of a novel study of their own design. In the current internship (as well as student-scientist partnerships and summer research programs), the brief nature of the experience allows for little movement away from the periphery and students therefore remain peripheral participants for the entirety of their experience.

Attitudes toward Science

In the literature examining attitudes toward science there is a dichotomy between students' general attitudes towards science and their attitudes towards school science specifically, with students often feeling favorably towards science as a discipline but unfavorably towards it as an object of study (Osborne, Simon, & Collins, 2003). Some of the earliest work in attitudes toward science were a delineation of six affective behaviors laid out by Klopfer (1971): (1) the acceptance of scientific inquiry as a way of thought, (2) the adoption of "scientific attitudes", (3) the development of an interest in pursuing a career in science or science related work, (4) the manifestation of favorable attitudes towards science and scientists, (5) the development of interests in science and science-related activities, and (6) the enjoyment of science learning experiences. Klopfer's goal was to provide a means to evaluate school science programs, and attitudes toward science were just one aspect of the entire evaluation scheme. From this early work, the study of attitudes toward science has grown greatly, and yet is still "poorly articulated and not well understood" (Osborne, Simon, & Collins, 2003, p. 1049), just as it was in the late 1960s (Klopfer, 1971). There has been a recent push though, to delineate aspects of attitudes toward science and construct a more valid and robust concept (e.g., Kind, Jones, & Barmby, 2007).

As an informal learning experience, internships may affect specific aspects of attitudes toward science, including the degree to which students feel like a scientist, desire to pursue science as a career, hold positive views of science, and desire to pursue science activities outside of school.

While not often an explicit goal of internships, the degree to which students feel like scientists is an important aspect of their overall attitudes toward science. In the GLOBE student-scientist partnership for example, the relevance and authentic nature of the data students collected was one of the most salient aspects of the program, and made them feel like they were “real scientists” (Means, 1998, p. 100). Fougere (1998) found similar results with her students’ involvement in the Forest Watch program. In another study of student participation in the Forest Watch program (among others), Moss, Abrams, and Kull (1998) found that students did not end up feeling like scientists, primarily due to lack of exposure to authentic science practices, almost no sense of partnership by students, and little direct contact with scientists.

The chance to engage in authentic science practices and feel like a scientist is also important for students in summer research programs, especially those that allow students to engage in legitimate science practices. In one study of a seven-week research apprenticeship, Richmond and Kurth (1999) found four dimensions of scientific practice and culture in which students began to identify themselves as scientists, including technical language, collaboration, uncertainty, and inquiry. They also found those students developed deeper and richer self-conceptualizations in these dimensions over the course of the internship, and therefore began to develop a sense of themselves as scientists.

A logical step after students feel like scientists is for them to want to become scientists, and an increased desire to pursue a science-related career is one of the most well-documented results of science internships. In studies of summer research apprenticeships, evidence suggests that such experiences may affect career aspirations in science through strengthening existing or creating new science career goals (Abraham, 2002; Cooley & Bassett, 1961), and maintaining these goals through college (Davis, 1999; Helm, Parker, & Russell, 1999), as well as an expanded knowledge of career options within science (Stake & Mares, 2001). In addition, such research experiences may affect the actual career selection of participants into science-related careers (Davis, 1999; Markowitz, 2004).

Internships have also been found to positively alter students' views of science and scientists. In one study of a two-week summer science program, the attitudes of the middle-school students who participated were found to remain more positive than their peers who did not participate (Gibson & Chase, 2002). In similar studies of summer research apprenticeships, Abraham (2002) and Cooley and Bassett (1961) found similar changes in students' views of science, as well as more positive views about scientists. These changes in attitude are notable not only in light of the short length of the internship programs but also because their method of pre- and post-test measures may have missed significant changes in students' attitudes (Stake & Mares, 2001), and thus the actual gains may have been even more significant. In a longitudinal follow up study of another relatively short summer program, Markowitz (2004) found that students generally felt more positive about science after their participation in the program.

Another way internships may affect students' attitudes toward science is by sparking an interest in other science activities outside of school, thereby increasing their participation in informal science programs. Specifically, after participating in summer research programs, students were found to pursue more in-depth study of their research topic or related laboratory assistant work (Markowitz, 2004), as well as beginning to view roles for non-scientists within science and a plan to pursue such roles (Abraham, 2002).

Knowledge of Science

An underlying assumption of most science internships is that students will gain some knowledge of science, either as conceptual knowledge or knowledge of the nature of science (NOS). Many studies have shown gains in some aspect of NOS views after participating in an internship (Barab & Hay, 2001; Bleicher, 1996; Charney et al., 2007; Cooley & Bassett, 1961; Richmond & Kurth, 1999), while others have shown little or no gains (Bell, Blair, Crawford, & Lederman, 2003). One aspect of students' NOS views not studied thus far is the role of teaching in the scientific enterprise. In the single study of a science internship based on teaching science, Diamond, St. John, Cleary, and Librero (1987) did not assess whether participants believed teaching was a part of the scientific enterprise, but did find that learning to teach was one of the most salient effects on participants. The type of communication teaching entails is often described within discussions of scientific discourse, and is not included in NOS discussions.

Student gains in science content knowledge also show mixed results in the literature. In a recent well-designed study of a summer research apprenticeship, Charney, Hmelo-Silver, Sofer, Neigeborn, Coletta, and Nemeroff (2007) found significant gains in biology content knowledge of interns. However, not all interns exhibited equal cognitive gains, and Bleicher's (1996) case study of an intern in a similar program calls into question the depth of such learning. There is also evidence that students who do develop a deeper understanding of science content in a research apprenticeship do not develop critical thinking skills (Hay & Barab, 2001). These few studies illustrate the paucity of evidence supporting cognitive gains in science as a result of participating in science internships, and lead us to question the ability of internships to significantly alter students' knowledge of science.

Participatory Science Learning

Barab and Hay (2001) laid out six characteristics of participatory science learning experiences that describe essential characteristics of science learning in internships. The six characteristics are (1) learners do domain-related practices to address domain-related dilemmas, (2) scientific and technological knowledge/practice are situationally constructed and socially negotiated, (3) learning is participatory, occurring "at the elbows" of more knowledgeable others, including teachers, scientists, and peers, (4) practices and outcomes are authentic to and owned by the learner and the community of practice, and are in response to real-world needs, (5) participants become a part of (developing an identity as a member of) a community of practice, and (6) formal opportunity and support for both reflection-in-action and reflection-on-action (Barab & Hay, 2001).

These characteristics provide a conceptual and evaluative framework for defining the degree to which interns engage in participatory science learning. It should be noted that these characteristics were developed by synthesizing research related to apprenticeship learning, sociology of science, and K-12 science education. While not all the synthesized literature is applicable to internships (K-12 science education literature in particular), I believe there are three reasons why the resultant six characteristics accurately describe the types of experiences occurring in internships. First, these characteristics rely heavily on the theoretical notions of situated learning and the subsequent concept of communities of practice. Communities of practice provide a useful framework for understanding the (inter)actions within groups of learners typical of internships, as they form an ingrained system to learn from during internship experiences (Lave & Wenger, 1991).

Second, these characteristics acknowledge the central role of social interactions in creating lasting science learning. In the available studies of internships in which students engage in authentic research, the analyses and program designs rarely focus on the social interactions that occur among interns and other participants, despite the fact that these social components often have the most significant impact on students (Abraham, 2002; Diamond, St. John, Cleary, & Librero, 1987; Richmond & Kurth, 1999). These interactions may serve a variety of functions, including the construction of scientific knowledge and practices (Barab & Hay, 2001).

Finally, the common thread of social interactions within all six characteristics aligns well with my definition of informal learning (*learning that begins with the motivations, needs, or interests of the individual and is socially constructed in everyday situations beyond the school classroom*). More specifically, the idea of learners' practices and knowledge being socially negotiated (characteristic number two) is explicit within my definition of informal learning and is also an underlying idea in the other five characteristics.

Conceptual Framework: Sociocultural Theory

Sociocultural theory combines aspects of social constructivism and critical theory, addressing both the situated construction of knowledge and issues of power relations inherent in educational settings (Lemke, 2001). This theory recognizes that learners bring their own subjectivities and cultural perspectives to every situation, and in particular to their construction of knowledge (O'Loughlin, 1992). Recognizing the social nature of learning and taking this a step further to expose the hidden social structures within educational situations is where sociocultural theory moves beyond the ideas of constructivism. This type of recognition is incredibly important for analyzing learning within schools because schools are a primary method of cultural reproduction and therefore schools can end up being "sites for reproducing societal inequalities" (Burns, 2001, p. 2). However, the inequalities exacerbated within schools can just as easily be played out within informal settings outside of school, so this type of power relationship must also be examined in these settings, lest unintended consequences of the learning turn into further inequalities. Many informal learning environments may, however, avoid some of the biases inherent within formalized schooling. For example, even though museums create exhibits with certain goals in mind, every person who interacts with that exhibit may learn something completely different from it, and in fact, individuals often seek out different types of experience within an exhibit (Falk & Dierking, 1992). Thus, museums provide a more malleable learning situation for individuals and therefore may provide more opportunities for those without power to participate in the culture of power. Designing exhibits to make explicit their underlying viewpoints and worldviews may support opportunities for all people to interact with and understand the culture of power. For example, providing clear explanations of the epistemological basis of scientific knowledge and the process by which that knowledge is created may produce additional opportunities for individuals to understand and evaluate the knowledge contained within science exhibits.

Sociocultural theory has been indicated as the most valid learning theory for research into informal learning environments for its focus on the context of learning (Rennie, Feher, Dierking, & Falk, 2003), and it has been incorporated into recent studies in this domain (see e.g., Grindstaff & Richmond, 2008). One important aspect guiding this research is the fundamentally contextualized nature of knowledge construction. For example, the actions of a lone scientist working to solve a vexing problem can only be understood in their relation to the larger social organizations of which they are a part (Latour & Woolgar, 1986). Without these larger institutions the scientist would not be a scientist at all; they would lose the definition and structures guiding their work without the practices, beliefs, knowledge, and values inherent within the institution (Kuhn, 1962). Analogously, a valid and comprehensive discussion of student learning in informal settings must take into account the context in which the learning takes place (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003).

Another important idea within sociocultural theory is the idea of practice. Practices are those activities or skills that define a particular type of learning experience, in both informal and formal learning environments. Practices are generative of learning in the sense that when an individual engages in an activity within a particular environment, their learning is linked directly to their engagement in that activity. In other words, learning is viewed not as internalization of external fact, but as a changing set of relations with the learning environment, mediated by activities (or practices) within that environment (Lave & Wenger, 1991). In this view, practices are usually social in nature, either in a direct negotiation with other people (e.g., a discussion between individuals) or in a more indirect negotiation with the sociohistorical framework that constitutes the learning environment (Latour & Woolgar, 1986).

Research Questions

This study seeks to investigate three central questions. First, *in what ways are high-school students'* ***attitudes toward science*** *affected during their participation in a museum internship program focused on learning and teaching astronomy?* This question directly addresses the construct of attitudes toward science, and is exploratory in nature. Within this broad construct, and based on literature related to attitudes toward science and internships, I have identified four questions of specific interest to this study: (1) How do interns describe feeling like a scientist?, (2) To what extent are interns' career aspirations affected by the internship?, (3) In what ways do interns feel positively about science?, and (4) Why do interns want to pursue science-related activities outside of school?

Second, *in what ways are high-school students'* ***knowledge of science*** *affected during their participation in a museum internship program focused on learning and teaching astronomy?* Based on the internship literature and the nature of this internship, I created four sub-questions: (1) To what extent do interns believe teaching is part of the scientific enterprise?, (2) What evidence is there of interns using scientific modes of thought?, (3) Through what aspects of the internship do interns acquire science knowledge?, and (4) What science concepts do interns use most frequently during the internship?

The third and final primary research question is, *do interns engage in participatory science learning (from an apprenticeship perspective) during their participation in a museum internship program focused on learning and teaching astronomy?* This question probed the degree to which interns engage in participatory science learning, as defined by Barab and Hay (2001), and can therefore be further delineated into the following six sub-questions. Since there are, in some cases, multiple meanings within the educational literature for terms used to describe participatory science learning, these questions require additional explanation.

1. *To what extent do interns believe they engage in authentic, or "real," scientific practices?* Essentially, this question is meant to explore the extent to which interns believe they engage in authentic practices. By authentic practices, I mean those activities that are unique or specialized for this internship experience and which are motivated by

issues within the internship. Thus, authentic practices are defined by the intern(s) and those involved directly in the everyday aspects of the internship (e.g., Museum staff).

2. *In what ways are scientific knowledge/practice situationally constructed and socially negotiated?* This question explores the ways interns engage in scientific practices with others in the internship. Two important practices within science are discourse and argumentation (Warren, Ballenger, Ogonowski, Roseberry, & Hudicourt-Barnes, 2001), and those types of practice should be an important part of interns' work on the activity carts. Thus, I will look for evidence of interns discussing or using argumentation strategies with science topics related to the internship while working.

3. *Does interns' learning occur "at the elbows" of teachers, scientists, and peers?* Based on the idea of cognitive apprenticeship (Collins, Brown, & Newman, 1989), the idea of learning "at the elbows" of others can be rephrased as "learning as an apprentice." Thus, I will be looking for evidence of interns moving from novices to experts through supported/scaffolded work, slowly working their way to autonomous work.

4. *How do interns feel ownership of their internship practices?* If interns feel their daily practices while working in the internship are ones they can identify with, are proud of, or "take up," then they could be said to be feeling ownership of their practices.

5. *In what ways do interns become part of a Community of Practice?* Aspects of communities of practice that will provide evidence for this question include becoming more skilled at the internship practices, perceiving their role as legitimate within the larger community, and feeling like they are becoming part of a community.

6. *How do interns use both reflection-in-action and reflection-on-action?* Given that the internship had a built-in mechanism for reflection-on-action (the reflective

journal), I will investigate the ways interns used this resource for reflection. Also, I will look for instances of the interns engaging in reflective discussions (or other types of reflection) while working on the activity carts as evidence for reflection-in-action.

III. METHODS

Internship Description

One of the leading institutions for science learning in the informal realm, the American Museum of Natural History (hereafter "Museum") has been dedicated to education since its inception in 1896. It currently introduces over 500,000 students and 6,000 teachers to its vast collections each year. The Museum is unique in the way it serves as both an educational and research institution, with scientists often involved in both primary research and education. In this way, scientists often act as educators – creating a specialized group of scientist-educators. There are numerous educational programs at the Museum, from one-hour workshops to year-long professional development programs. The Saltz Internship Program is one of these many programs, and is the focus of this thesis.

As both an internship and an informal learning experience, this internship was unique in its treatment of high school students as both learners and teachers of science. The goals of the internship were multifaceted and radiated from the central object of the internship: three hands-on activity carts (hereafter "carts"; see Figure 1). These carts included numerous hands-on, participatory experiments and demonstrations illustrating various ideas found in the Museum halls, themed broadly around the topics of light, telescopes, and planets. These themes were chosen not only to highlight aspects of the Museum halls but also because many of the underlying concepts are fundamental to astronomy in particular, and to science in general. For example, the light cart explored two different wavelengths of light that human eyes cannot see–infrared and ultraviolet. Because almost all information astronomers use for their research comes in the form of electromagnetic waves, providing the public with some insight into the non-visible portions of the electromagnetic spectrum is essential to forming a deeper conceptual understanding of astronomy. Similarly, the telescope cart was meant to develop visitors' understanding of the tools astronomers use to gather information about the universe. With the use of lasers, prisms, and mirrors, the carts were used to describe and demonstrate various configurations of telescope and let visitors interact with these setups. The planet cart helped visitors explore the ways astronomers have developed their understanding about various celestial bodies within the Solar System. For example, a cratering activity helped visitors discover and alter important variables related to impacts between solid bodies and then apply their knowledge to a three dimensional Moon model located in the Museum hall.

Other connections between activities on the carts and exhibits in the Museum halls were even more explicit. For example, an activity on the planet cart helped visitors feel and test (with a magnet) the difference between stony and iron meteorites, before taking their magnet over to the 15 ½ ton Willamette meteorite located prominently in the Hall of the Universe. Guided by interns, visitors could check for themselves that the Willamette meteorite was similar to the small iron meteorite sample and unlike the stony one. Similar connections with Museum exhibitry were made at both the light and telescope carts.

The carts provided a basis for other internship activities and a touchstone for interns' interactions with the public, peers, Museum scientists, and program staff. Each of the carts accommodated two interns behind their semi-circular swath, with space on top reserved for the various hands-on activities stored inside the cart (each cart had three to five primary activities to choose from). Some of the carts had specialized equipment used to explore their specific science topics. For example, the light cart had an infrared video camera mounted to a post on the top of the cart, linked to a monitor on the same pole so visitors could "see" themselves in infrared light (see Figure 1).

Figure 1. Picture of the "light" activity cart. Notice the infrared camera and monitor attached to the vertical pole on one side of the cart. Each cart could fit two interns comfortably behind them. They were mobile, but could be locked in place during use.

During regular Museum hours, all three of the carts were placed on the periphery of the (roughly circular) Hall of the Universe, each separated by less than 20 meters. The Hall of the Universe has exhibits on important topics within astronomy, such as planets, stars, and galaxies. Many of the exhibits in the hall are text-based, and the carts were designed specifically to complement these exhibits by providing a hands-on component.

The internship took place over the course of seven weeks during the summer of 2006. The first week was used to train interns, with the remaining six weeks encompassing the main body of the internship. During the training week, interns participated in three types of activities. First, interns were introduced to practical aspects of working at the Museum. This involved going over Museum rules and regulations, getting to know their way around the Museum's extensive halls (through tours and scavenger hunts), providing them with access to the Museum, and describing the important structures of the program (e.g., signing-in procedures and writing reflective journal entries). Second, an outside consultant began a six-step career exploration program with interns, which continued throughout the remainder of the internship. Specifically, interns spent two and a half hours during one day of their training week to reflect upon and discuss their "self-portrait," including their likes, dislikes, skills, challenges, and the type of environment in which they enjoyed working. After constructing this "self-portrait," they compared it to the set of skills they believed to be important for careers in which they were interested. For example, if an intern wrote that they enjoyed taking apart televisions and then put advertising for a career, they might find their "self-portrait" misaligned with their career interests. After taking a substantial amount of time to reflect individually, interns discussed their responses with the rest of the group.

The third, and most important, aspect of the training week was an introduction to the activity carts. This process was designed to closely follow the stages of cognitive apprenticeship (Collins, Brown, & Newman, 1989). First, interns were introduced to the carts' activities by program staff, who provided a manual describing the important aspects of each cart. The manual included a setup checklist, detailed descriptions of each activity on the cart (including instructions, a "challenge" question for visitors, connections to the Museum halls, and a fact sheet), a shutdown checklist, and tips for operating the cart. With the manual in their possession, interns followed along as program staff demonstrated the operation of each cart. This introduction provided interns with a model of best practices and appropriate pedagogical strategies for each cart.

After best practices were modeled for them, interns were given time to freely explore each cart's activities, supported by program staff and two of the previous year's interns. This guided exploration, lasting almost an entire day, afforded interns an opportunity to try out each activity with the help of program staff and without the pressure of interacting with Museum visitors. Following the guided experiences within the relative safety of the intern group, interns worked directly with visitors in groups of four or five for short periods, monitored the entire time by program staff. The practice time with visitors (in small groups) marked the conclusion of the training week, and interns started the following Monday with the weekly schedule they followed for the subsequent six weeks. See Table 1 for a summary of the training week schedule.

Table 1

Training week schedule.

	10:00-12:00	**1:00-4:00**
Wednesday	Welcome • Welcome, Forms, Rules	Introduction to activity carts: • Pedagogy/philosophy of activity carts

	• Motivational Talk by previous interns • Scavenger Hunt • Receive Museum badge	• Inquiry activity • Introduction to activity carts • Questioning techniques • Creating an observation form
Thursday	Welcome, announcements, check in Get to know the Museum halls	Learning the individual activity carts • Distribute manuals for each cart • Model instruction at each cart • Words of wisdom from previous year's interns • Rotate through activities • Practice time
Friday	Practice session: Continued from yesterday, groups should rotate among carts, taking turns presenting to each other	Career exploration begins: Create "self-portraits" and discuss
Saturday	Connecting the activity carts to the Museum halls	Procedures and Practice: • Walk through set up procedures • Practice with visitors • Walk through shift change • More practice • Walk through shut down • How to use the journal and figure out your work schedule

Each of the six working weeks of the internship began with a "seminar day" on Monday, devoted to community building, learning science content, and exploring career paths. Sometimes the science content was taught by Museum scientists, who are somewhat unique in their dual role as practicing research scientist and educator. In this sense, interns were exposed to a unique subset of scientists. During the career exploration portion of the seminar days, interns learned about possible careers within the Museum, interviewed Museum staff, and rehearsed and presented a final presentation on possible Museum careers. The remainder of each week was dedicated to paired two-hour shifts, requiring interns to complete a total of eight hours of time each week working on the three activity carts (see Table 2 for a visual summary of a typical week of the internship).

Table 2

Typical internship week.

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Seminar Day: Hear talk from Museum scientist and participate in career development	10:30-12:30: Work on "Planet" cart 12:30-2:30: Work on "Light"	2:30-4:30: Work on "Telescope" cart	2:30-4:30: Work on "Planet" cart	Off	Off	Off

program	cart

Note. This schedule is meant to illustrate one possible schedule for a week of work (not including the training week) and is not indicative of every intern's schedule.

Population

In 2006, eighteen interns participated in this study. These eighteen interns were demographically heterogeneous, representing at least eight different ethnic groups (including Chinese-American, African American, Liberian, Hispanic, Romanian, Indian, and Caucasian American), multiple socioeconomic groups, and diverse geographic regions of New York City. The interns represented all five boroughs of New York City and their overall heterogeneity was representative of New York City as a whole. Interns also came to the internship from all types of public high school, including specialized schools for science. At the beginning of the internship, the youngest was 15; while the oldest was 18. It should be noted that two of the eighteen interns had participated in the internship during 2005 and were returning for a second year.

My Role in the Internship

During the primary study year, in 2006, I acted as a researcher with almost no involvement in the instruction or management of the internship. This role was different from the previous, pilot, year (2005; when I was the program director) and allowed me to interact with the interns in numerous settings. More specifically, my role as a researcher provided opportunities to interview and observe the interns without them being concerned about the repercussions of disclosing information to me. I was introduced during the training week as a "researcher," although the two returning interns knew me from the previous year as the program director. During my introduction (at the request of program staff), I highlighted the importance of understanding the effects of the internship program on the interns.

Having been the program director the previous year, I was occasionally called upon by the program staff to help. For example, during the training week I led tours of the Museum halls. This type of involvement was confined to a few isolated incidents and the majority of my interactions with the interns were while I was acting as a researcher (e.g., discussing their experiences during an interview).

Research Methods

The three studies included in this thesis are mixed-methods qualitative studies based on comparative case-studies, using archival data. Case studies are built upon five methods chosen to maintain thorough and comprehensive descriptions of possible impacts. This methodology is based on the idea that there are a multitude of factors that influence individuals and groups of people, therefore dictating a complex and multi-faceted analysis lens (Cambell & Fiske, 1959; Keeves, 1998). Specifically, I combined observations and audio recordings of intern-visitor interactions while working on the activity carts, interns' reflective journal entries, three different types of intern-generated artifact, and interviews to form layered descriptions of the numerous ways interns were affected by the internship experiences. While the resultant descriptions focused on interns' attitudes towards science, knowledge of science, and participatory science learning, the research methods cut across constructs and were used to build a holistic description of the internship's pattern of influences. In this way, there is not a one-to-one mapping of method to construct; rather, each method contributed one or more pieces to the overall description of the internship's influences on the participants.

Within the framework of a mixed-methods approach, I now describe the specific research methods I used in this study. See Table 3 for a summary of the methods.

Direct Observation (Field Notes)

One of the primary methods used in this study was the ethnographic method of direct observation. This method was used to generate field notes, following the conventions of Lofland and Lofland (1984). Observations were made during interns' work on the activity carts, when I acted as an outside observer. From these observations, I constructed descriptive field notes describing the chronological series of events observed between intern(s) and museum visitor(s). It is important to note that these field notes describe only interns' experiences on the activity carts and are not therefore a comprehensive description of the internship experiences. They include contextual background (e.g., time of day, relative number of visitors in the Museum hall, other relevant physical factors) and a running commentary on the interactions between intern(s) and visitor(s) primarily, but also secondarily the interactions between interns.

Audio recordings

During their time working on the carts, I used a digital voice recorder to record thirteen separate instances of interns' interacting with visitors. I selected pairs of interns randomly over the course of the internship and recorded their conversations with

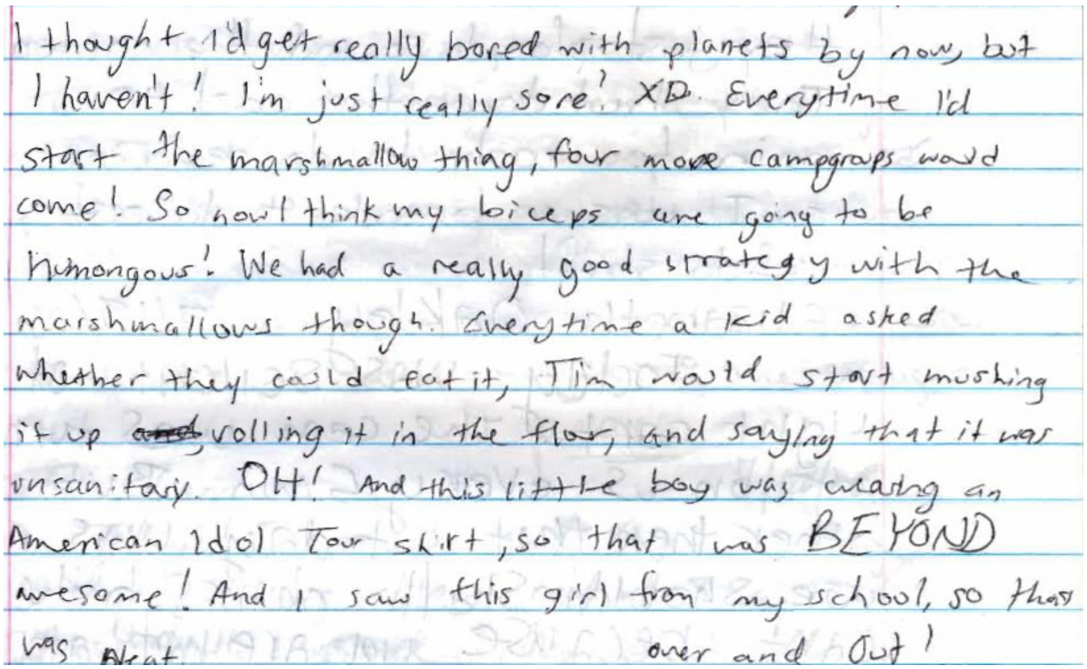
Museum visitors for five to twenty five minutes at a time. The recording time depended on the number of visitors and the natural daily variation within the Museum hall, with longer recording times corresponding to more visitors and therefore longer visitor-intern interactions. Shorter recording times corresponded to fewer visitors and therefore shorter interactions between visitors and interns. As interns worked in pairs on the carts, the audio recordings captured interactions between all combinations of intern(s) and visitor(s); e.g., individual intern with individual visitor, intern with intern, etc. These audio recordings were done while I was taking down observations, and they are therefore paired with the field notes.

Reflective Journal

This thesis used a daily reflective journal as a naturalistic research method. The journal was a part of the interns' daily ritual, in which they were required to write an entry after each shift, reflecting on their experiences that day or describing general thoughts pertaining to the internship. Depending on the number of shifts they worked each day, interns wrote two to four entries per week, resulting in an average of thirteen entries for each intern over the course of the internship. Interns' journal entries span the six weeks they worked on the activity carts, and the resulting public journal is 109 pages. The journal was kept as a public document to which all interns had access and which they were encouraged (but not required) to read. For a sample journal entry, see *Figure 2*.

Figure 2. Sample journal entry. This particular entry was written after a week of working on the carts, and highlights one of the many practical strategies interns developed to work

with Museum visitors. It also is indicative of the type of language interns used when writing journal entries.



I thought I'd get really bored with planets by now, but I haven't! I'm just really sore! XD. Everytime I'd start the marshmallow thing, four more campgroups would come! So now I think my biceps are going to be humongous! We had a really good strategy with the marshmallows though. Everytime a kid asked whether they could eat it, Tim would start mushing it up ~~and~~, rolling it in the flor, and saying that it was unsanitary. OH! And this little boy was wearing an American Idol Tour shirt, so that was BEYOND awesome! And I saw this girl from my school, so that was neat. over and Out!

Interviews

Semi-structured interviews were conducted (and the audio digitally recorded) with eleven interns during the fifth and sixth weeks of the internship. The eleven interviewees were selected as a representative sample of the entire group of eighteen interns, based on demographics (age, ethnicity, sex) and level of science background (i.e., selecting interns both with little science background and with extensive in- and out-of-school science experiences). The interview protocol was developed specifically for this study using the process model (Chatterji, 2003), with the majority of questions aligned with the framework of participatory science learning by Barab and Hay (2001). Additional questions were designed to probe interns' attitudes toward science as well as the social aspects of the internship, which may be one of the most important aspects of internships (Abraham, 2002; Diamond, St. John, Cleary, & Librero, 1987; Richmond & Kurth, 1999).

In addition to the semi-structured interview conducted with eleven interns, a second, follow-up, interview was arranged with one intern at her request. This follow-up interview occurred two weeks after her initial interview and was much less structured than the initial one. It was arranged because she expressed a desire to describe her internship experience in more detail and to follow up with some of the ideas discussed in the initial interview.

See Appendix for a listing of the (initial) interview questions.

Artifact collection

I collected various intern-produced documents over the course of the internship to provide a more comprehensive description of interns' characteristics, and to triangulate analyses with the other methods. These documents provided demographic information, contextual descriptions, as well as intern-generated narratives. Documents collected included internship applications, reflections done as part of the career exploration program, and end-of-internship evaluations. It should be noted that interns' applications were submitted for one of two separate programs that were eventually funneled into a single internship, and therefore the applications of accepted interns are not uniform in format.

Table 3

Summary of research methods and data coverage.

Method	**N (# interns)**	**When**	**Number/Frequency**
Direct Observation	11	Weeks 2 & 4	Nine total sets of observations of interns working on carts
Audio Recording	11	Weeks 2 & 4	Twelve total audio recordings of interns working on carts
Reflective Journal	18	Weeks 2-7	109 pages of written entries, interns wrote every day they worked
Interviews	11	Weeks 5-7	12 interviews, 1 of which was a follow-up with an intern
Artifact Collection	18	Pre-internship, Weeks 1 & 7	Applications, career reflections, and final evaluations for all interns

Note. The 11 interns sampled for the direct observations are the same 11 as in the audio recordings. However, the 11 interns interviewed are a separate subsample (although there is an overlap of five interns between the two methods). There are seven weeks total in the internship, and week one is the training week.

Data Analysis and Reduction

To maintain the strength of a mixed-methods approach and to triangulate results across methods (Mathison, 1988), results arising from the data analysis are grouped in this thesis according to the three primary research questions and therefore comprise three distinct manuscripts presented in the Results Chapter. As this is a qualitative study with various types of data, I used qualitative data analysis software (ATLAS.ti) to develop and apply coding themes. In general, these coding themes were emergent from the data, but were based on the framework provided by the research questions. The themes were developed in three phases. First, I scanned (read or listened) through all the data to become re-familiarized with them and to form first impressions regarding their content. Second, an inductive (open) coding of the data was performed to establish themes across and within methods. This inductive coding was followed by the third step of re-analyzing the data using the emergent themes as a guide. The final resulting themes allow for comparison across cases and comprise the majority of the results. Each resulting theme has, as its evidentiary basis, a set of linked tags that correspond to quotes (written or oral), drawings, or other combinations thereof. These sets of quotes and drawings are used to support the themes resulting from the analysis as well as providing support for issues argued within the discussion.

Reliability

The reliability of results presented in this dissertation was enhanced through four techniques (as explicated in LeCompte & Preissle, 1993). First, I provided a full description of my role in the internship to clearly identify my status within the group of interns. Thus, results should be understood from my viewpoint as a researcher with special access to the participants and with a unique understanding of the program (having been the program coordinator the previous year). Second, the data gathered from interns was representative. Specifically, data sources were either collected for all interns (artifact collection and reflective journal), as a representative sample (interviews), or as a random sample (direct observation and audio recording). In addition, detailed descriptions of interns used for case studies were provided within all studies to further elaborate the sources of data. Third, data were collected in multiple forms and from different parts of the internship in order to triangulate results and provide evidence across social situations within the internship, thereby accounting for variations between different data collection methods (e.g., self-reported data revealed in a one-on-one interview versus direct observation of behaviors within a group of peers). Fourth, whenever possible data were presented verbatim and interpretations were made explicit to provide transparency in the presentations of results. This was done to allow peers, researchers, and reviewers to assess the worth of the results presented in each study.

Study 1: Attitudes toward Science

Evidence in this study includes interview data, all three types of collected artifacts and, for one sub-question, the reflective journal. I delineate each of the sub-questions and the specific data I will use to support these questions in Table 4.

Study 2: Knowledge of Science

In this study, I use a combination of interview data, two types of collected artifacts (career reflection and final evaluation), and the reflective journal to provide support for my results. See Table 4 for a more detailed breakdown by sub-question.

Study 3: Participatory Science Learning

In this study, I use all forms of data except the interns' applications. See Table 4 for a more detailed breakdown by sub-question.

Research Matrix

To summarize the research methods used in this thesis and their alignment with the research questions, I present the following research matrix (Table 4). This matrix clarifies the relationship between the collected data and the research questions, to make transparent the specifics of the study.

Table 4

Research Matrix.

1. In what ways are high-school students' **attitudes toward science** affected during their participation in a museum internship program focused on learning and teaching astronomy?	1.1 How do interns describe feeling like a scientist?	I: Oral responses to Q9, Q12, Q13a, Q20 RJ: Written entries describing feeling like a scientist AC-CR: Written "self-portrait" describing feeling like a scientist AC-AP: Written responses describing feeling like a scientist
	1.2 To what extent are interns' career aspirations affected by the internship?	I: Oral response to Q21 AC-CR: Written "self-portrait" describing aspirations for a science career AC-AP: Written responses describing aspirations for a science career
	1.3 In what ways do interns feel positively	I: Oral responses to Q2, Q7 AC-AP: Written responses in application

	about science?	describing an enjoyment or appreciation of science AC-CR: Written "self-portrait" describing an enjoyment or appreciation of science
	1.4 Why do interns want to pursue science-related activities outside of school?	I: Oral responses to Q3b, Q4, Q8, Q12 AC-AP: Written responses in application describing a desire to pursue science activities outside of school RJ: Written entries describing a desire to pursue science activities outside of school
2. In what ways are high-school students' **knowledge of science** affected during their participation in a museum internship program focused on learning and teaching astronomy?	2.1 To what extent do interns believe teaching is part of the scientific enterprise?	I: Oral responses to Q11b, Q13, Q13b, Q14, Q20a AC-AP: Written responses in application describing teaching as part of science AC-CR: Written description of science careers, that include teaching
	2.2 How do interns use scientific modes of thought?	I: Oral responses to Q13a, Q20, Q20b AC-CR: Written "self-portrait" describing use of scientific modes of thought RJ: Written entries describing use of scientific modes of thought AC-AP: Written responses describing use of scientific modes of thought
	2.3 Through what aspects of the internship do interns describe acquiring new science knowledge?	I: Oral responses to Q12, Q15, Q16 AC-EV: Written responses describing learning of science knowledge during internship RJ: Written entries describing learning of science knowledge while working on activity

		carts
	2.4 What science concepts do interns use most frequently during the internship?	AR: Oral accounts and frequency counts of interns using science concepts while working on the carts FN: Written description of interns using science concepts while working on the carts RJ: Written entries describing the use of science concepts while working on the carts I: Oral responses to Q5, Q6, Q6a, Q8
3. Do interns engage in **participatory science learning** (from an apprenticeship perspective) during their participation in a museum internship program focused on learning and teaching astronomy?	3.1 To what extent do interns believe they engage in authentic, or "real," scientific practices?	FN: Written descriptions of interns enacting authentic internship practices AR: Oral accounts of interns enacting authentic internship practices RJ: Written entries describing authentic internship practices while working on carts AC-EV: Written responses in evaluation form describing participation in authentic science practices during internship activities I: Oral responses to Q9, Q11, Q11b, Q13a, Q13b

	3.2 In what ways are scientific knowledge/practice situationally constructed and socially negotiated?	RJ: Written entries on scientific topic(s) discussed (in writing) by one or more interns AR: Oral accounts of interns discussing science with visitors, other interns, or staff FN: Written descriptions of discussions between interns and others on science topic(s) I: Oral response to Q6a, Q9, Q18 AC-EV: Written responses describing science practices developed with others
	3.3 Does interns' learning occur "at the elbows" of teachers, scientists, and peers?	FN: Descriptions of intern-staff and intern-intern interactions I: Oral responses to Q10, Q15 RJ: Written entries describing learning from interaction(s) with staff, intern(s), or visitor(s) AC-EV: Written responses describing learning from interaction(s) with staff, intern(s), or visitor(s)
	3.4 How do interns feel ownership of their internship practices?	RJ: Entries detailing their response to an issue that arose during a shift; sharing effective strategy (e.g., pedagogical) in an entry FN: Descriptions of intern responses to interactions with visitors AR: Oral accounts of challenges (and their resolution) during intern-visitor interactions I: Oral responses to Q6, Q8, Q16

	3.5 In what ways do interns become part of a Community of Practice?	I: Oral responses to Q11, Q11b, Q19 AC-EV: Written response describing membership in a community or a legitimate role within Museum (or different) community FN: Descriptions of developing common practices during interactions
	3.6 How do interns use both reflection-in-action and reflection-on-action?	**Reflection-in-action**: FN: Descriptions of reflective moments/discussions with others AR: Oral accounts of reflective moments/discussions with others RJ: Written accounts of reflective moments during cart interactions AC-EV: Written response describing reflective moments/discussion during cart interactions **Reflection-on-action**: I: Oral responses to Q17, Q17a RJ: Basic data about journal entries (number of entries, average word length), level of focus on cart interactions AC-EV: Written response describing use of reflective journal

Note. This table contains the research questions, data collection methods used, and the data collected to address each question. In this table, I = Interview, AC-AP = Artifact Collection – Application, AC-CR = Artifact Collection – Career Reflection, AC-EV = Artifact Collection – End-of-internship Evaluation, RJ = Reflective Journal, FN = Field Notes, and AR = Audio Recording.

Procedures for Drawing Inferences

Based on the theoretical grounding provided by sociocultural theory and the emergent themes resulting from the data analysis, the three primary research questions are presented in three separate manuscripts (presented in Chapters four, five and six), including a more thorough and pertinent description of the methods used in the research reported in each manuscript. The three research questions, as listed in Chapter two, were developed based on a review of the literature and guided by sociocultural theory and are therefore internally consistent with both the underlying theory of learning (sociocultural) and the focus of the study (interns participating in a museum-based science internship).

IV. STUDY 1: ATTITUDES TOWARD SCIENCE IN A MUSEUM-BASED INTERNSHIP

Abstract

Informal learning experiences (such as those found within museums) have been indicated in positive increases in students' attitudes toward science. This study used mixed methods to investigate four aspects of attitudes toward science within a museum-based internship, including the ways in which participants felt like scientists and pursued science as a career, and their reasons for feeling positive about science and for pursuing science activities outside of school. Interns held mixed views of themselves as scientists, depending on the degree to which they distinguished between professional and everyday science. The internship also solidified, but did not alter, their careers aspirations, which were largely science related. Four reasons were provided for their positive attitudes, including viewing science as a common link with friends or family, feeling curious about science, believing that science is fun, and being interested in teaching others about science. Interns also provided twelve reasons for their pursuit of science activities outside of school, with a desire to gain knowledge the most frequently cited.

Introduction

Adolescent's attitudes toward science are one of the most well-studied, yet poorly understood, domains within science education (Osborne, Simon, & Collins, 2003). Recent efforts have highlighted the importance of this domain for science learning and for the selection of science-related careers (Organisation for Economic Co-operation and

Development (OECD), 2007). At least some of the recent interest in this topic stems from the well documented drop in adolescent's attitudes toward science during their middle school years (Osborne, Simon, & Collins, 2003; Simpson & Oliver, 1990). One potential solution to this drop in students' attitudes is participation in informal science education programs. Participation in programs such as internships (Abraham, 2002; Cooley & Bassett, 1961; Davis, 1999; Gibson & Chase, 2002; Markowitz, 2004; Stake & Mares, 2001) and student-scientist partnerships (Fougere, 1998; Means, 1998) has been shown to increase participant's attitudes toward science. These types of program offer an exceptional opportunity to bolster students' attitudes toward science during a time in their life when they might otherwise lose interest in science entirely, rescuing them from dropping out of the science "pipeline" entirely. The present study adds to the growing literature on students' attitudes toward science within informal settings through an exploration of a museum internship for high school students.

In the attitude literature, there is a dichotomy between students' general attitudes towards science and their attitudes towards school science specifically, with students often feeling favorably towards science as a discipline but unfavorably towards it as an object of study (Osborne, Simon, & Collins, 2003). Some of the earliest work in attitudes toward science were a delineation of six affective behaviors laid out by Klopfer (1971). Klopfer's goal was to provide a means to evaluate school science programs, and attitudes toward science were just one aspect of the entire evaluation scheme. From this early work, the study of attitudes toward science has grown greatly, and yet is still "poorly articulated and not well understood" (Osborne, Simon, & Collins, 2003, p. 1049), just as it was in the late 1960's (Klopfer, 1971). There has been a recent push though, to delineate aspects of attitudes toward science and construct a more valid and robust concept (e.g., Kind, Jones, & Barmby, 2007).

To construct a more valid and robust concept, it is essential to consider context, as specific characteristics of attitudes toward science are closely tied to the context in which they are evaluated (Osborne, Simon, & Collins, 2003). In considering the contextual factors of internships (such as their proximity to scientists/experts and their location within the workplace of those scientists/experts), four aspects of attitudes toward science are most likely to be affected.

First, internships may affect the degree to which students feel like scientists. In the GLOBE student-scientist partnership for example, the relevance and authentic nature of the data students collected was one of the most salient aspects of the program, and made them feel like they were "real scientists" (Means, 1998, p. 100). Fougere (1998) found similar results with her students' involvement in the Forest Watch program, while Moss, Abrams, and Kull (1998) found that students did not end up feeling like scientists, primarily due to lack of exposure to authentic science practices, almost no sense of partnership by students, and little direct contact with scientists.

Summer research programs, unlike student-scientist partnerships, provide students with greater depth of experiences involving scientists and their practices. In one study of a seven-week research apprenticeship, Richmond and Kurth (1999) found four dimensions of scientific practice and culture in which students began to identify themselves as scientists, including technical language, collaboration, uncertainty, and inquiry. They also found those students' developed deeper and richer self-conceptualizations in these dimensions over the course of the internship, and therefore began to develop a sense of themselves as scientists.

Second, an increased desire to pursue a science-related career is one of the most well documented results of science internships. In studies of summer research apprenticeships, evidence suggests that such experiences may affect career aspirations in science through strengthening existing or creating new science career goals (Abraham, 2002; Cooley & Bassett, 1961) and maintaining these goals through college (Davis, 1999; Helm, Parker, & Russell, 1999), and an expanded knowledge of career options within science (Stake & Mares, 2001). In addition, such research experiences may affect the actual career selection of participants into science-related careers (Davis, 1999; Markowitz, 2004).

Third, internships have also been found to positively alter students' views of science and scientists. In one study of a two-week summer science program, the attitudes of the middle-school students who participated were found to remain more positive than their peers' who did not participate (Gibson & Chase, 2002). In similar studies of summer research apprenticeships, Abraham (2002) and Cooley and Bassett (1961) found similar changes in students' views of science, as well as more positive views about scientists. These changes in attitude are notable not only in light of the short length of the internship programs but also because their method of pre- and post-test measures may have missed significant changes in students' attitudes (Stake & Mares, 2001), and thus the actual gains may have been even more significant. In a longitudinal follow up study of another relatively short summer program, Markowitz (2004) found that students generally felt more positive about science after their participation in the program.

Fourth, internships may affect students' attitudes toward science is by sparking an interest in other science activities outside of school, thereby increasing their participation in informal science programs. Specifically, after participating in summer research programs, students were found to pursue more in-depth study of their research topic or related laboratory assistant work (Markowitz, 2004), as well as beginning to view roles for non-scientists within science and a plan to pursue such roles (Abraham, 2002).

Purpose

The primary purpose of this study is to explore the ways in which high-school students' attitudes toward science are affected during their participation in a museum internship program focused on learning and teaching science. More specifically, this study answers four research questions within the domain of attitudes toward science. These questions are: (1) How do interns describe feeling like a scientist?, (2) To what extent are interns' career aspirations affected by the internship?, (3) In what ways do interns feel positively about science?, and (4) Why do interns want to pursue science-related activities outside of school? Through answering these questions, I hope to reveal those aspects of internships that may be most beneficial in promoting (or maintaining) positive attitudes toward science—ideas that can be leveraged in creating new internship programs and which also may be relevant for both informal and formal science education more generally.

Internship Description

This internship took place over seven weeks during the summer of 2006 at a large museum (hereafter "Museum") in New York City. Interns began the internship with a week of training, to familiarize them with the focus of the internship – three hands-on science activity carts set up in the Museum's astronomy exhibit hall. Using activities on these carts, interns worked in pairs to teach science to Museum visitors during the six primary weeks of the internship, working at least 8 hours per week on the carts. Interns also participated in a number of activities as a group during sessions held every Monday of the internship. These activities included a career reflection program, lectures by Museum scientists, and guided exploration time of the Museum.

Methods

This study uses a mixed-methods qualitative approach based on comparative case-studies. Cases were built upon three methods chosen to maintain thorough and comprehensive descriptions of possible impacts. This methodology is based on the idea that there are a multitude of factors that influence individuals and groups of people, therefore dictating a complex and multi-faceted analysis lens (Keeves, 1998). Specifically, reflective journal entries, three different types of intern-generated artifact (internship application, career exploration reflection, and end-of-internship evaluation), and interviews were combined to form layered descriptions of the numerous ways interns were affected by the internship experiences. One unique method in this study was the use of a daily reflective journal as a naturalistic research method. The journal was a part of the interns' daily ritual, in which they were required to write an entry after each shift, reflecting on their experiences that day or describing general thoughts pertaining to the internship. Depending on the number of shifts they worked each day, interns wrote two to four entries per week, resulting in an average of thirteen entries for each intern over the course of the internship. Interns' journal entries span the six weeks they worked on the activity carts, and the resulting public journal is 109 pages. The journal was kept as a public document to which all interns had access and which they were encouraged (but not required) to read.

Population

In 2006, eighteen interns participated in this study. These eighteen interns were demographically heterogeneous, representing at least eight different ethnic groups (including Chinese-American, African American, Liberian, Hispanic, Romanian, Indian, and Caucasian American), multiple socioeconomic groups, and diverse geographic regions of New York City. Interns also came to the internship from all types of public high school, including specialized schools for science. At the beginning of the internship, the youngest was 15; while the oldest was 18. It should be noted that two of the eighteen interns had participated in the internship during 2005 and were returning for a second year.

A factor of note is that interns applied to two different internships, which were combined into a single internship after all applicants were notified of the change. One of the internships was marketed as providing an inside view to museum work, and was not tied to a specific content area. The other internship was linked to the Museum's astronomy-themed exhibit hall and was therefore content-specific. The final internship program was mostly modeled after the content-specific one, with the addition of a career exploration segment that had previously been part of the museum-wide internship.

The following descriptions provide additional details of the two case study interns used in this study (all names are pseudonyms). These interns were selected as case studies because their responses represented the most frequently occurring themes found within the data, as well as elucidating the range of responses found among interns.

Ben

Ben was a well-spoken and quiet 18 year old first generation Chinese-American, who attended a specialized science high school in New York City. At the time of the internship, he had just finished his junior year of high school and was preparing to begin college applications in the autumn. His teachers described him as a “fine student”, who was “highly intelligent, motivated, responsible, and reliable.” He lived at home with his mother and father, who made lunches for him during the internship. He spoke Chinese at home, and had learned some Spanish in school. He also participated in a second, concurrent, internship synthesizing gels in a local university’s laboratory.

Marisa

Marisa was a thoughtful and well-spoken 18 year old Caucasian-American who had just graduated from a fine-arts high school in New York City and was looking forward to being challenged while attending a local college in the fall. Her teachers described her as “the top academically performing student in all of my science classes. She is enthusiastic, reliable, and creative in all learning activities.” She lived at home with her father and her two sisters (one younger, one older). She had learned some Spanish in school, and planned on learning Italian in college.

Results

To provide a deep description of the results, general themes are presented first for all interns (along with any quantitative results that support the results), followed by specific results for the two case study interns.

Interns' Scientist Identities

All interns reported engaging in scientific practices, but results suggest that interns held mixed feelings of themselves as scientists (herein called "scientist identity"). Of the eleven interns interviewed, six explicitly described feeling like scientists. Although almost half of the interviewed interns did not feel like scientists, all interns described engaging in some type of scientific practice (e.g., doing experiments or asking questions). In other words, all interns believed they engaged in practices similar to those of scientists, but only six subsequently considered themselves as scientists. The five interns who did not feel like scientists appeared to make a distinction between science as a profession (i.e., scientist) and scientific practices, describing scientific practices as a necessary, but not sufficient, condition to becoming a scientist.

Interns' scientist identities included thirteen behaviors and characteristics. These behaviors and characteristics were used by interns to describe their own practices (both inside and outside the internship) and were also, separately, used by interns to describe the practices of scientists. The practices and the number of interns exhibiting (self-reported or observed) each of them are summarized in **Table 1**.

[Insert Table 1 here]

Ben

Ben was one of the five interns who did not feel like a scientist but who did feel that he engaged in scientific practices, making a distinction between the profession of a scientist and acting scientifically. Some of the examples he gave of scientific activities included improving his existing knowledge, as "when I pack things in my bag, I try to find better ways to put them so I get more space" (Ben's interview) and observing, when he wrote about how "I noticed some thing cool about the IR camera. If the visitor has thin flip flops, then they leave IR foot prints" (Ben's journal entry, August 8^{th}). He provided similar examples of scientific practices in which others could engage, such as:

> [I]f you ever look in your garden and ask yourself 'how is this happening?', 'how should I have my plants grow better?', 'where should I move them?', or something. Or 'should I adapt the amount of water I give them?' - then that's also real science being applied (Ben's interview).

These examples illustrated Ben's belief that science could be brought into everyday life and the ways in which he engaged in this type of everyday science. Engaging in scientific practices, though, was not sufficient for him to feel like a scientist and he further distinguished these two domains when he described not feeling like a scientist, stating:

> I haven't really thought of myself as a scientist. Sometimes I see a possible role in science later on, but for the most part I see myself as learning about the world right now, not really as part of a scientist or anything of that sort (Ben's interview).

Again, Ben made a distinction between "learning about the world" and being a scientist, a distinction that held some tension for him. He recognized this tension and acknowledged that his beliefs may have been relative when he said:

> if you were working on something that's really complicated you feel more like it's real science, but if you work on something less complicated you feel it's not really scientific, and yet you're still using the scientific method…(Ben's interview)

Marisa

Unlike Ben, Marisa did report feeling like a scientist, albeit in limited ways. As she explained in her interview, she felt that her view of the world was the same as that of a scientist, encompassing both professional and everyday activity.

> Interviewer: Do you think of yourself ever as a scientist?
>
> Marisa: Well, in the way that I look at things around me…. So, I think that as long as I am looking at things and constantly coming up with ideas about how something might work, then that does constitute as scientific looking.

This excerpt revealed that Marisa felt like a scientist because of the way she looked at the world, through her "science goggles" (a term she used later to describe her scientific view of the world). In fact, Marisa reported later in her interview that she had "dual goggles – science and art". She used the goggle metaphor frequently to explain her worldview and to signal her belief that it overlapped significantly with the worldviews of scientists. In this way, Marisa held a scientist identity that included her own practices as well as the perceived practices of scientists.

Career Aspirations of Interns

Overall, the internship seemed to solidify, not change, the career aspirations of interns, many of whom described wanting to pursue a science-related career. Quantitatively, 14 out of 18 interns described at least one science-related career as a career option on their career reflection worksheet, seven out of 18 mentioned wanting to pursue a science-related career in their application, and nine of the 11 interviewed interns spoke about wanting to pursue a science-related career. All interns who mentioned wanting to pursue a science-related career in their application also noted this in their career reflection.

Ben

Ben entered the internship somewhat unsure of his career goals, and those goals underwent little change over the course of the internship. In his application, Ben was unsure of his career goals, but laid out the possibility of a career in astronomy or astrophysics when he reported that he had "been pursuing studies and interests in astronomy/astrophysics and have begun to seriously consider a career in the fields." He continued by relating the way he believed the internship would affect his career goals: "I've always dreamed of having a chance to help contribute to the research and discoveries being made instead of only reading about them. I feel that the Saltz Internship could be a first step towards the direction of that dream." Thus, while he was not sure he wanted to pursue a career in astronomy/astrophysics, he was sure he wanted to contribute to "research and discoveries" – an important aspect of any science-related career.

In his career reflection worksheet, Ben listed “Engineer” and “Researcher” as two (out of four) possible careers for him. The other possible careers he listed as “Film Production” and “Entrepreneur”. Even though he listed two science-related careers as possible careers, he noted that the “technical knowledge” necessary for those jobs made them “not a good fit”.

Ben reiterated and clarified his uncertain career goals as well as the possibility of pursuing a science-related career in his interview: “Sometimes I see a possible role in science later on, but for the most part I see myself as learning about the world right now…” (Ben’s interview). This passage suggests underlying tensions in Ben’s view of himself as a scientist, or at least in the way he differentiates science careers from a scientific view of the world.

Marisa

Unlike Ben, Marisa began the internship with a very concrete idea of her career goals, which were not directly related to science. In her application, Marisa described her desire to pursue a journalism career and the way she believed the internship would further that goal: “Having all the information around me, and having the museums as my work place would be inspiring to me as an aspiring writer (journalism is to be my major in college)”. On the face of it, her career goals did not appear to involve science in any meaningful way. It is only through studying her career reflection worksheet and her interview responses that a strong link between her stated career goals and a science-related career was revealed. While the majority (15 of the 18) of interns expressed an interest in pursuing a science-related career in at least one of the data forms, many of those interests were similar to Marisa’s in their weak link to science.

Taking her application as a starting point, Marisa's ideas exhibited little change over the course of the internship. Early on in the internship, when filling out the career reflection, she elaborated on possible careers she was interested in pursuing. Of the four possible careers she listed, three were not directly related to science ("Investigative Journalist", "Art Historian", and "English Professor"), while one of them was ("Cosmologist"). Aligning with her application, the career reflection revealed that journalism was clearly an interest of hers and was one she hoped to pursue in the future. Her interest in journalism began at an early age, as she related in her interview: "Well, ever since I was six years old, actually, I wanted to be a journalist." Art was another interest of hers, and she described her plan to pursue journalism and art in college in her interview: "That's my major and my minor is going to be study art because I went to fine arts for four years and I want to continue that."

Taken together, the three data sources revealed a strong interest in pursuing a career in journalism, with a potential role in the arts. The addition of "Cosmologist" to her list of possible careers is therefore interesting for its marked difference from the other three careers, and almost seems inconsistent with the others. However, her interview revealed the connection she saw between her varied interests:

Marisa: A lot of my art pieces are actually science theories conveyed in art.

Interviewer: Ah, okay. That's very interesting. So you're combining your two passions…

Marisa: I really got really into Cosmology, mostly, and Biology

Interviewer: When did you get into Cosmology and Biology?

Marisa: Also at a young age. I think when I was ten. I am always, like, researching things, and drawing diagrams, and making up theories.

She went on to describe various conceptual art pieces she had done and their connection to science. In this way, she bridged disciplines which are often viewed as disparate, and felt they are each worthy of a possible career for her.

Reasons for Interns' Positive Feelings toward Science

Ten interns reported feeling positive toward science since they were young, and by the beginning of the internship all interns felt positive toward science. Many interns reported similar reasons for their positive feelings, including an interest in teaching others about science (17 interns), science as a commonality between friends and/or family (10 interns), and a feeling that it is fun (8 interns). All three reasons were reported by Ben and Marisa, and the details of their responses are given below.

Ben

In his application, Ben revealed strong positive feelings toward science and provided some insight into how and why he came to hold those feelings:

> I've held a passion for science starting at an early age. The mechanics and fundamental workings of the world around us have always intrigued me and ever since I received my first science almanac as a young child, my interest has continued to grow. Although, every branch of science fascinates me, astronomy and astrophysics are my most favorite. The massive proportions of the universe in contrast to the miniscule scales of our everyday lives consistently amaze me.

> Furthermore, the little knowledge we have of the uncharted expanses of the universe and the physics that drive it provokes my curiosity (Ben's application).

The general tone of this paragraph is very positive, and his use of words like "intrigued", "fascinates", "amaze", and "provokes my curiosity" to describe his feelings toward science suggests an entirely positive view of science. Later parts of his application revealed additional positive feelings:

> I've always had an indescribable sense of pleasure at seeing a child learn something new or grasp a hard to understand concept. Their "ooo"s and "ahh"s always set off a mix of joy and pride at having helped broadened their horizons. (Ben's application).

Thus, not only did Ben like science (especially Astronomy and Astrophysics), he also enjoyed teaching others about science. He took this task quite seriously, and suggested in his interview that one of his roles in the internship was to raise the potential number of people interested in science, which may ultimately increase the amount of funding for science. He believed increasing the public's interest in science was a greater good, because "[t]he more interest the better it is" (Ben's interview)

One way the internship changed Ben's feelings toward science, which he described in his interview, is that he came to realize "science is fun":

> It has, like, changed the fact that science can be kinda fun. Because for the most part all I've done is read journals and read textbooks. After awhile you don't really find it fun, you just have to learn it for the sake of taking a

> test. So, like, when you just learn interesting facts that seems to be more fun because it's something you understand and like (Ben's interview).

His interview responses also suggest that Ben found his positive feelings toward science a commonality with his friends, as they "… are pretty interested. Like if something new happens or some kind of new development, they like to hear about it and understand it" (Ben's interview). He did not specify whether he was the one to share these new developments with them, or whether they learned about them on their own, but Ben's curiosity was well-aligned with his friends'.

Marisa

She had, similar to Ben, very positive feelings toward science, and revealed those in her application and interview. Her application had a generally positive tone regarding science. One section near the beginning was particularly salient:

> Since I was young, I had always been fascinated by science. Nature, experimentation, and especially the cosmos were all engrossing to me. To this day I don't tire of watching documentaries on The National Geographic Channel and the Science Channel, or reading Scientific American, and The Origins of Species from cover to cover (Marisa's application).

As with Ben, Marisa had been interested in science from a young age, and listed some of her favorite topics within science. Unlike Ben, however, Marisa provided examples of how her interest in science translated into specific actions (e.g., watching science television shows and reading science-themed writing).

An interest in science was also a common bond between Marisa, her family, and her friends. In her interview, she described in some detail her father's interest in natural history and their plan to embark on an expedition together:

> Marisa: Yeah, actually, my dad is kindof really into natural history. One thing that me and him want to do together, just us, we want to drive the Alaskan highway into the Eskimo village.
>
> Interviewer: That's great.
>
> Marisa: He's, like, really fascinated by stuff like evolution and things like that (Marisa's interview)

She also reveals that her boyfriend is "as much of a nerd as I am" and that they "go on all our scientific endeavors together" (Marisa's interview).

Similarly to Ben, Marisa reported a sense of satisfaction and enjoyment in teaching others about science, in being the "ignition in the engine for them" (Marisa's interview). She also felt "a certain satisfaction in teaching kids. Like, I love it - they get so excited. Like, you know, just knowing that I maybe told a child something that can influence them to explore other things that could potentially build up over their life - it's very satisfying" (Marisa's interview).

Pursuing Science Activities Outside of School

Interns pursued numerous activities outside the scope of the internship, including reading science magazines and books, watching science-related television programs, visiting science museums, and researching science topics. A couple interns even participated in other, research-based, internship programs in active laboratories. Keeping these ideas in mind, the interesting topic worthy of further exploration is the underlying reasons for interns pursuing science-related activities outside of school.

From their interviews, applications, and reflective journal entries, interns reported twelve reasons for their interest in pursuing science-related activities outside of school (including both the internship itself and other activities). These reasons can be grouped into two categories, based on their prevalence within the data. Frequent reasons were those reported by eight or more interns and infrequent reasons were those reported by four or less interns. All twelve reasons and the number of interns reporting each reason are listed in **Table 2**. The following two case studies illustrate the frequent reasons (as well as a few of the infrequent reasons) why interns wanted to pursue science-related activities outside of school.

[Insert Table 2 here]

Ben

In addition to participating in the Saltz internship, Ben took part in another research-based internship in a local college's biotechnology laboratory. He also found opportunities to research topics on his own that were of interest to him, as when he related an experience on the carts during the internship that led him to research optics: "Today was pretty good except for the part when me and Leona had a "disagreement" regarding the physics of light and optics. This has motivated me to review and touch up on my optics. After we discussed it though, we worked a lot better and took turns explaining things" (Ben's journal entry, July 12th).

This high level of motivation to explore science activities outside of school was fairly normal among the intern group, but the types of activities in which they engaged varied greatly. The above journal entry also provides an example of one of the most common reasons interns provided for their interest in pursuing science-related activities outside of school—wanting to learn science. This was also one of the most frequent reasons interns provided in their applications for how they envisioned the internship impacting them, and Ben followed this trend when he wrote that the "[i]nternship would give me a chance to learn more about astrophysics/astronomy and work in the two fields as well as a chance to help others learn more about them too." This quote was also an example of another of the frequent reasons: the desire of interns to teach others about science. A desire to teach others was motivated by many reasons, as some interns (such as Ben) felt joy in helping others while other interns (such as Marisa; see below) viewed teaching as a path to deeper learning. Ben had some previous experiences teaching, and he went into some depth explaining his positive experiences and the way in which they motivated his application to the internship. He described these experiences as an essential reason for his application to the internship:

> While a chance to help make discoveries in astrophysics/astronomy would be immensely enjoyable, a chance to help someone else make a new discovery about astrophysics/astronomy would be even better. I've interacted with many children during my experiences volunteering at a summer school and helping out with summer programs at the library and I've always had an indescribable sense of pleasure at seeing a child learn something new or grasp a hard to understand concept. Their "ooo's" and "ahh's" always set off a mix of joy and pride at having helped broadened their horizons. I would especially love the chance to teach others in the fields I like the best (Ben's application).

Ben provided several additional reasons for his interest in pursuing science-related activities outside of school, including wanting to have fun, to create better cart presentations, to solve practical problems in his life, and to experience scientific work.

Marisa

Besides participating in the internship, Marisa pursued numerous other science-related activities outside of school, including reading science magazines and books, watching science television programming, researching topics of interest to her, visiting science museums, and incorporating scientific ideas into her artwork. One of the primary motivations for her to pursue these activities was to inform her other interests, especially her interests in art and journalism. She provided examples in her application and interview of times where she had done extensive reading and research in order to incorporate a science idea into her art work. For example, her application included a lengthy description of Robert Wright's book on Evolutionary Psychology and its influence on her art, which she referred to again during her interview. She also viewed the internship as an excellent opportunity to further her career goals, and wrote in her application that

> [h]aving all the information around me, and having the museums as my work place would be inspiring to me as an aspiring writer (journalism is to be my major in college), and give me a good upper hand with knowledge for my minor in college (which is either to be cosmology or natural sciences) (Marisa's application).

Even though her career goal (journalism) did not directly involve science, she connected this goal to her interest in science (see results in career aspiration section for a more detailed description of this point). Furthermore, she believed the internship would allow her to both teach and learn science, and she continued in this vein in her application:

> Due to my infatuation of the aformentioned [sic] topics, I would be readily able to embellish upon information given in exhibits about evolution to the visitors of the museum because of my own extensive studies on the topic, and expand my own knowledge at the same time (Marisa's application).

Related to her desire to teach others, Marisa pursued certain activities to create better cart presentations. When asked in her interview whether she had a role within science, Marisa replied:

> … if you have to convey information to the public you can't just, like, read from the little handouts you guys made us. You have to really research on your own and find a way to really put together a good and enriching presentation, and to also expand your own knowledge of the topic. So it's always important to constantly research and figure out new things (Marisa's interview).

When she described "research" it appeared (from this and other quotes in her interview) she was referring to the common student conception of research, which involves looking things up in books or on the world wide web. Regardless of her view of research, Marisa also placed value on gaining science knowledge, and offered it as another reason for her pursuit of science-related activities outside of school. For example, later in her interview she described one way the internship had expanded her view of science:

> I would think that definitely the way that light and telescopes work together. I thought it was really cool because, like, I read a lot of science magazines and I always read about them, but the people who are writing those articles already have a lot of the basic knowledge, so they don't really build it from the rudimentary blocks for you. But, like, here when I got all the basic things, because we're trying to present it to people who have no knowledge of it, it sort of like really helps me understand what they were talking about more and it became all the more engrossing. (Marisa's interview)

In this last quote she connected many of the ideas discussed above, such as the type of activities she pursued outside of school (reading science magazines), gaining knowledge of science, and teaching others. It also provided an example of her curiosity in science and the way it led her to explore science-related activities. For Marisa, the intern experience provided a venue to improve her interest in, and knowledge about, science through her research and teaching.

Discussion

After years of research on the topic, students' attitudes toward science are still not well understood (Osborne, Simon, & Collins, 2003), especially in contexts outside science classrooms. This study begins to advance our knowledge on the topic by investigating four aspects of students' attitudes toward science within the context of a summer internship program.

The research questions addressed in this study yielded numerous important results and four of the most noteworthy are discussed below. First, interns held mixed views of themselves as scientists (herein called "scientist identity"). The extent to which interns held a scientist identity depended on the degree to which they made a distinction between the practices of professional science and everyday science. That is, interns who made a distinction between professional and everyday science were less likely to hold a scientist identity whereas interns who did not make this distinction were more likely to hold a scientist identity. This suggests that interns' definitions of what it means to be a scientist influenced their own scientist identities. Thus, while not exhibited by all interns, the distinction between professional science and everyday science is an important feature in understanding the extent to which interns hold scientist identities in informal settings.

Previous research has indicated that authenticity of science practices was central to understanding students' conceptualizations of themselves as scientists. Specifically, research on student-scientist partnerships has demonstrated a positive link between the perceived authenticity of practices and students' feeling like scientists (Fougere, 1998; Means, 1998; Moss, Abrams, & Kull, 1998). Combining the present finding with previous research on authenticity, we can speculate that it is not only the perceived authenticity of interns' practices that matters, but also the type of practice in which they engage (e.g., everyday versus professional scientific practices). In other words, the degree to which interns hold scientist identities may be positively influenced by participating in authentic scientific practices and by a belief that the practices of scientists (professional scientific practices) overlaps with the practices of lay people (everyday scientific practices). Thus, the key to understanding interns' scientist identities may be in examining their definition of the work of scientists in combination with the perceived authenticity of their own practices. This aligns with work by Richmond and Kurth (1999), who found that interns developed a more rich sense of themselves as scientists through their participation in authentic science practices, which involved both everyday and professional practices of scientists (not formally labeled as such by the authors). Clearly, this result is a simplification of a complex set of interwoven ideas, and a full understanding requires a more comprehensive investigation of the myriad influences that determine an intern's scientist identity. Future work should aim to untangle the potential associations between authenticity and definitions of scientific practices (the degree to which professional and everyday science practices are integrated) in their impact on students feeling like scientists, along with other variables that may affect this construct.

Second, the internship solidified interns' career aspirations, the majority of which were science-related. Indeed, the positive effect of internships on students' career goals is well established, with previous work demonstrating that internships strengthened existing career goals (Abraham, 2002; Cooley & Bassett, 1961) and expanded knowledge of career options in science (Stake & Mares, 2001). Although consistent with previous work overall, interns' career goals may have been affected to a lesser degree than in previous studies. It may have been the case that interns became disillusioned with their science-related career aspirations after learning more about the realities of being a scientist (e.g., during the talks from Museum scientists), similar to findings of Tassel-Baska and Kulieke (1987), thereby limiting the degree of positive change in their career goals. However, interns did not categorically alter their career goals, nor did they feel less positive about scientists, decreasing the possibility of this explanation. Alternatively, as indicated in the final evaluations, interns found the career exploration section of the internship to be onerous and not at all worthwhile, with 16 of the 18 interns believing the career exploration portion was the least useful aspect of the internship. Thus, it may be that any strong positive effects on their career aspirations were (at least partially) cancelled out by their strong negative reactions to the career exploration aspect of the program. Thus, the large percentage of interns (>80%) who wanted to pursue a science-related career is notable not only because they persisted through a negative related experience, but also in light of recent international tests of students attitudes toward science that reveal 37% of 15-year-old students would like to work in a career involving science (Organisation for Economic Co-operation and Development (OECD), 2007). Additionally, there is evidence that internships may help students maintain their science career goals through college (Davis, 1999; Helm, Parker, & Russell, 1999) and affect their selection of a science-related career (Davis, 1999; Markowitz, 2004), suggesting a longitudinal follow-up with interns would be worthwhile.

Third, interns reported four key reasons for their positive feelings toward science: (1) viewed science as a common link between themselves and their friends/families; (2) felt curious about science; (3) believed science was fun; and (4) were interested in teaching others about science. Previous research has demonstrated that internships both engender more positive views of science (Gibson & Chase, 2002) and alter interns' existing views to become more positive (Abraham, 2002; Cooley & Bassett, 1961; Markowitz, 2004), but there is little research that uncovers how internships produce these types of changes. There is, however, a substantial body of literature describing factors that influence students' attitudes toward science and as such, this work could be extended to attempt to explain the mechanisms underlying the positive changes seen in attitudes toward science in internships. Two such factors are parental and peer support, with research demonstrating a positive link between parental support and attitudes toward science (Breakwell & Beardsell, 1992; Simpson & Oliver, 1990) and the influence of peers on attitudes toward science (Breakwell & Beardsell, 1992; Talton & Simpson, 1985). In accord with these associations, in the present study interns identified a common interest in science with friends and family as an important reason for their positive attitudes toward science. The three other reasons interns provided are not similarly supported by previous research. Of these reasons, interns' interest in teaching others about science is the most salient for the purposes of this study. Notably, only three of the interns began the internship with positive feelings toward science stemming from their experiences teaching others. Thus, for most interns, this was a new reason to hold positive attitudes towards science, likely the result of their teaching experiences during the internship (e.g., during their work interacting with Museum visitors on the carts). Thus, we can speculate that one mechanism by which internships produce positive changes in interns' attitudes through science is by providing them with experiences that give them new reasons to hold these positive views.

Fourth, interns provided twelve reasons for pursuing science-related activities outside of school, with a desire to gain knowledge of science as the most frequently cited. Indeed, internships (one type of science-related activity outside of school), especially research apprenticeships, have been shown to increase science content knowledge (Abraham, 2002; Bleicher, 1996; Charney et al., 2007; Cooley & Bassett, 1961), and the results of the present study suggest that such learning is also a reason for interns to participate in internships. Notably, interns also cited a desire to create better cart presentations and gaining access to resources not available to the public as reasons for pursuing outside science-related activities. Thus, interns chose to participate in additional science-related activities (beyond the internship itself) to enhance their internship experience. Although the data do not allow a determination of causality, it may be that the internship provided interns with new reasons for their pursuit of science activities outside of school, thereby expanding their positive views towards science and strengthening their scientist identities (see discussion above). To place these findings in a broader context of interns' international peers, recent results found that a minority of adolescent students reported engaging regularly in science-related activities (e.g., 21% regularly watched television programs about science) (Organisation for Economic Co-operation and Development (OECD), 2007), and interns may therefore represent a uniquely motivated subset of students whom chose to pursue numerous science-related activities outside of school.

In looking across the research questions, two themes emerged. First, interns held generally positive attitudes toward science. One way to understand this theme is to take note of the strong selection effect present in the participant population. Interns were selected into the internship based on a number of criteria. Generally, interns were selected if they showed evidence of responsible behavior and demonstrated a level of confidence that suggested they would be approachable by Museum visitors. Preference was also given to interns who were motivated to deepen their science knowledge and work on their public speaking skills. As such, interns came into the internship with strong motivations to succeed and with strong interests in science, at a minimum. Stake and Mares (2001) have found this type of strong selection effect creates a ceiling effect in traditional pre-post assessments of attitudes toward science within internships, as students often enter such programs with already very positive attitudes. Their results also support a preparedness model, with students benefiting the most who went through an initial program prior to a second program. Thus, previous research suggests that selecting motivated students with already positive attitudes may have provided the most benefit to their attitudes. If true, interns therefore represent an upper bound on attitude gains from internships—a rather disappointing thought given that interns did not experience significant positive changes to their attitudes from the internship.

Second, the internship expanded, but did not alter, interns' attitudes toward science. This "expanding" effect on interns' attitudes toward science is demonstrated by the internship providing additional reasons for them to feel like a scientist, pursue a science-related career, feel positive about science, or pursue science-related activities outside of school. This is in contrast to a shift in attitude that would result in more positive or more negative attitudes toward science; a result which the evidence in this study does not support. In other words, interns' attitudes toward science did not, in general, become more or less positive, but did become more multifaceted. A good example of this effect is found in the type of reasons interns provided for wanting to pursue science-related activities outside of school. As discussed above, for some interns, these reasons came to include aspects unique to the internship, including a desire to create better activity cart presentations and gain access to resources not available to the public. For other interns, the internship brought to the fore a desire to teach others about science. These motivators for interns pursuing science activities outside of school served to add in a new layer, or build up an existing one, in their attitudes toward science, without making them feel more (or less) positive toward science. This suggests an interesting relationship between school (formal) science and informal science, whereby students' attitudes toward science are formed and altered in school science (Osborne, Simon, & Collins, 2003) and then expanded upon through informal experiences. Speculating further, this process may be cyclical in nature, with students' expanded attitudes toward science impacting their future school science experiences.

An interesting alternative explanation for interns' "expanded" attitudes is that the internship may have expanded their ability to describe their attitudes, not the attitudes themselves. In other words, interns' language abilities (as evidenced by self-report data), not their attitudes, may have been altered by the internship. Much of the evidence for interns' expanded attitudes was from self-reports of beliefs and feelings, such as their feelings toward science. While it is difficult to disentangle perceived change in attitudes from actual change in attitudes within self-report data, behaviors may be more reliable indicators of such changes (Ajzen & Fishbein, 1980). Thus, it is important to look at interns' behaviors in order to more fully understand changes in attitude. For example, interns reported pursuing additional science activities as a result of participation in the internship. This suggests that either interns' knew about such activities previously and the internship made them desirable or the internship revealed such activities as new and desirable activities. The first instance is indicative of a positive shift in attitudes toward pursuing science activities (one aspect of attitudes toward science), while the second instance is indicative of an expansion in attitudes toward pursuing science activities. This example highlights one way in which interns' attitudes, not just their language, were altered by the internship. Thus, there is some direct evidence of changes in interns' attitudes toward science; although it remains unclear to what extent their language abilities may be intertwined with other evidence of changes in attitudes.

One limitation of this study is that the participating students had generally positive attitudes toward science, and therefore it is not clear how the results would differ if students with neutral or negative attitudes toward science were included. It is possible that interns experienced a shift in their reference point in relation to the other highly motivated and positive interns, similar to results found by Sax (1994) for mathematical self-concept.

This study holds important implications for science education, especially in the connection it suggests between informal and formal science. In particular, it implies that informal learning experiences can expand students' attitudes toward science, possibly leading to greater achievement in science class (Oliver & Simpson, 1988). Thus, science teachers may want to utilize such experiences with their classes in order to positively impact their students.

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Table 1

Behaviors or characteristics of interns identified as indicative of scientists.

Behavior/Characteristic	*n*
Asks questions	18
Teaches others about science	18
Makes observations	16
Learns science knowledge	14
Performs experiments	9
Does research	9
Creates new knowledge	6
Uses “the scientific method”	6
Uses logic	5
Generates theories	4
Feels curious	3
Improves existing knowledge	2
Feels skeptical	2

Table 2

Reasons provided by interns for their pursuit of science-related activities outside of school.

Category	*Reason*	*n*
Frequent	Learn science	14
Frequent	Aid pursuit of science-related career	11
Frequent	Teach others science	10
Frequent	Experience scientific work	9
Frequent	Have fun	8
Infrequent	Curious about science	4
Infrequent	Aid college entrance	4
Infrequent	Gain access to non-public resources	4
Infrequent	Spend time with friends or family	2
Infrequent	Create better cart presentations	2
Infrequent	Inform other interests	1
Infrequent	Solve practical problems	1

V. STUDY 2: LEARNING AND TEACHING SCIENCE IN A MUSEUM-BASED ASTRONOMY INTERNSHIP

Abstract

The potential for gains in scientific knowledge from participation in an internship are great, yet this domain has been studied only little. This study explores the roles of four aspects of scientific knowledge within a museum internship for high school students. After participation, the majority of interns believed teaching was part of the scientific enterprise, likely due to the centrality of teaching practices within the internship. Interns also used at least six modes of scientific thought, only one of which was taught explicitly to them. The amount and depth of science content learned during the internship depended on interns' prior knowledge, and was learned during three specific aspects of the internship. Finally, interns used numerous science concepts during the internship, the most frequent of which were closely related to the internship activities.

Learning and teaching science in a museum-based astronomy internship

An increasingly common belief within science education is that science learning occurs in diverse settings and across the lifespan (Banks et al., 2004). Informal science education, as it is most often termed, has begun to garner attention by researchers and funding agencies and is very likely poised for a rapid expansion in coming years. One promising form of informal science education is internships. The underlying educational theory of apprenticeship learning has long held sway within graduate education in the sciences. Internships for secondary students, however, are less frequent and are for shorter periods of time. These internships span a broad range of science content and time spans, but are most often conducted as research apprenticeships with practicing scientists. Thus, while not always explicit, they hold a common unifying theory of learning based on apprenticeship. In this model, learning occurs when individuals participate directly in the practices of scientists, through a process of legitimate peripheral participation (Lave & Wenger, 1991). In this way, individuals learn from their actions working with more knowledgeable others (Brown, Collins, & Duguid, 1989) and are supported as legitimate participants in the already existing communities of scientists.

An underlying assumption of most science internships is that students will gain some knowledge of science, either as conceptual knowledge or knowledge of the nature of science (NOS). Many studies have shown gains in some aspect of NOS views after participating in an internship (Barab & Hay, 2001; Bleicher, 1996; Charney et al., 2007; Cooley & Bassett, 1961; Richmond & Kurth, 1999), while others have shown little or no gains (Bell, Blair, Crawford, & Lederman, 2003). Much of this variation is likely due to different definitions of NOS (Sadler, Burgin, & McKinney, 2007) or to the type of instruction supplied around NOS (implicit or explicit).

One aspect of students' NOS views not studied thus far is the role of teaching in the scientific enterprise. In the single study of an informal science experience based on teaching science, Diamond, St. John, Cleary, and Librero (1987) did not assess whether participants believed teaching was a part of the scientific enterprise, but did find that learning to teach was one of the most salient effects on participants. In particular, they found that "teaching provided many of the students with critical communication skills that proved to be useful in their subsequent work and school" (Diamond, St. John, Cleary, & Librero, 1987, p. 655). The type of communication teaching entails can be considered part of scientific discourse, and yet is not included in NOS discussions.

Student gains in science content knowledge from internships also show mixed results in the literature. In a recent well-designed study of a summer research apprenticeship, Charney, Hmelo-Silver, Sofer, Neigeborn, Coletta, and Nemeroff (2007) found significant gains in biology content knowledge of interns. However, not all interns exhibited equal cognitive gains, and Bleicher's (1996) case study of an intern in a similar program calls into question the depth of such learning. There is also evidence that students who do develop a deeper understanding of science content in a research apprenticeship do not develop critical thinking skills (Hay & Barab, 2001). These few studies illustrate the paucity of evidence supporting cognitive gains in science as a result of participating in science internships, and lead us to question the ability of internships to significantly alter students' knowledge of science.

Combining informal science and astronomy education, informal astronomy education has also seen recent growth as a field, being recognized as a critical research strand for future astronomy education research (e.g., the "Astronomy Education Research Charter" at http://www.aavso.org/astroed/index.php/Talk:The_Astronomy_Education_Research_Charter_Edition_1.0), and becoming the focus of national conferences (e.g., the Astronomical Society of the Pacific's 2005 Conference "Building Community: The Emerging EPO Profession). While there is an increasing emphasis on informal learning environments within astronomy education, there remain few empirical studies on any aspect of informal astronomy education.

Many studies within formal astronomy education focus on understanding student conceptions of astronomical concepts (for a recent review of the literature, see Bailey & Slater, 2004), such as phases of the moon (Stahly, Krockover, & Shepardson, 1999), stars (Bailey, 2007), gravity (Kavanagh 2007), cosmology (Prather, Slater, & Offerdahl, 2002) and the development of instruments to assess these concepts (e.g., Light & Spectroscopy Inventory and Astronomy Diagnostic Test, respectively Bardar & Brecher, 2008; Hufnagel, 2002). These assessments of student learning of astronomical concepts are almost entirely confined to classrooms, especially college classrooms. In addition, there is little more than anecdotal evidence of learning outside of science classrooms (at any grade level).

To expand the research literature on internships and informal astronomy education, this study explored high-school students' knowledge of science during their participation in a museum internship program focused on learning and teaching astronomy. Specifically, this study sought to answer the following four research questions:

1. To what extent do interns believe teaching is part of the scientific enterprise?
2. How do interns use scientific modes of thought?
3. Through what aspects of the internship do interns describe acquiring new science knowledge?
4. What science concepts do interns use most frequently during the internship?

Internship Description

This internship took place over seven weeks during the summer of 2006 at a large natural history museum (hereafter "Museum") in a large northeastern U.S. city. Interns began the internship with a week of training, to familiarize them with the focus of the internship – three hands-on science activity carts set up in the Museum's astronomy exhibit hall. Using activities on these carts, interns worked in pairs to teach science to Museum visitors during the six primary weeks of the internship, working at least 8 hours per week on the carts. Interns also participated in a number of activities as a group during sessions held every Monday of the internship. These activities included a career reflection program, lectures by Museum scientists, and guided exploration time of the Museum.

Methods

This study used a mixed-methods qualitative approach, with examples of results provided by data from two interns. This methodology is based on the idea that there are a multitude of factors that influence individuals and groups of people, therefore dictating a complex and multi-faceted analysis lens (Keeves, 1998). Specifically, semi-structured interviews, three different types of intern-generated artifact (internship application, career exploration reflection, and end-of-internship evaluation), reflective journal entries, direct observations, and audio recordings were combined to form layered descriptions of interns' science knowledge during the internship. The specific methods used are detailed below.

Interviews

Semi-structured interviews were conducted (and the audio digitally recorded) with eleven interns during the fifth and sixth weeks of the internship. The interview protocol was developed specifically for this study using the process model (Chatterji, 2003).

In addition to the semi-structured interviews conducted with eleven interns, a second, follow-up, interview was arranged with one intern (Justine) at her request. This follow-up interview occurred two weeks after their initial interview and was arranged because Justine expressed a desire to talk more about her experiences with the researcher.

Artifact Collection

Three intern-produced documents were collected over the course of the internship to provide a more comprehensive description of interns' characteristics, and to triangulate analyses with other methods. These documents provided demographic information, contextual descriptions, as well as intern-generated narratives. Documents collected included internship applications, reflections done as part of the career exploration program, and end-of-internship evaluations.

Reflective Journal

This study used a daily reflective journal as a naturalistic research method. The journal was a part of the interns' daily ritual, in which they were required to write an entry after each shift working on the carts, reflecting on their experiences that day or describing general thoughts pertaining to the internship. Depending on the number of shifts they worked each day, interns wrote two to four entries per week, resulting in an average of thirteen entries for each intern over the course of the internship. Interns' journal entries span the six weeks they worked on the activity carts, and the resulting public journal is 109 pages. The journal was kept as a public document to which all interns had access and which they were encouraged (but not required) to read.

Direct Observation (Field Notes)

This study used the ethnographic method of direct observation to generate field notes, following the conventions of Lofland and Lofland (1984). Observations were made during interns' work on the carts, when the author acted as an outside observer. From these observations, descriptive field notes were constructed describing the chronological series of events observed between intern(s) and Museum visitor(s). It is important to note that these field notes describe only interns' experiences on the carts and are not therefore a comprehensive description of the internship experiences. They include contextual background (e.g., time of day, relative number of visitors in the Museum hall, other relevant physical factors) and a running commentary on the interactions between intern(s) and visitor(s) primarily, but also secondarily the interactions between interns.

Audio recordings

While interns worked on the carts, a digital voice recorder was used to capture thirteen separate instances of interns' interacting with visitors. Pairs of interns were selected randomly over the course of the internship and their conversations with Museum visitors recorded, for five to twenty five minutes at a time. These audio recordings were done contemporaneously with the direct observations and are therefore paired with the field notes.

All data were analyzed using qualitative data analysis software (ATLAS.ti), using an iterative process to code and synthesize relevant themes. Analyses were guided by the research questions and were emergent from the data.

Population

Eighteen high school students participated in the internship during the summer of 2006. At the beginning of the internship, the youngest was 15 and the oldest was 18. These eighteen interns were demographically heterogeneous, representing at least eight different ethnic groups (including Chinese-American, African American, Liberian, Hispanic, Romanian, Indian, and Caucasian American), multiple socioeconomic groups, and diverse geographic regions. Interns came to the internship from all types of public high school, including specialized schools for science. It should be noted that two of the eighteen interns had participated in the internship during 2005 and were returning for a second year. The following descriptions provide additional details of the two exemplar interns used in this study. These interns (all names are pseudonyms) were selected to represent the range of results found within the data.

Justine. At the time of the internship, Justine was a self-assured and empathetic 18-year-old Caucasian-American who had just graduated from a fine arts high school. She was planning on attending a local university in the fall (on a full scholarship) and was thinking about becoming a history teacher. She had an interest in, but little formal schooling in, science.

Victor. Victor was a 17-year-old Romanian-American and one of two returning interns from the previous year. He had pursued numerous science-related (and astronomy-related specifically) activities outside of school, including taking science classes afterschool at the Museum. He was, self-admittedly, not a social person by nature. He attended a nationally-recognized specialized science high school.

Results

To what extent do interns believe teaching is part of the scientific enterprise?

From an analysis of interview responses, application essays, and career reflection worksheets, 13 of the 18 interns showed some evidence suggesting they viewed teaching as part of the scientific enterprise. Among the thirteen interns who believed teaching was part of the scientific enterprise, three related results support this general result. Some of those interns (1) had their views altered by the internship, (2) cited Museum staff and scientists as examples of people combining teaching and science, and (3) equated teaching and publishing.

Of the interns who believed teaching was part of science (13 interns) and who were interviewed (11 of the 13), four described the internship as changing their view of the relationship between science and teaching. Specifically, these four interns came to see significant overlaps between the jobs of teacher and scientist. The overlap between science and teaching went both directions – with some interns viewing science as part of being a teacher and others viewing teaching as part of being a scientist. Justine was in the former group, and described her new view of science as follows: “Now I consider teaching as being a scientist. Before I just considered a teacher a teacher" (Justine's initial interview). Victor, on the other hand, was part of the latter group, and described his changed view of science as follows: "[being a scientist] is much less singular than I originally thought it would be. It's all about sharing information with people and relying on people's help and that kind of stuff" (Victor's interview). In other of his interview responses, Victor equated sharing information with teaching.

Those interns who described teaching as part of the scientific enterprise often cited Museum staff or scientists as examples of scientists who taught and did research. Justine identified one of the program staff (a Museum educator) as an example of a scientist who also taught. She described how "Zorn is a scientist and he teaches and he still does camp groups, and you know he still does this program and all kinds of different things related to science, not just research" (Justine's initial interview). Similarly, Victor identified a Museum scientist, one who had given a lecture to all interns, as an example of a scientist who incorporated teaching into his work, also noticing that the scientist's work relied more on other people than he had originally thought.

Six of the thirteen interns who described teaching as part of the scientific enterprise also equated teaching and publishing. They viewed publishing as an essential part of scientific work, and made a connection between publishing, specifically, and teaching, generally. Victor exemplified the views of these interns when he said that "you learn something but it's not really … science until it's published. You have to share it so other people learn about and can continue your work, expand it in other directions" (Victor's interview).

How do interns use scientific modes of thought?

From an analysis of interview responses, application essays, career reflection worksheets, and reflective journal entries, evidence suggested that interns used at least six different modes of scientific thought during the internship, including (1) asking and answering questions, (2) generating and testing hypotheses, (3) using logic or reason, (4) doing research, (5) discussing science topics, and (6) feeling skeptical. Although interns exhibited varied degrees of usage, all interns used at least one of these modes of thought. Interns used the first three scientific modes of thought (asking and answering questions, generating and testing hypotheses, using logic or reason) most commonly while interacting with visitors on the activity carts. For example, interns asked visitors questions to attract them to the activity cart (e.g., "want to see how a crater is made?"), to push visitors' learning (e.g., "why do you think a heavier ball will make a bigger crater?"), and to have visitors make predictions about a cart topic (e.g., "which ball do you think will make the bigger crater?"). When visitors asked questions about cart activities, interns provided answers based on knowledge learned during the internship, from their own research, from other interns, or from a school science class. The type of answers they provided depended on their level of content knowledge as well as their level of comfort in explaining science concepts to others. Due to the nature of the internship, all interns asked and answered questions numerous times during its course.

Six interns also generated and tested hypotheses while working on the carts. These hypotheses often related to the science content of the cart activities, as when interns hypothesized that a marshmallow placed inside a plastic bag would not expand when subjected to a vacuum (the related cart activity involved placing a marshmallow into a vacuum chamber and removing some of the air). They tested this hypothesis in front of visitors and on their own, to try different conditions.

Five interns also used reason or logic while working on the carts. In one interesting example, Victor related his use of reason to predict the movement of groups of visitors within the Museum's exhibit hall: "if you are doing stuff on the carts you can reason how the camp groups are going to move, where they are, when they are going to leave." He likened this process to forecasting in meteorology, and provided a detailed description of its implications for his cart practices.

Interns used the last three scientific modes of thought (doing research, discussing science topics, feeling skeptical) almost entirely while not working on the carts. For the nine interns who reported doing research, this meant looking up information, usually in books or on the internet, with the goal of learning more about a science topic. Justine described her attempt to learn more about the science topics she taught on the carts: "I brushed up on all the stuff again, but I really didn't do any hardcore research about any particular topic" (Justine's initial interview).

Science discussions occurred between at least eight interns after shifts working on the carts and with their friends outside of the internship. The discussions for which there is data (those held during the internship but not while working on the carts) were initiated by interns writing in the reflective journal and therefore were about science topics encountered on the carts.

Two interns also reported feeling skeptical in their everyday lives, and they felt strongly that being skeptical was an important part of being a scientist. This skepticism affected their life both in and out of the internship, providing a lens with which they viewed the world around them, or, as one intern put it, “wearing science goggles.”

Through what aspects of the internship do interns describe acquiring new science knowledge?

From an analysis of interview responses, final evaluations, and reflective journal entries, 14 of the 18 interns reported acquiring new science knowledge during the internship. Interns who reported learning science knowledge described this learning as occurring during three aspects of the internship: (1) during the training week, (2) during lectures from museum scientists, (3) and from discussions with other interns. Each of these aspects of the internship affected interns in different ways, with eight interns learning science content from only one aspect and six learning content across two aspects. Specifically, eight interns learned science from the training week, ten from discussions with other interns, and two from scientists’ lectures. Of the six interns who learned from more than one part of the internship, five learned from the training week and other interns while one intern learned from lectures and other interns.

Taught by museum staff, the training week provided several opportunities for interns to learn science content specific to the carts. In both content-focused seminars and sessions where the science content was embedded within the practices of the carts, interns reported learning new science knowledge. The focus of the training, however, was not on learning science content knowledge, but on developing effective pedagogical practices to interact with museum visitors. Victor described the training as “more about how to interact with museum people, the visitors – how to pose questions, how to respond, how to make them think for themselves instead of spouting off the information” (Victor’s interview). All interns found the training valuable, and 15 of the 18 rated it as "very valuable" in their final evaluations.

In its focus on pedagogy, Justine found the training week lacking in its science content, and mentioned in her interview that "the only way I learned certain things about the carts was from Steve, cause he was here last year" (Justine's follow-up interview). Learning science from other interns was a primary method of acquiring new science knowledge for at least two interns, including Justine. Learning science from other interns also occurred while working on the carts, as interns with more extensive science backgrounds taught other interns relevant science content. In addition to acquiring new science knowledge from other interns while on the carts, interns also felt they gained a deeper understanding of certain science concepts by explaining them to visitors.

Unlike Justine, Victor did not find the same faults with the training week because he had participated in the previous year's internship, and described the training week that year as follows: "The one last year was much better in explaining the information. On the Monday sessions we always learned more about why the stuff on the carts, what we should say, and why it works, and how it works specifically" (Victor's interview).

Interns also learned new science knowledge from listening to lectures by museum scientists. During two Mondays of the internship, interns gathered together as a group to listen to a museum scientist talk about their research. Interns greatly enjoyed these lectures (16 of the 18 interns rated it as somewhat or very valuable on their final evaluations), and Justine mentioned that "I would definitely love to learn more stuff like that" (Justine's follow-up interview).

What science concepts do interns use most frequently while working on the activity carts?

An analysis of interns' interactions with visitors (audio recordings and field notes), reflective journal entries, and interview responses revealed that interns used science concepts from over ten fields of science. Not surprisingly, astronomy and physics were overwhelmingly the most common science fields used by interns while working on the carts. Within astronomy and physics, interns used at least 40 specific concepts during their work on the carts. Of these concepts, 12 were found ten or more times within the data. 'Science concept' was used broadly to indicate a scientific term, theoretical construct, tool, condition, or physical artifact. The most frequently used science concepts are presented in Table 1, along with the scientific mode of thought most frequently associated within the data. These results reveal that all but two of the most prevalent science concepts were most often associated with interns asking and answering questions, and five concepts (Crater, Meteorite, Space survival, Temperature, and Prism) were linked to this mode of thought more than 75 percent of the time. The seven remaining concepts were more evenly distributed among the six modes of thought exhibited by interns.

The science concepts used most frequently by interns closely mirrored activities on, and themes of, the activity carts. For example, the theme of one of the carts was planets, and the three most popular activities on that cart were (1) a crater-making activity, (2) a demonstration of the effect of being in space on a human (using a marshmallow as a human analog), and (3) an activity to test the magnetic properties of meteorites. These three activities, linked to the theme of the cart by interns, accounted for five of the most frequently used science concepts (crater, meteorite, planets, space survival, and magnets). The remainder of the most frequently used concepts can be accounted for by activities on the other two activity carts, themed around light and telescopes.

Discussion

Students' knowledge of science is affected by numerous factors, both in- and out-of- school (Dierking, 1991). This study explored four aspects of science knowledge specific to the context of a museum internship for high school students: (1) a belief in teaching as part of the scientific enterprise; (2) the use of scientific modes of thought; (3) aspects of the internship where interns learn science; and (4) science concepts used most frequently while working on the carts.

First, the majority of interns believed teaching was part of the scientific enterprise. This result was somewhat unexpected, because previous research on students teaching science outside of school has found increases in students' interest in learning science (Diamond, St. John, Cleary, & Librero, 1987) and in their teaching skills (Rothenburger, Diem, Van derVeen, & Bellows, 2003) but not in their beliefs about teaching as part of science. This may be because these studies did not focus on this specific aspect of students' knowledge. Additionally, most adults in the United States do not associate teaching with science (a 2003 Harris poll of adults age 18 and over in the U.S. found that 99.7% of respondents did not think of "teaches/educates" as the first thing that came to mind when hearing the word scientist), and these interns may therefore be unique among the greater population. One way to understand the current finding is in the strong link between teaching and science within the internship. Science and teaching were linked in the practices of both interns (in teaching science to museum visitors) and Museum staff (in their perceived role as both scientists and teachers). Thus, it can be hypothesized that the implicit and explicit overlapping of science and teaching within the internship led to a change in interns' views of science to include teaching. Even though there was direct evidence for only 4 of the 18 interns having their views of science changed to include teaching, there were seven additional interns who believed teaching was part of science who may have also had their views altered by the internship (although this is unclear from the data). Further work is needed to determine the actual significance of overlapping science and teaching on interns' concepts of the nature of science. Interestingly, if the hypothesis holds it may suggest that both implicit and explicit factors (such as the degree of overlap between science and teaching practices) are significant for determining students' nature of science views, a result that would bolster work by some researchers (Moss, Abrams, & Robb, 2001; Ryder & Leach, 1999) and conflict with others (Bell, Blair, Crawford, & Lederman, 2003). If true, this would suggest that programs should be designed to incorporate both implicit structures linking practices to science (e.g., teaching) as well as explicit instruction on this aspect of the nature of the scientific enterprise.

Second, interns used at least six modes of scientific thought while working on the carts and at other times during the internship. Three of the modes of thought (asking and answering questions, generating and testing hypotheses, and using logic or reason) were used almost exclusively while working on the carts, while the other three (doing research, discussing science topics, and feeling skeptical) were used during other, "down", times of the internship. In other words, interns' cart practices were associated with an ability to ask and answer questions, generate and test hypotheses, and use logic or reason, whereas doing research, discussing science, and feeling skeptical were not associated with these practices. To understand this finding, it must be noted that Museum staff explicitly taught only one of these modes (asking and answering questions) to interns during the internship. The other five modes must therefore have been brought into the internship, learned elsewhere in the internship, or some combination thereof.

Third, for interns who reported acquiring new science knowledge during the internship, there were three aspects of the internship from which they learned science knowledge: (1) the training week; (2) lectures from Museum scientists; and (3) discussions with other interns. These aspects of the internship align somewhat with previous studies of knowledge gain in internships, which found learning from scientist's lectures (Abraham, 2002) and discussions with scientists (Charney et al., 2007). The type of science each intern learned from these three aspects of the internship varied depending on their background level of science knowledge. Interns with higher levels of background science knowledge generally learned less new knowledge, but gained a deeper understanding of the concepts and saw real-world applications of concepts they already knew about. Those interns also found the training week useful because it allowed them to see science concepts in practice and also found that teaching the concepts on the carts helped them to gain a deeper understanding of the concepts. In contrast, interns with lower levels of background science knowledge generally learned more new science knowledge, and they learned this knowledge during the training week, from other interns and from scientists' lectures. Taken together these results suggest that knowledge acquisition depended on the extent to which interns held background science knowledge; that is, interns who held greater background science knowledge learned less new knowledge, but their level of understanding became deeper. This aligns with work by

Stake and Mares (2001), which found a differential impact on students depending on their level of preparation (experience with a science enrichment program).

Fourth, interns used a large number of science concepts while working on the carts, with the most frequent directly related to cart activities, suggesting that these concepts were learned during the internship. In that line, the concepts used less frequently by interns were almost entirely concepts interns had learned outside of the internship, either in school or on their own time. These results suggest that interns learned only those concepts they encountered while working on the carts. Previous studies on internships have found similar results, with interns learning concepts with which they engaged directly (e.g., Charney et al., 2007).

Conclusions

Interns learned science content specific to the internship, and their science learning was critically linked to social interactions within the internship. Through teaching science content to Museum visitors, talking with other interns about science, listening to Museum staff and scientists, and researching on their own, interns learned science content relevant to their practices within the internship. Seeing the same science content used by different people and in multiple contexts highlighted the multifaceted nature of science and provided interns with a deeper understanding of relevant science concepts.

It is important to note several limitations. First, neither the specific science concepts interns learned nor their depth of understanding of these concepts were studied. These are both meaningful and important aspects of internships, and bear further study (Sadler, Burgin, & McKinney, 2007). Second, results based primarily on interviews likely represent lower bounds. For example, all interviewed interns believed teaching was part of science, but similar evidence was difficult to ascertain for the other seven interns and therefore only a total of 13 interns were found who felt that teaching was part of science.

Acknowledging its limitations, there are several important implications of these findings for both informal educators and researchers. For informal educators, this study reveals the importance of social interactions in learning science, which should be encouraged and supported in informal science programs. It also reveals that by providing opportunities for students to teach science, programs can create meaningful science learning (Diamond, St. John, Cleary, & Librero, 1987). This brings to mind the famous quote by Aristotle that “teaching is the highest form of understanding”. This study also has implications for researchers in science education, to investigate further the longitudinal impact of science learning from internships and to explore the placement of teaching within the nature of science research framework.

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Table 1

Science concepts used most frequently by interns while working on carts.

Science Concept	Number of observed occurrences within data	Most frequently associated scientific mode of thought (percentage of associated occurrences)
Crater	77	Asking and answering questions (96%)
Meteorite	57	Asking and answering questions (79%)
Infrared light	43	Discussing science topics (50%)
Planets	38	Asking and answering questions (40%)
Ultraviolet light	37	Asking and answering questions (58%)
Light	32	Discussing science topics (54%)
Telescope	24	Asking and answering questions (50%)
Space survival	24	Asking and answering questions (89%)
Temperature	17	Asking and answering questions (75%)
Magnets	15	Asking and answering questions (33%)
Spectrum	13	Asking and answering questions (67%)
Prism	10	Asking and answering questions (100%)

Note. The most frequently associated scientific modes of thought are also listed, with their corresponding percentage of associated occurrences within the data. The lower the percentage, the more evenly distributed the associations were among the six possible modes of thought.

VI. STUDY 3: PARTICIPATORY SCIENCE LEARNING WITHIN A MUSEUM INTERNSHIP

Abstract

Six aspects of participatory science learning were investigated within a museum internship for high school students. Internship activities centered on teaching science to museum visitors using hands-on activity carts. From their internship experience, interns found teaching to be the most salient aspect, viewing it as an authentic practice and a path to science learning, as well as providing a sense of ownership in their practices. Also, interns created a unique community within the internship, combining aspects of the pre-established museum educators' community of practice and an internship-centered activity group.

Participatory science learning within a museum internship

An increasingly common belief within science education is that science learning occurs in diverse settings and across the lifespan (Banks et al., 2004). Informal science education, as it is most often termed, has begun to garner attention by researchers and funding agencies and is very likely poised for a rapid expansion in coming years. One promising form of informal science education is internships. The underlying educational theory of apprenticeship learning has long held sway within graduate education in the sciences. Internships for intermediate-grade students, however, are less frequent and are for shorter periods of time.

Barab and Hay (2001) presented six characteristics of participatory science learning experiences, which describe essential characteristics of science learning in internships. The six characteristics are (1) learners do domain-related practices to address domain-related dilemmas, (2) scientific and technological knowledge/practice are situationally constructed and socially negotiated, (3) learning is participatory, occurring “at the elbows” of more knowledgeable others, including teachers, scientists, and peers, (4) practices and outcomes are authentic to and owned by the learner and the community of practice, and are in response to real-world needs, (5) participants become a part of (developing an identity as a member of) a community of practice, and (6) formal opportunity and support for both reflection-in-action and reflection-on-action (Barab & Hay, 2001).

These characteristics provide a conceptual and evaluative framework for defining the degree to which interns engage in participatory science learning. It should be noted that these characteristics were developed by synthesizing research related to apprenticeship learning, sociology of science, and K-12 science education. While not all the synthesized literature is applicable to internships (K-12 science education literature in particular), there are at least two reasons why the characteristics accurately describe the types of experiences occurring in internships. First, these characteristics rely heavily on the theoretical notions of situated learning and the subsequent concept of communities of practice. Communities of practice provide a useful framework for understanding the (inter)actions within groups of learners typical of internships, as they form an ingrained system to learn from during internship experiences (Lave & Wenger, 1991). Second, these characteristics acknowledge the central role of social interactions in creating lasting science learning. In the available studies of internships in which students engage in authentic research, the analyses and program designs rarely focus on the social interactions that occur among interns and other participants, despite the fact that these social components often have the most significant impact on students (Abraham, 2002; Diamond, St. John, Cleary, & Librero, 1987; Grindstaff & Richmond, 2008; Richmond & Kurth, 1999). These interactions may serve a variety of functions, including the construction of scientific knowledge and practices (Barab & Hay, 2001).

Purpose

Six characteristics of participatory science learning (Barab & Hay, 2001) were used as a framework to guide this study, and were expanded or altered based on the specific nature of the internship program. As such, the purpose of this study is to investigate the following six research questions with the overall aim of assessing whether interns engaged in participatory science learning during the internship program: (1) To what extent did interns believe they engaged in authentic scientific practices?, (2) In what ways were scientific knowledge/practice situationally constructed and socially negotiated?, (3) Did interns' learning occur "at the elbows" of teachers, scientists, and peers?, (4) How did interns feel ownership of their internship practices?, (5) In what ways did interns become part of a Community of Practice?, and (6) How did interns use both reflection-in-action and reflection-on-action?.

Methods

Data Sources

Interviews. Semi-structured interviews were conducted (and the audio digitally recorded) with eleven interns during the fifth and sixth weeks of the internship. The interview protocol was developed specifically for this study using the process model (Chatterji, 2003).

In addition to the semi-structured interviews conducted with eleven interns, a second, follow-up, interview was arranged with one intern (Justine) at her request. This follow-up interview occurred two weeks after their initial interview and was arranged because Justine expressed a desire to talk more about her experiences with the researcher.

Artifact Collection. Three intern-produced documents were collected over the course of the internship to provide a more comprehensive description of interns' characteristics, and to triangulate analyses with other methods. These documents provided demographic information, contextual descriptions, as well as intern-generated narratives. Documents collected included internship applications, reflections done as part of the career exploration program, and end-of-internship evaluations.

Reflective Journal. This study used a daily reflective journal as a naturalistic research method. The journal was a part of the interns' daily ritual, in which they were required to write an entry after each shift working on the carts, reflecting on their experiences that day or describing general thoughts pertaining to the internship. Depending on the number of shifts they worked each day, interns wrote two to four entries per week, resulting in an average of thirteen entries for each intern over the course of the internship. Interns' journal entries span the six weeks they worked on the activity carts, and the resulting public journal is 109 pages. The journal was kept as a public document to which all interns had access and which they were encouraged (but not required) to read.

Direct Observation (Field Notes). This study used the ethnographic method of direct observation to generate field notes, following the conventions of Lofland and Lofland (1984). Observations were made during interns' work on the carts, when the author acted as an outside observer. From these observations, descriptive field notes were constructed describing the chronological series of events observed between intern(s) and Museum visitor(s). It is important to note that these field notes describe only interns' experiences on the carts and are not therefore a comprehensive description of the internship experiences. They include contextual background (e.g., time of day, relative number of visitors in the Museum hall, other relevant physical factors) and a running commentary on the interactions between intern(s) and visitor(s) primarily, but also secondarily the interactions between interns.

Audio recordings. While interns worked on the carts, a digital voice recorder was used to capture thirteen separate instances of interns' interacting with visitors. Pairs of interns were selected randomly over the course of the internship and their conversations with Museum visitors recorded, for five to twenty five minutes at a time. These audio recordings were done contemporaneously with the direct observations and are therefore paired with the field notes.

Data Analysis

After all data were collected, a three-step analysis procedure was performed. First, the researcher read or listened to all the data to become re-familiarized with them and to form first impressions regarding their content. Second, an inductive (open) coding of the data was performed (using ATLAS.ti) to establish themes across and within methods. This inductive coding was followed by the third step of re-analyzing the data using the emergent themes as a guide. The final resulting themes allow for comparison across individuals and comprise the majority of the results. Each resulting theme has, as its evidentiary basis, a set of linked tags that correspond to quotes (written or oral), drawings, or other combinations thereof. These sets of quotes and drawings are used to support the themes resulting from the analysis as well as providing support for issues argued within the discussion.

Population

Eighteen high school students participated in the internship during the summer of 2006. These eighteen interns were demographically heterogeneous, representing at least eight different ethnic groups (including Chinese-American, African American, Liberian, Hispanic, Romanian, Indian, and Caucasian American), multiple socioeconomic groups, and diverse geographic regions of the city. Interns also came to the internship from all types of public high school, including specialized schools for science. At the beginning of the internship, the youngest was 15 and the oldest was 18. It should be noted that two of the eighteen interns had participated in the internship during 2005 and were returning for a second year.

Two interns were selected to illustrate the results of this study based on the representative nature of their responses. Brief descriptions follow (all names are pseudonyms).

Leona. Leona was a 16 year-old Caucasian-American who was self-assured but not very social, mentioning that "people isn't really my thing" (Leona's interview). She attended a nationally renowned science high school and was, according to other interns, very smart. Her level of science content knowledge was very high, especially compared to the other interns, and she attributed much of her interest and engagement in science to her father and a few good science teachers. She believed that "the most interesting things, especially in science, aren't usually taught in schools" (Leona's application).

Ashanti. Ashanti was a 18 year-old African-American who was very outgoing and talkative, who could strike up a conversation with just about anyone and got "along with everybody" (Ashanti's interview). Her science background was not as extensive as many of the other interns', especially in the school courses she had taken, but she had taken a number of afterschool science courses at the Museum. She had a difficult home life, with ongoing paternal problems (requiring moving states and police action) and two younger siblings for which she was responsible. One reason she enjoyed the internship was because it allowed her to get out of the house and escape some of her home responsibilities.

Results

To what extent did interns believe they engaged in authentic scientific practices?

Unlike other science internships, the goal of this program was to provide interns with experience teaching and learning science, not “doing” science. Interns had frequent interactions with Museum educators but only limited interactions with Museum scientists, and interns’ daily practices involved, almost entirely, aspects of teaching science to Museum visitors. Thus, an investigation of interns’ beliefs about their engagement in authentic science practices needs to be expanded to include beliefs about their engagement in authentic science teaching practices.

While not all interns believed they engaged in authentic science practices, those who viewed teaching as an integral aspect of science did believe their internship practices were “real” science. Teaching science to Museum visitors was mentioned by interns as an authentic science practice, for example when Ashanti mentioned that teaching is part of science because “you gotta tell everybody else what you discovered and make them understand what it is you discovered” (Ashanti’s interview). Teaching science was the central theme of the internship, and 13 of the 18 interns believed teaching was part of the scientific enterprise. Those interns who held this belief also, logically, viewed teaching science as an authentic scientific practice. This was often equated with the work of scientists, for example when Leona explained how a scientist is “[a]dvancing knowledge, in general” (Leona’s interview), and later in the same interview, how science “wouldn’t proceed at the rate that it does without people like me who have a real interest in what they’re doing and will do it just for the joy of doing it, which is what I see an intern as” (Leona’s interview).

In addition to the broad practice of teaching science to Museum visitors, interns participated in a number of other practices unique to the internship. These practices, identified by internship staff as authentic practices within the internship, included (1) engaging visitors' interest, (2) answering visitors' questions, (3) asking visitors questions, (4) explaining cart activities to visitors, (5) working with camp groups, (6) working with non-English speaking visitors, (7) trouble-shooting problems with equipment, and (8) working with a partner. Responses on the final evaluation (on which interns rated whether or not they had strategies to successfully engage in these eight practices) indicated that interns, as an entire group, believed they had strategies to handle the eight unique internship practices (80 responses for "I developed some strategies for this, sometimes they work, and sometimes they don't" or "I have strategies for this that work most of the time" as compared to 6 responses for "I found this difficult; there should be more on this in training next year"). While not a direct measurement of their engagement in these practices, the final evaluation was a useful proxy to understand their engagement through the use of strategies. Table 1 presents frequency counts for all eight authentic practices.

[Insert Table 1 here]

In sum, the majority (13) of interns believed teaching was part of science and subsequently believed they engaged in authentic science practices during the internship. In addition, interns felt able to participate in practices identified by internship staff as authentic to the internship.

In what ways were scientific knowledge/practice situationally constructed and socially negotiated?

This question explored the ways in which interns engaged in scientific practices with others in the internship, through social interactions. There were countless instances of interns interacting socially with others during the internship, only some of which were important for constructing scientific knowledge and practice. The types of interaction used most frequently by interns and which resulted in science learning were discussion (10 of 18 interns), explanation (18 of 18 interns), and argumentation (2 of 18 interns).

Discussions on the carts between and among interns and Museum visitors were salient for many interns' science learning. Evidence suggests at least ten interns learned new science knowledge and deepened existing science knowledge from these discussions, which took place during their daily work on the carts. Discussions among the interns about the cart activities almost always involved one intern who felt knowledgeable about the science and one who felt less knowledgeable about the science. Sometimes these discussions sparked learning that occurred outside the internship. For example, Ashanti related in one of her journal entries how she had asked Leona

> "about the spectral tube, because on the wall behind us was this little bio about Cecilia Payne who did research on spectral analysis of stars, and the wall said that it's not the chemical makeup of stars that determine the spectrum, but the temperature. She told me to disregard the wall, so I did. But…any info or explanation would be good, because I'm now officially confused" (Ashanti's journal entry, August 4th).

After this discussion Ashanti did some research on her own to answer her question, an indication that the discussion prompted her to learn about stars in greater detail. Ashanti, as well as at least three other interns, described other instances of discussing science topics with Leona, who they felt was "so smart – it's like a breath of fresh air" (Ashanti's interview). Leona confirmed that she would talk "to anybody" about science, and enjoyed doing so.

Similar to the discussions among interns, interactions between interns and Museum visitors deepened interns' science content knowledge. Specifically, when interns explained the science of the cart activities to Museum visitors, they came to hold a deeper understanding of those concepts. The power of explaining science concepts for interns' understanding was well noted by all the interns as well as program staff. Leona spoke about her belief that

> "anybody can read out of a textbook and recite it word for word, but once you're explaining you really get a deeper understanding of it. You don't really understand something that's really complex until you can explain it to your 8 year old sister and she understands it" (Leona's interview).

As an example of an intern getting a deeper understanding of science through discussion, Ashanti better understood the concept of weight after discussing how weight was different on different planets. Initially, she described the difference as due to some aspect of the "center of gravity" of the planets, and after talking with her fellow intern she extended her understanding of weight by exclaiming that

> we should live on the Moon, okay. The moon you'll weigh like nothing. But if you live on the Sun you'll weigh... [laughs] I wouldn't want to live on the Sun. I think you'd weigh like a thousand pounds on the Sun (Audio Recording, July 27th, Planet Cart).

Unlike discussion and explanation, interns engaged in scientific argumentation (i.e., forming logical arguments from evidence) only rarely during the internship. The two documented instances of interns using argumentation occurred when an intern's understanding of a science concept conflicted with that of a visitor or other intern. For example, one of Leona's peers disagreed with her regarding the underlying physics of the optics in one of the cart activities. In this instance, the other intern described using previous knowledge, as well as logic and reason, to come to a common understanding with Leona. The intern also described how the disagreement "motivated me to review and touch up on my optics" (Reflective Journal, July 12th).

Did interns' learning occur "at the elbows" of teachers, scientists, and peers?

The internship's training week was structured around a cognitive apprenticeship model (Collins, Brown, & Newman, 1989), and guided interns from no knowledge of the carts to a working knowledge within just a few days, from "newbies" to core participants in the internship's practices. In this model, interns worked through the following steps in their movement from cart novice to cart expert: (1) experiencing learning situations that modeled proficiency, (2) providing coaching and scaffolding as interns became immersed in authentic activities, (3) slowly removing scaffolding as interns developed competence, and (4) providing opportunity for independent practice so interns could use practices specific to the carts in varied situations. The only time interns learned at the elbows of Museum staff was during this training week, and even then it was short-lived (just the first few days). The small amount of time spent working closely with Museum staff was not deemed adequate preparation by at least one intern, before being sent off to work a full shift on the carts with only a partner. Interns did feel they could ask the program staff for help, or for answers to questions, at any time during the internship, and they learned useful science content this way. For example, Leona said that "there are people in the staff who know a lot about this stuff and you can just go up and ask them if something totally baffles you" (Leona's interview).

Even though it was condensed into a short time, the training week did provide interns with a substantial amount of the essential practices and knowledge they needed for their work on the carts (albeit not gained from working closely with experts). Interns' learning from Museum scientists was even more limited. Through two lectures from scientists, interns learned varying amounts of science knowledge, none of which occurred "at the elbows" of these scientists. Also, all of the instruction was lecture format and there was no exposure to science practices.

Beyond the training week, the majority of the science knowledge and practices interns learned occurred while working on the carts, either from other (more knowledgeable) interns or from direct experience with cart activities. At least two interns described apprenticeship-style learning while interacting with returning interns on the carts, particularly for acquiring different ways of explaining activities and for learning practical cart practices that they were not otherwise taught. Learning from other interns, however, was not as significant as learning through direct experience teaching science to visitors, which became the most important form of learning after the training week (see previous section for additional results pertinent to this point). Whenever interns worked on the carts, they were confronted with many different groups of people, some large, some small, as well as a dizzying array of languages, cultures, ages, and learning styles. For all these various people, the interns had to find ways to explain difficult science concepts using the specific activities contained on the carts. Within these constraints, interns tried out many different strategies and techniques with their existing knowledge, often using creativity or trial and error. During their time on the carts, interns came up with unique (but not always scientifically accurate) explanations for numerous different science concepts, and these explanations reflected the personality, knowledge, and interests of the interns who came up with them. In one such case, a group of three interns decided to name marshmallows used for a demonstration of air pressure. They drew a face on each marshmallow and gave it a name based on a character from a popular reality television show at the time, and proceeded to use the name when explaining the demonstration to visitors. This strategy worked well to connect with many visitors, especially those familiar with the television show. In another instance, a returning intern used a black plastic bag to hide their hand from visitors, which was subsequently revealed when looking through the infrared camera. There were also examples of interns using their language abilities to communicate with foreign visitors, as when one intern spoke French to a young couple in order to explain a cart activity to them. There were many other, similar, instances of interns using their creativity and interests to tailor explanations and this was a primary way that interns learned practices (and sometimes knowledge) from their experiences on the carts.

In sum, interns' learning did not occur "at the elbows" of teachers, staff, or scientists, and occurred in only limited ways from more knowledgeable peers.

How did interns feel ownership of their internship practices?

Interns felt ownership of their internship practices across numerous dimensions, including personal, procedural, and identity. In the personal dimension, interns described feeling proud, empowered, and excited about their internship practices. They took pride in the work they did on the carts, enthusiastically sharing their experiences with parents, siblings, friends, and sometimes even strangers on the subway. The internship, for some, was their "entire life" (Leona's interview) and they felt a sense of empowerment in the way it helped them overcome difficulties in their life. These difficulties ranged from family problems at home to difficulty working with people and were especially important for at least three interns who described the positive impact of the internship on their social skills. All but one intern also showed some form of excitement when working on the carts (five explicitly mentioned being excited), and they often shared this excitement with visitors. Ashanti recognized the importance of her excitement for visitors when she explained that she tried "to get the excitement up so that they can be interested in what I have to say, that way if they're excited I'm excited" (Ashanti's interview). Ashanti was one of the most outwardly excited interns in her work on the carts, often raising the overall energy level of the other interns she was working with.

In the procedural dimension, interns provided numerous recommendations and pieces of useful information for other interns to use while working on the carts. For example, Ashanti described her technique of giving visitors a short oral quiz before giving them a set of photochromatic beads (beads that change color when exposed to ultraviolet light), while Leona wrote a journal entry about a technique she used to attract visitors to one of the carts. Interns shared their recommendations and information through discussions and the reflective journal. Some of these recommendations came from creative usage of materials, such as when Ashanti tested visitors' sunglasses using an ultraviolet light and photochromatic beads. Other times, the recommendations resulted from an experience they had with a visitor, as when Leona simplified a description of spectra based on the age of the visitor.

New identities taken on by interns also provided evidence for interns feeling ownership of their internship practices. Specifically, interns took on identities linked to their internship practices, often contrasting them with their school identities (all of the interviewed interns believed they had a role in the museum different from school). One noted difference between the internship and school was that they were not just learning, but were also teaching and felt they were not passive actors. For example, Ashanti exemplified the thoughts of many interns, who believed their role in the Museum was "to educate people, and to enjoy it while we are doing it. It's also a learning experience for us" (Ashanti's interview). This was in contrast to their school experience, which the interviewed interns viewed as being more controlled/passive (eight of eleven interns), not as fun as the internship (five of eleven interns), and more stressful (three of eleven interns).

In what ways did interns become part of a Community of Practice?

Interns became legitimate members in two nested communities of practice – of the Museum staff and of the internship. Eleven interns (all of those whom were interviewed) saw their work during the internship as authentic to the needs of the Museum and they felt as though their role was a legitimate one. They saw their role as an intern as "an extension of the museum" and the internship as "a hands-on approach to the museum" (Leona's interview). They felt like insiders when they visited the Museum because they had experienced the Museum as a worker instead of as a visitor, and they felt many of their practices were authentic ones. As part of the internship, interns were asked to take on many of the practices and tools used by Museum staff, such as strategies to teach visitors about particular science concepts and the specialized demonstration equipment used to engage the visitors.

Within the broader community of the Museum, the interns also became part of the smaller, nested, community of the internship. Unlike the community of practice of Museum staff, the internship community did not exist prior to the beginning of the internship. This smaller, and shorter-lived, community of practice began from the larger Museum educator community (during the training week) but rapidly took on its own set of relations that set it apart. For example, interns felt a strong connection to the internship community, finding commonalities in their general interests as well as their specific internship practices, and they differentiated themselves as a group from other youths working in the Museum. To be accepted into the internship, interns had to exhibit an interest and excitement for science and this interest was a commonality among all interns. They also felt the internship was a safe place to "act smart", as when Ashanti contrasted her friends at school to those in the internship:

> "The kids that I work with, the intelligence level is really great because kids like Leona, she's like so smart – it's like a breath of fresh air because the people that I hang out with at school are just stupid" (Ashanti's interview).

Interns also found common ground through their internship practices, especially their cart practices. After only a short training on the carts, the interns were placed as core participants on the carts, with roles essential for their operation and success. The experiences while working on the carts provided interns with numerous stories, anecdotes, and recommendations, and they shared these with each other throughout the course of the internship. Leona described this as "[e]verybody has something in common to relate to other people by" (Leona's interview).

How did interns use both reflection-in-action and reflection-on-action?

Interns were provided with a daily opportunity to reflect on their actions, through the reflective journal. All interns took the opportunity to write in the journal about their experiences on the carts. The journal was used in at least seven related ways, including (in decreasing order of frequency) to (1) describe practical aspects of daily activities, (2) describe problems that arose on the carts, (3) provide recommendations for cart practices, (4) tell stories, (5) socialize, (6) communicate to program staff, and (7) ask questions about science content. One of the most interesting aspects of interns' journal usage was in their high degree of thoughtfulness and insight when describing how to best interact with specific types of visitor. For example, interns provided many recommendations for working with summer camp groups, which often came into the exhibit hall in groups of more than 100 students. Ashanti recommended that "when on the Telescope Cart , please, when you give out the goggles to campers tell them that if they don't STAY NEAR THE CART, <u>THEY DON'T GET GOGGLES</u>!!" (Ashanti's journal entry, July 11th). Not all interns' entries were insightful, and the content and length of their entries varied greatly. In many entries, interns were direct and used youth language to tell stories or socialize. In this way, they made the journal their own, thereby altering its usage from its intended use as a space to reflect on their practices. Furthermore, they were cognizant of the shift from intended usage to actual usage.

Opportunities for reflection-in-action were not directly supported, unlike those for reflection-on-action (through the reflective journal). Interns did, however, engage in discussions while they worked on the carts, and some of those discussions were reflective in nature, especially when interns were confronted with difficult visitor questions or challenged by another intern. These types of discussions occurred rarely though, and were underutilized by interns. For additional details regarding this type of discussion, see the second results section.

Discussion

Internships have been touted as a promising method to involve students in authentic science learning experiences and participate in scientific practices as apprentices (Abraham, 2002; Barab & Hay, 2001; Bell, Blair, Crawford, & Lederman, 2003; Charney et al., 2007; Davis, 1999; Etkina, Matilsky, & Lawrence, 2003; Richmond & Kurth, 1999). This study investigated a unique internship designed to involve students in both the learning and teaching of science within a museum setting. To assess the degree to which interns engaged in participatory science learning, the evaluative framework laid out by Barab and Hay (2001) was used, with modifications based on the specifics of the internship program. We found slight modifications to be necessary to account for the design of the internship, especially the focus on teaching science. From an analysis of interview responses, reflective journal entries, collected artifacts, direct observations, and audio recordings, results indicated varying levels of engagement in the six aspects of participatory science learning. Looking across results, two primary findings emerge.

First, teaching science was the most salient aspect of the internship for interns, cutting across all six characteristics of their participatory science learning. Specifically, interns viewed teaching as an authentic practice, learned new (and deepened existing) science knowledge through their teaching, felt ownership of their teaching across multiple dimensions, generated a community of practice based on their teaching, and reflected on several aspects of their teaching. This makes sense in light of the central role teaching played in all of their internship experiences. This finding extends previous work that found social aspects of internships to be most salient (Abraham, 2002; Diamond, St. John, Cleary, & Librero, 1987; Grindstaff & Richmond, 2008; Richmond & Kurth, 1999), by revealing teaching as an important factor within this internship.

Second, interns came to hold a feeling of ownership and identity around their internship practices, and these practices constituted a unique community of practice based around the internship. Unlike other internships reported upon in the literature (see e.g., Barab & Hay, 2001), the community of practice interns generated in this internship both began and ended with the internship. This finding broadens the conventional sense of community of practice, defined as an already existing set of relationships between people, actions, and the world to which new participants may join as legitimate peripheral participants (Lave & Wenger, 1991). In this study, interns did begin the internship by joining the already existing community of practice of Museum educators (during the training week), but their internship experiences very rapidly moved them in a new direction. Thus, the training week provided the seed for a new community of practice, in which interns created a distinct set of practices, relationships, and identities that set them apart from the Museum educators' community. One possible way to view this new community of practice is as a nested community within the larger community of Museum educators, because the interns did feel their practices were authentic to, and in response to the needs of, the Museum community. Another way to view this new community is as an activity group, a “temporary coming together of a group of learners around a shared task intentionally designed to support learning” (Hay & Barab, 2001, p. 292). Activity groups do not, however, exhibit close links to already existing communities of practice and are therefore not a fully adequate categorization for the unique type of community instantiated within this internship. Thus, the distinctive community formed by interns may be classified as a combination of a community of practice and an activity group, joining the temporary nature of activity groups to the entrenched relationships found in communities of practice.

We recognize a couple specific limitations to this study. First, only 11 of the 18 interns were interviewed and some of the quantitative results may therefore represent lower bounds. Second, results of this study may be limited in their generalizability, as the internship program studied was unique in many regards. However, an attempt was made to provide sufficient detail so results of interest could be interpreted for other contexts.

Conclusions

Taken together, results suggest that many aspects of interns’ experiences during a museum-based science internship can be classified as participatory science learning. This is true even though the internship was not explicitly designed to provide such an experience, and was instead meant to provide interns with experience teaching and learning science in a museum setting. Their experiences teaching science to Museum visitors were, in many respects, the most significant experiences for interns. Also of note, interns developed a unique form of community combining aspects of both communities of practice and activity groups.

Implications

Results of this study imply a number of results. First, providing authentic opportunities for internship participants to teach may strengthen their engagement in participatory science learning and such opportunities should therefore be studied in greater detail within other internships. There is a dearth of research on such programs, with only one peer-reviewed study examining the impact of teaching on students within a museum setting (Diamond, St. John, Cleary, & Librero, 1987). There is, however, literature on students collaborating with (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997) and tutoring their peers (Topping, Peter, Stephen, & Whale, 2004) within classrooms. Thus, even though these studies did not investigate participatory science learning as such, their exploration of aspects of teaching suggests that programs within informal learning environments may be able to learn from research in formal learning environments.

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Table 1

Frequency counts for interns' final evaluation of their cart practices.

Cart Practice	Possible Response Statements and their frequency			
	I found this difficult; there should be more on this in training next year	I developed some strategies for this, sometimes they work, and sometimes they don't	I have strategies for this that work most of the time	I enjoy this part of the job
Engaging visitor interest	0	4	8	6
Answering visitor questions*	1	2	6	8
Asking visitor questions	0	6	7	5
Explaining cart activities to visitors	2	2	2	12
Working with camp groups*	1	7	6	3
Working with non-English speaking visitors	2	8	4	4
Trouble-shooting problems with equipment*	0	6	10	1
Working with a partner	0	0	2	16

* Cart practices have only 17 responses, as one intern circled multiple statements and were therefore discarded

Note. For each cart practice, the number of responses for a given statement indicates the number of interns who circled that statement for their response.

VII. SUMMARY & DISCUSSION

This chapter summarizes the major findings from the three studies, discusses broad conclusions drawn from across the studies, and provides implications and limitations of this dissertation.

Summary of Major Findings

Study 1: Attitudes toward science in a museum-based internship

In the first study examining interns' attitudes toward science, there were four major findings. First, interns held mixed views of themselves as scientists (herein called "scientist identity"). The extent to which interns held a scientist identity depended on the degree to which they made a distinction between the practices of professional science and everyday science. That is, interns who made a distinction between professional and everyday science were less likely to hold a scientist identity whereas interns who did not make this distinction were more likely to hold a scientist identity.

Second, the majority of interns wanted to pursue science as a career and the internship solidified, but did not change, their career aspirations. Even though the internship did not appear to change interns' career aspirations, it did provide them with additional insight into science careers, including details about the daily practices of scientists and additional paths to engage in science activities without becoming a scientist (e.g., a museum science educator).

Third, interns reported four primary reasons for their positive feelings toward science: (1) viewed science as a common link between themselves and their friends/families; (2) felt curious about science; (3) believed science was fun; and (4) were interested in teaching others about science. The internship strengthened their views, but did not make them more or less positive. By altering their existing views of science, interns did not report feeling more or less positive about science, but did report knowing more about the practices of scientists.

Fourth, interns pursued many science activities outside of school in addition to the internship. Of the twelve reasons they provided for pursuing these activities, the most frequently cited ones were to gain science knowledge and to share their interest in science with others.

Study 2: Learning and teaching science in a museum-based astronomy internship

The second study investigated four aspects of interns' knowledge of science, and there are correspondingly four major findings. First, the majority (13 of 18) of interns viewed teaching as part of the scientific enterprise and had their views altered by the internship. Specifically, interns who believed teaching was part of science had their beliefs changed by the internship, believed Museum staff and scientists were the embodiment of combining teaching and science, and equated teaching with publishing.

A second major finding was that interns used at least six modes of scientific thought while working on the carts and at other times during the internship. Three of the modes of thought (asking and answering questions, generating and testing hypotheses, and using logic or reason) were used almost exclusively while working on the carts, while the other three (doing research, discussing science topics, and feeling skeptical) were used during other, “down”, times of the internship.

Third, the majority (14 of 18) of interns reported learning science knowledge from the training week, scientist’s lectures, or discussions with other interns. Some interns learned the science from only one aspect of the internship, while others learned science across contexts.

The fourth major finding from study two was that interns used science concepts from over ten fields of science, 40 concepts within astronomy and physics alone, and 12 concepts found ten or more times within the data. The 12 concepts interns used most frequently closely paralleled the activities on and themes of the carts.

Study 3: Participatory science learning within a museum internship

In the third study, six characteristics of participatory science learning within the internship were studied. The six major findings are as follows. First, interns who viewed teaching as part of the scientific enterprise believed their internship practices were authentic scientific practices. Authentic practices included teaching science to visitors, as well as engaging their interest, asking them questions, answering their questions, and working with diverse types of visitor (camp groups, non-English speaking, etc.) and partners.

Second, interns engaged in social interactions that resulted in learning science knowledge or practice, including discussion, explanation, and argumentation. These interactions occurred with other interns and with visitors during interns’ work on the carts.

Third, interns learned authentic internship knowledge and practices briefly from Museum staff and extensively from other interns and direct experience. Their experiences during the training week were structured for cognitive apprenticeship but were for only a few days, while their experiences on the carts were ongoing for the six primary weeks of the internship and involved learning from other interns and their experiences with visitors.

Fourth, interns felt ownership of their internship practices along the three dimensions of personal, procedural, and identity. Personal ownership included feeling proud of, empowered by, and excited about their internship practices. Procedural ownership included providing recommendations for cart-based teaching practices. Identity ownership included the "taking up" of new identities, as a museum insider and in contrast to their school identity.

Fifth, interns became legitimate participants in two nested communities of practice, of Museum staff and of the internship. They associated most strongly with the internship community, which was initiated by interns and reproduced continually over the course of the internship.

Sixth, interns used the reflective journal to reflect on their daily internship experiences, describe problems that arose on the carts, provide recommendations for cart practices, tell stories, socialize, communicate to program staff, or ask science content questions. The reflective journal was an integral part of the internship, and it supported interns' reflection-on-action. Reflection-in-action was not similarly supported, and interns rarely engaged in this practice.

Discussion

The impact of teaching in informal settings

Teaching science undergirded most of the major findings in the three studies, in everything from interns' reasons for feeling positively about science, to the knowledge they used during the internship, to their strong sense of ownership of their internship practices. As a social interaction, teaching science to Museum visitors grounded the practices of interns in a community of practice and was the vehicle through which they formed strong social bonds with other interns. As the central aspect of the internship, teaching was the primary method through which interns learned science and it provided them an opportunity to talk about something about which they were passionate and receive positive feedback for doing so.

Results from this dissertation suggest that informal settings can offer opportunities for students to engage in learning experiences not found in typical formal settings. These types of experiences, most notably teaching, are more exploratory in nature. In other words, by taking on the role of teacher, students explored science concepts and their knowledge of those concepts in a novel fashion (i.e., in a different form than their interaction with school science). Through interpreting science for a diverse public and incorporating personal and creative touches, students took ownership of their science teaching practices. Thus, teaching within informal settings may serve to enrich the ways in which students engage in science, including their science practices and the ways they view themselves within those practices. That is, interns' views of scientific practices came to include their practices within the internship (primarily teaching), thereby expanding their view of science.

In summary, teaching and learning were vitally linked within the internship, and their relationship structured most of the central findings in this dissertation.

Social aspect of internship

Social aspects of internships have been identified as some of their most salient characteristics (Abraham, 2002; Diamond, St. John, Cleary, & Librero, 1987), and this dissertation supports that conclusion. Specifically, social interactions provided the basis for interns' science learning, a feeling of ownership of their cart practices, the development of identities as part of a community of practice, and the making of friends.

The social interactions were varied and included types of scientific discourse (discussion, argumentation, and explanation) and practices (asking and answering questions, etc.). The social interactions were also novel for interns, in that they provided an opportunity to connect with individuals similar to themselves in terms of their interest in science and their intellectual abilities. This was especially salient for those interns who had previous difficulties relating to their peers and who were able to easily form friendships with their co-interns. Social bonds were facilitated by the opportunity to reflect on their practices with other interns, specifically through the use of the public journal.

One way to understand the importance of social interaction is through sociocultural theory. Sociocultural theory implies that interns' learning can only be understood within the framework of the Museum generally, and the internship specifically. The Museum and internship provided the institutional and organizational frameworks within which the interns could participate in authentic practices, learn relevant science knowledge, and become part of a community of practice. If we imagine that the interns, along with the carts, were taken out on the street away from the Museum, the experience of the interns would have been completely different. As such, the carts played a central role as objects for learning (Leinhardt & Crowley, 2002) within the internship, and when viewed thusly they take on an importance that is tied closely to the overall context of the Museum's learning environment.

In summary, social interactions play a pivotal role in the experience of interns and in the impact of the internship on their attitudes toward, knowledge of, and participatory learning of science.

Contextualization versus transferability of science content knowledge

The science content knowledge that interns learned was specific to, and resulted from, their practices in the internship; this provides evidence for the contextualization of their science content knowledge. For example, interns contrasted their science knowledge from school to that which they learned during the internship. Further, the science content presented to visitors was specific to the cart activities.

On the other hand, even though interns did not explicitly view a connection between their school knowledge and that used during the internship, in fact a connection existed. A connection between informal and formal learning was forged by interns using prior knowledge and adapting it to fit specific cart activities, providing evidence for the transferability of their science knowledge.

Thus, it is important to note that there was evidence for both the contextualization and transferability of science knowledge. The key distinction was whether results were viewed subjectively or objectively, with intern's perceptions (subjective) supporting contextualization and their practices (objective) supporting transferability. While it is widely believed that science knowledge depends strongly on the context in which it was learned (Millar & Driver, 1987), there is also substantial evidence suggesting that prior knowledge is beneficial for learning new knowledge (Pintrich, Marx, & Boyle, 1993). Taken together, these suggest that learners may be most successful when they are able to use their prior knowledge in a flexible way so as to better understand new information (Anderson, 1990).

Another way of understanding this arises from the conceptual change literature, which describes a difference between assimilation (integrating new information into a new framework) and accommodation (integrating new information into already existing alternative frameworks) (Pintrich, Marx, & Boyle, 1993). More specifically, interns exhibited instances of both assimilation (e.g., developing an understanding of science topics unique to the internship) and accommodation (e.g., adapting prior knowledge to fit activities on the carts).

Implications

There are a number of implications of this study, especially for educational researchers, informal educators, and astronomy educators.

For educational researchers

Calls have been put forth to conduct research in informal settings with multiple methods (Rennie, Feher, Dierking, & Falk, 2003) and with a sociocultural framework

(Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003). This work answers these calls and furthers the research agenda within education by suggesting directions for future research while noting limitations of such work. Specifically, the use of naturalistic and ethnographic methods (e.g., reflective journal and direct observation, respectively), combined with self-report data (e.g., semi-structured interviews) can form rich descriptions of the various effects found within informal settings, including social interactions.

For informal educators

Opportunities to teach science are rarely provided, either in or out of classrooms, and this work points to the great promise such opportunities may hold for learning and participating in science and for holding positive attitudes toward science. Informal educators could benefit from incorporating teaching into existing programs or designing new programs around the teaching of science. Teaching expands on the personal nature of learning within museums (Rennie & Johnston, 2004) by involving participants directly in learning, synthesizing, and explaining information. It allows participants to take ownership of their knowledge and present it in a way that suits them best, using their creativity, prior knowledge, and personal experience. An interesting conjecture meriting further exploration is that providing opportunities to teach science within informal settings may lead to greater participation in careers related to science teaching. In other words, informal science teaching experiences may be an entry point into the science teaching pipeline. While there is no direct evidence within the current study to suggest this, there are subtle hints that support making such a conjecture.

For informal educators to properly incorporate teaching into their programs, the intended audience for the teaching should be considered. By taking into account the intended audience, informal educators can support best practices in teaching through program structures. For example, if the current internship had built in opportunities during the training week for interns to practice a single activity with different types of Museum visitor, it may have provided an opportunity to showcase the type of creative and dynamic teaching practiced by museum educators (Tran, 2007). Similarly, the programmatic structures needed to support an intern expected to teach a group of peers and scientists during a final presentation in a summer research program may include sessions to practice their presentation with peers and mentor scientists, or, possibly, a guided viewing of a talk by an established scientist. In either of these cases or in the myriad other types of informal science education program where teaching may be included, it is essential to incorporate opportunities for students to experience and try out successful teaching practices with their intended audience.

The specific pedagogical techniques used by students will also differ based on the audience, and one idea this work made clear was that giving students opportunities to teach different types of people (e.g., families, non-English speakers, large groups of young kids) allowed them to develop ownership of their pedagogy, as well as a deeper understanding of the relevant science content. Thus, if informal educators desire to create a more robust set of pedagogical techniques specific to informal science education, it will be important to engage numerous types of audience in this endeavor. Doing so will not only allow informal educators to take ownership of their pedagogy but may also strengthen their content knowledge.

For astronomy educators

This type of experience peels back the mystique of astronomy to reveal the accessible and real aspects. While it may not serve to produce more astronomers, internships like this do serve to produce more individuals interested in and with a personal connection to astronomy. As Ben (one of the interns) put it, "…when you expand the interest of kids in science, you raise the potential of them going into science, as well as with more interest more people will spend more funding on science" (Ben's interview). Those involved in astronomy education, from practicing astronomers, to teachers, to educators engaged in public outreach, can use the results of this work to create activities and programs that draw on the strengths of the internship. Allowing opportunities for students to teach the science content to others (peers, teachers, etc.) may be an especially salient way to engage them in astronomy content.

This work also reinforced the idea that internships based on teaching can strengthen the science knowledge of participating interns, thus introducing another form of learning experience for those hoping to bolster the astronomy content of students. In other words, a good way for students to learn astronomy is to teach astronomy.

Limitations

All three studies in this dissertation used some form of case study to present results. A recognized limitation of case studies is their reliance on a small number of participants, greatly limiting their generalizability. Their strengths lie in their rich descriptions of experiences, not their ability to generalize to other contexts. Whenever possible, results were presented quantitatively and supported by case studies.

The research methods used in this dissertation were not able to infer causality directly, as there was no retesting done on any measure. In some cases though, interns self-reported changes due to the internship and these reports were taken as evidence for causality in specific instances.

Many of interns' experiences during the internship were not studied, as I was not with all interns throughout the entire internship. This limitation is common in ethnographic studies, and is remedied by familiarity with the setting, collection of corroborating data, and careful attention to the selection of activities to be monitored (Bernard, 1988; LeCompte & Preissle, 1993).

Perhaps most notably, there are significant limitations to the generalizability of this study, as the internship was unique in at least two regards. First, the majority of the internship practices were centered on teaching science, not learning science. Second, teaching occurred with physical objects within the larger context of an internationally-renowned artifact-based natural history museum. Thus, these findings may only apply to other internships based on teaching in artifact-based museums and not to research apprenticeships or student-scientists partnerships (two common modes of internship). However, there were some commonalities between this internship and other forms of internship. Specifically, the training week was similar to training periods within research apprenticeships (e.g., Etkina, Matilsky, & Lawrence, 2003) and also provided opportunities for peer socializing similar to research apprenticeships (e.g., Abraham, 2002) and a museum-based internship (Diamond, St. John, Cleary, & Librero, 1987).

Results may also be applicable to specific types of informal learning environment, in particular those that are based on teaching and learning with objects. The types of teaching and learning experiences that occur in these types of environments may overlap enough with specific aspects of the internship (such as interns' experiences on the carts) to allow for meaningful application of the results.

Recommendations for Future Research

This dissertation suggests at least two directions for future research. First, longitudinal studies of this (and similar) internship program(s) would greatly enhance our understanding of the longevity of the results presented in this dissertation. Following up with interns in the months and years after the internship ended would provide insight into the long-term impacts of the internship.

Second, future studies should include both quantitative and qualitative methods, to capture the products as well as the process of participation in internship programs. Specifically, these types of studies could benefit greatly from more specific data quantifying gains in science content knowledge, to bolster the more rich and descriptive qualitative findings. In addition, methods to capture both cognitions and behaviors would allow a disentanglement of contextualization versus transferability of science content knowledge.

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APPENDIX

Semi-structured Interview Questions

1. Do you speak languages besides English?
2. Do you like science? Do your friends?
3. Who lives at home with you?
   - 3a. Do you ever talk with them about science and/or internship?
   - 3b. Are they supportive of your participation in the internship?
4. How have previous experiences prepared you for this internship?
5. What kind of activity do you think works best with visitors?
6. Is there a type of visitor that learns the most from you? The least?
   - 6a. What do you think they learn when they interact with you? Evidence?
7. What are some feelings you experience when you're working on the carts?
8. Tell me about a time when you used your personal experience while working with visitors.
9. Describe what you do for the internship as if I were a stranger.
10. During the internship, have you ever had a chance to work with experts?
11. Do you think you have a role within the museum?
    - 11b. Do you think you have a role within the field of science?
12. How is this internship different from school?
13. Imagine someone who is doing science and describe for me what this person is doing.
    - 13a. Have you done any of these things during the internship?
    - 13b. Do you think these activities were real science?
14. Has the internship changed your view of science? How?
15. Did you learn any science during the internship? When?
16. How is what you do now different from when you started the internship?
17. What kinds of things do you write in the journal?
    - 17a. What do you think the role of the journal is?
18. Tell me about what it's like to work with the other interns.
    - 18a. Have you made any friends?
19. Do you feel like you are part of a community?
20. Do you ever think of yourself as a scientist? If so, how?
    - 20a. Do you think teaching is part of being a scientist? Why?
    - 20b. Do you ever talk or think like a scientist?
21. Do you see yourself pursuing a science-related career?
22. What was the best part of the internship?
23. What was the worst part of the internship?
24. If you could tell one thing to an intern next year, what would it be?