TRAN, LYNN UYEN. Teaching science in museums. (Under the guidance of Drs. John Penick and Eileen Parsons)

ABSTRACT

Museums are free-choice, non-threatening, non-evaluative learning and teaching environments. They enable learners to revisit contents, authentic objects, and experiences at their own leisure as they continually build an understanding and appreciation of the concepts. Schools in America have used museums as resources to supplement their curriculum since the 19th century. Field trip research is predominantly from the teachers' and students' perspectives, and draws attention to the importance for classroom teachers and students to prepare prior to field trips, have tasks, goals, and objectives during their time at the museum, and follow up afterwards. Meanwhile, museum educators' contributions to field trip experiences have been scantily addressed. These educators develop and implement programs intended to help students explore science concepts and make sense of their experiences, and despite their limited time with students, studies show they can be memorable. First, field trips are a break in the usual routine, and thus have curiosity and attention attracting power. Second, classroom science teaching literature suggests teachers' teaching knowledge and goals can affect their behaviors, and in turn influence student learning. Third, classroom teachers are novices at planning and implementing field trip planners, and museum educators can share this responsibility. But little is reported on how the educators teach, what guides their instruction, how classroom teachers use these lessons, and what is gained from these lessons. This study investigates two of these inquiries.

The following research questions guided this investigation. (1) How do educators teaching one-hour, one-time lessons in museums adapt their instruction to the students that they teach? (2) How do time limitations affect instruction? (3) How does perceived variability in entering student knowledge affect instruction? Four educators from two museums took part in this participant observation study to examine one aspect of the teaching culture in museums, that is instruction during one-time science lessons. The researcher remained a passive participant in all 23 lessons observed. Data included observations, interviews, and researcher field notes. An inductive analysis model incorporating constant comparison and domain analysis methods was adopted to analyze the data. Five major findings emerged from this analysis. (1) Repeating lessons develop comfort and insight to compensate one-time nature of lessons. (2) Details within science lessons can vary according to the students. (3) A lifelong learning perspective forms the foundation for educators' choices. (4) Refine teaching to use time efficiently. (5) Educators designate roles to teachers and chaperones to maximize time. These findings had implications for museum educators, classroom teachers, and all those involved in school field trips. Recommendations for action and future research emerging from this study were listed and discussed.

Teaching Science in Museums

by

Lynn Uyen Tran

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Department of Mathematics, Science and Technology Education

Raleigh

2004

Approved by:

Glenda S. Carter	Eileen R. C. Parsons Co-chair of Advisory Committee
David B. Eggleston	John E. Penick Chair of Advisory Committee

For all those moments in your life
when despair and depression consumes you,
read me and remember …

Strength comes in many forms
and is tested in many ways.
Search deep within yourself and find that
you are stronger than you think.

- Lynn Uyen Tran, 2004

AUTOBIOGRAPHY

My family history. My family and I were refugees of the Vietnam War. I was born the year the South fell and the U.S. troops withdrew from Vietnam. We remained in the country for a few years, but my parents and family elders knew they needed to leave for a better life and for the sake of the next generation. They packed what they could carry and fled the country cloaked in the darkness of the night via a dilapidated boat packed with hundreds of other refugees. In modern American terms, we were *boat people*. We were among the many thousands of people displaced by the atrocities of warfare. My family surreptitiously escaped Vietnam by boat after the fall of the South, and then floated in the Pacific Ocean for months waiting to be rescued by any country willing and able to take in refugees. We were lucky enough to be picked up after 11 months at sea, and arrived in Alaska in the middle of winter. I was two and a half years old at the time, and the flashes of images that I once thought were from my dreams, I realize now to be memories through the eyes of a toddler.

However, fleeing for freedom was not unfamiliar. My family had only settled in Vietnam one generation ago. World War II drove both sets of my grandparents to Vietnam from China. For the same reason many Chinese families resettled in Southeast Asia, my grandparents, like my parents, packed what they could carry and escaped China amidst the Japanese invasion and occupation of China during the late 1930s. However, soon after settlement in Vietnam, rebellion against French colonial rule and then civil war drove my grandparents further and further south into Saigon and surrounding rural communities and eventually out to sea.

Twenty-five years after we fled from Vietnam, my family and I (including uncles, aunts, cousins, and grandparents) have become naturalized citizens of the United

States. Our first home was in Korea town, a poor, rundown community in Los Angeles, California. We eventually settled into Alhambra, a white, middle class suburban city 15 miles east of downtown Los Angeles. This has become our new home.

My journey into science education. My experience in scientific research and learning in museums started with a special high school program at the Natural History Museum in Los Angeles County during my sophomore year of high school. The next nine years consisted of working with and learning from Dr. Gordon Hendler, the museum's curator of echinoderms. It's incredible how one little project during a critical moment in your youth can take you to so many places, give you so much confidence, and continue to teach you so much even though it's been more than a decade since you started. The most integral component of that experience was not the research itself, but the support and guidance from Gordon, my incredibly patient and caring teacher. I would never have predicted then that 12 years later my high school science fair project would be published, that I would have graduated with a degree in biology, and am now pursuing graduate degrees to teach science. Especially since science was my least favorite subject in school.

However, my time with Gordon and my research project was different. It was fun, non-judgmental, and interesting. So my experience with science outside the classroom made me enjoy and appreciate the science learning that was necessary inside the classroom. As a result of this growing revelation, I took a teaching position at the Natural History Museum after graduating from UCLA with a degree in biology. Being an outreach instructor immersed me into a side of teaching, about which I never knew, but found incredibly exciting. By the middle of my second year as an outreach instructor, I was at an impasse. I began to question my own teaching practices, and curious whether I as the educator was doing all that I could to teach my students. That snowballed into graduate school at NC State with John Penick in pursuit of improving my instructional methods. Thanks to the support from John and the faculty here, I am beginning my trailblazing journey into the world of non-formal science education.

Important words to myself. In the last five years, I have learned a lot about life and myself. I write this last paragraph to myself as a way to help me remember all the hard lessons learned: Do things that will make you smile for days, laugh out loud, dream during daylight, and beam with pride; do not forget to make and keep friends along the way. Never underestimate the experience of others. There is always a choice, just choose wisely; but if you do not choose, do not be upset with the outcome. It is never too late to be who you want to be. Stretch and sit up straight. Do not rush; you mess up your dinner that way. Keep close those who inspire, challenge and make you smile; do not worry about the others. If you wait until the situation is perfect to do things, you will never do anything. Unbridled joy, boundless confidence, righteous fury. Time passes whether you are ready or not, so pay attention and look alive. Loneliness is only a state of mind. You are a fool if you rely solely on the support and guidance of others. There will always be a multitude of things happening at once, so get over it; make a list, use a calendar, and don't forget to floss. Doing a dissertation is like fighting Orcs; you need to keep swinging your sword and moving forward with determination.

ACKNOWLEDGEMENTS

There are so many people who made this whole adventure possible and successful. This is only a short list of those who cannot be overlooked. I thank John Penick for all his support and confidence in me and my ideas over the last four and a half years. Special thanks to Glenda Carter, Dave Eggleston, and Eileen Parsons for challenging me to take intellectual risks and helping me grow cognitively. I greatly appreciate all the great people at the Institute for Learning Innovation for taking me in and helping me grow professionally, especially the invaluable thoughts, advice, and support from Kirsten Ellenbogen, Joe Heimlich, John Falk, and Lynn Dierking. Vicki Grantham is my super-important behind-the-scenes “text” support, without whom this massive document could not be written. I am grateful to Debra Constantine (my physical therapist), Brett Hightower (my chiropractor), and Michael LePardt (my massage therapist), whose expertise and gentle touch helped me prevail beyond the physical pains of tendonitis and carpal tunnel.

There are those who helped without even knowing it and those who helped simply through their everyday acts of kindness; both must be acknowledged. Amos Hatch for teaching me how to do qualitative research; Peter Jackson and J.R.R. Tolkien for their help in distracting me creatively and philosophically; and Borders Bookstore in Cary for allowing me to spend nine hours a day, six days a week in its café without buying anything. I am thankful for the incredible friendships of those who stood by me through all the good and bad moments these last few years. Especially, Kelly and Mike for treating me like family through their unconditional generosity; Gordon and Florence for teaching me the beauty behind logic and love, and Jen for her sagely advice and thoughts. Immense gratitude to Masters Steve Follick (may he rest in peace) and Randy

Berger along with all the Black Belts and students of Sun Yi's Academy in North Carolina for teaching me courtesy, respect, perseverance, self-control, and indomitable spirit. Thanks to my family for their patience, support, and wonderful food.

Final praises go to the educators and Fred. None of this would be possible without the educators who welcomed me into their classrooms and volunteered their time and thoughts. Thank you for putting up with me and teaching me so much about the amazing things you do. Though they remain anonymous in this dissertation, their thoughts and contributions are forever documented and available. Thanks to Kihlon Golden, my partner in crime and all things adventurous in life, for his never-ending support, strength, patience, and love. You put the smile on my face and help me find the strength within myself on days when all I want to do is hide from the world.

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CHAPTER I. INTRODUCTION

> "Learning is the reason people go to museums, and learning is the primary 'good' that visitors to museums derive from their experience."
> (Falk & Dierking, 2000, p. 2, quotation in the original)

Free choice, non-evaluative, and non-threatening learning environments promote and nurture learning (Falk & Dierking, 1992, 2000; Falk, Koran Jr., & Dierking, 1986; Oppenheimer, 1975). Csikszentmihalyi and Hermanson (1995) state that humans, especially children, have an innate desire to learn and the attributes that characterize informal settings drive the intrinsic motivation of learning. Thus informal science education institutions are unique learning environments. And we can say that experiences at informal science education institutions such as botanical gardens, science centers, aquariums, and zoos are valuable to science learning and interest.

Similarly they are unique teaching environments. Whether through self-guided exploration of exhibits and corresponding labels or more formal lectures and demonstrations, informal science education institutions are places where science teaching occurs although not always in direct ways. The scientist and educator writing the labels and designing the exhibits indirectly teach the visitors who eventually explore the exhibition. Additionally, the educator leading tours through galleries or the expert presenting in a lecture series also teach visitors.

The question arises as to how fully the teaching in informal settings takes advantage of the learning potentials characteristic of informal science education institutions. If learning in these settings is less linear, compartmentalized, or judgmental compared to the structure of formal school, then how does teaching in informal settings accommodate and take advantage of this? This dissertation explores science teaching in informal science education institutions, focusing exclusively on short, one-time science lessons taught to school groups visiting these settings during field trips. These informal institution lessons are pre-planned, instructor-led, self-contained experiences that usually accommodate one class of students at a time and relate to the science contents and resources featured at the institution (Tran, 2002). This study examines the instruction by educators who teach these lessons and investigates how they address factors that could limit their instruction.

Research Questions

This investigation continued a prior exploration of the teaching culture in museums through a participant observation study with educators at two science museums in the United States. The previous inquiry examined instruction by eight different educators at eight museums and reported a general description of how educators teach ephemeral lessons based on observable teaching behaviors (Tran, 2002). Despite variability in the learning environments in that study, there were strong similarities in instruction, lesson plan design, and variables that constrain instruction among all eight educators. This current inquiry refined and continued this previous study with an in-depth examination of the educators' instruction and how they adapt their instruction to the variety of students that enter their classroom. Further, this study explored educators' actions and goals, and searched for an appropriate theoretical framework to understand and describe instruction in museums. The following questions guided this dissertation research:

- How do educators teaching one-hour, one-time lessons in museums adapt their instruction to the students that they teach?
- How do time limitations affect instruction?
- How does perceived variability in entering student knowledge affect instruction?

Defining Terminology

Museum

The International Council of Museums (ICOM) defines a museum as “a non-profit making, permanent institution in the service of society and of its development, and open to the public which acquires, conserves, researches, communicates and exhibits, for the purposes of study, education and enjoyment, material evidence of people and their environment” (McManus, 1992, p. 157 quoted from ICOM Statutes, 1989). Similarly, the Museum Services Act of 1977 defines a museum as a “public or private non-profit agency or institution organized on a permanent basis for essentially educational or esthetic purposes which, utilizing a staff, owns or utilizes tangible objects, cares for them, and exhibits them to the public on a regular basis” (Hein, 2000, p. 3).

These definitions are inclusive of museums for art, history, science, and children, nature centers, aquariums, zoos, historic sites, visitor centers, and botanical gardens. They are educational institutions with goals and responsibilities to educate the public, and often use objects to visualize, stimulate, and communicate complex subject matters (McManus, 1992; Roberts, 1997; Storksdieck, 2004). American museums have embraced this responsibility since their inception in the 18th century (Orosz, 1990).Thus museum is used as an umbrella term referencing all such institutions for the public in this dissertation, unless explicitly indicated.

Educator and Teacher

It is assumed in this study that teaching is teaching, regardless of where it is done. Strategies change or are modified according to the goals of the lesson, the audience, and the setting. The person teaching is responsible for helping the learners learn, and her personal beliefs and intentions for teaching drive her instruction. There are individuals in museums and schools who hold these roles and responsibilities. In this study, “educator” or “museum educator” refers to those teaching in museums and “teacher” or “classroom teacher” references those teaching in schools.

Rationale

Significant members of the public that museums serve include teachers and students. Museums have been used as school field trip destinations since the 1800s (Griffin, 1998; Orosz, 1990). Classroom teachers use field trips to out-of-school learning environments as a way to teach subject matter that cannot be covered effectively in the classroom, for complementing and supplementing classroom instruction, for variety, and for introducing students to resources in their community (Anderson & Zhang, 2003; Kisiel, 2003; Storksdieck, 2004). The National Science Teachers Association (NSTA, 1998) formally recognizes the value of and need to include informal settings in school curriculum as a way to supplement and complement school children’s science experiences in its 1998 position statement. In addition, the *National Science Education Standards* (National Research Council, 1996) recommend that teachers of science (Teaching Standard D) and K-12 science programs (Program Standard D) provide opportunities for students to engage in science inquiry activities outside of the school environment. This includes field trips to museums.

The American Association of Museums (AAM) and Association of Science-Technology Centers (ASTC) conservatively estimate that approximately 1,500 science museums exist in the United States (St. John, Dickey, Hirabayashi, & Huntwork, 1996). ASTC reports approximately 75% of the 440 science museums that responded to their national survey offer education programs to support school needs (St. John *et al.*, 1996). These programs can enhance school field trips before, during, and after the excursion, as well as offer science instruction resources to classroom teachers. The programs and resources include, but are not limited to, tours, demonstrations, teacher in-services, and summer internships for classroom teachers. Short, one-time educator-led science lessons are also commonly offered to visiting school groups to enhance their field trip, and is sometimes the primary activity in which students participate during their field trip (Tran, 2002).

Educators in museums are responsible for developing and implementing these programs intended to teach the scientific phenomena featured at their institutions. This responsibility includes developing resources for teachers, such as activity kits and school loan materials, and creating and teaching lessons to school groups. Educators teaching one-hour science lessons to school groups visiting informal settings are analogous to teachers teaching in traditional schools. Both are in positions at their learning environments, where they are responsible for teaching groups of students and nurturing student learning. However, there is little reported in the literature regarding how museum educators teach and whether they are effective. While they are responsible for teaching and promoting learning in museums, and are a major factor in the potential success of museums, little is known about their actions, qualifications, efficacy, and potential influence on learning. What are these educators doing or not doing? How does their teaching accommodate with their learners? This study examined museum educators' instructional strategies and explored their teaching goals and purposes.

There are multiple reasons to examine museum educators' teaching actions, goals, and efficacy. First, field trips are a break in the usual school routine and potentially take place in locations new to the students. Thus, while the lessons themselves are limited in duration, the educators can play a crucial role in the integration of the experience with school and personal experiences. The educators, their lessons, and the learning environment are usually novel to the students, and therefore, have tremendous attention attracting power (Carson, Shih, & Langer, 2001; Phaf & Wolters, 1993). Though these lessons typically are only one hour in duration, they are memorable to the students (Anderson, Lucas, Ginns, & Dierking, 2000; Anderson, Piscitelli, Weier, Everett, & Tayler, 2002; Wollins, Jensen, & Ulzheimer, 1992) possibly because they offer tangible and personal experiences to which students can relate their pre-existing knowledge and experiences. Thus, the educators have the potential to influence the contributions of a one-hour experience towards the conceptual understanding that students build.

Second, the wealth of science classroom teacher research literature suggests that teachers' teaching knowledge and goals can affect their behaviors, and in turn influence student learning (Doran, Lawrenz, & Helgeson, 1994; Fraser, 1994; Tobin, Tippins, & Gallard, 1994). This sentiment is perhaps applicable to museum educators. Tran (2002) and Rhoads (2001) report that these educators tend to lack formal preparation in teaching, but usually have strong backgrounds in the sciences. They learn to teach by observing and imitating veteran educators, and rely on their personalities and experiences to develop their teaching styles (Tran, 2002). Interestingly, classroom teachers, educators, museum administrators, and science education researchers in a focus group study all state that the educators' knowledge of teaching can contribute to a quality field trip experience for students (Falk & Storksdieck, unpublished data). These science education professionals in museums and schools voice that educators teaching in museums should not only know content but also know to be developmentally appropriate in their instruction.

Finally, increased research and refined methodologies in recent years (Dierking & Martin, 1997; Feher & Rennie, 2003; Lucas, 1991) provide growing evidence that learning takes place in museums, and have been predominantly from the perspective of teachers and students. Current field trip literature indicates that the ways in which classroom teachers use field trips and the extent of their preparation prior to the museum visit influence student learning from field trips (Chesebrough, 1994; Olson, Cox-Peterson, & McComas, 2001). Novelty to the field trip environment and going on field trips in general, referred to as novelty space (Falk & Balling, 1982; Falk, Martin, & Balling, 1978; Martin, Falk, & Balling, 1981; Orion & Hofstein, 1994) also affect how students behave and how much they learn on field trips. The effects of these individuals on student learning in museums are consistent with the wealth of science education literature identifying the contributions of the teacher and student prior knowledge to science learning in schools (Gabel, 1994).

"Craft wisdom" prompted educators to provide teachers with pre- and post-visit material as a way to help them prepare and then process their students' visit to a particular informal setting, and research discussed above supports their decision. Meanwhile, education programs at the museums, such as the one-time science lessons currently under investigation, provide activities to engage and focus students and ways to fit the field trips into teachers' classroom curriculum. Unfortunately, Griffin and Symington's (1997) observations of school group visits revealed tasks and agendas during field trips may not be communicated to students. Anderson and Zhang (2003) and Storksdieck (2001) reported teachers usually did not integrate the field trip experiences when they returned to the classroom. Even though educating classroom teachers on how to use museums emerges in practice and research literature (Olson et al., 2001;

Smith, McLaughlin, & Tunicliffe, 1998), many teachers are inexperienced novices who conduct field trips based on memories of experiences from their time as school children (Kisiel, 2001). This investigation proposes that perhaps it is time to reflect on contributions from museum educators through their instructional approaches in order to explore ways to maximize field trip experiences.

General Overview of Research Design

This participant observation study was situated in the post-positivist research paradigm (Glesne, 1999; Hatch, 2002), and explored how four educators taught short, one-time lessons offered to school groups visiting two museums during February to May 2004. It examined one specific aspect of the teaching culture in informal settings, that is instruction during short-duration science lessons. Two full-time paid educators from each museum, one in North Carolina and the other in Maryland, participated. Data for each educator included a semi-structured interview, four to six videotaped lessons at their respective museums, researcher field notes, and post-lesson interviews. The lessons observed were all pre-planned, approximately one-hour science lessons taught to intact classes of 2nd through 5th grade students visiting the museum during a school field trip. Classroom teachers determined availability of observed lessons since they planned the field trips and brought the students, thus topics of observed lessons varied among institutions and educators.

The researcher remained a passive participant throughout all observed lessons (Patton, 1990), and was present during the lesson to videotape and take field notes but not participating or interacting with other people. Researcher field notes of lessons were supplemented with review of videotapes and excerpted transcripts of these videotapes after the lessons. The researcher conducted post-lesson interviews with the educators in private immediately following each lesson or set of lessons if the educators taught two or three consecutive lessons on the same topic to the same grade level. All interviews were verbatim transcribed by paid transcribers.

An inductive analysis model (Hatch, 2002) incorporating elements of constant comparative (Glaser & Strauss, 1967) and domain analysis methods (Spradley, 1980) provided a framework to analyze and compare all the data. The results were rich descriptions explicating how these educators taught and the factors influencing their instruction. The findings offer an understanding of the teaching culture in informal settings that could be useful in future investigations into teaching preparation for educators.

Limitations of the Study

As with any research investigation, there are limitations to generalizability inherent in this study. First, the topics of lessons observed were not always consistent between the two museums. Although the two museums featured similar science content and concepts, only a few lesson topics overlapped. Selection of observed lessons was limited to the pool of lessons that classroom teachers scheduled for their field trips, which varied considerably in the North Carolina museum. Consequently, the lessons observed were selected according to age group and availability of lessons at a museum so that both educators from the same museum would teach the same lesson.

Second, the number of lessons observed per educator from each museum varied due to scheduling differences between the two museums. The same lesson scheduled more than once on the same day was taught consecutively in the North Carolina museum and simultaneously in the Maryland museum. Thus more lessons were observed for North Carolina educators since it was possible for them to teach the same lesson more than once on the same day. The sets of lessons were treated as one data point since the lessons were taught consecutively and only one post-lesson interview was conducted following the last lesson.

Finally, only two museums were included in this study. Time, access, and financial support restricted the inclusion of more museums. Furthermore, the researcher intended to conduct an in-depth investigation of instruction in museums, and believed two museums allowed for comparisons between locations while offering a manageable sample size. The findings were not generalizable to all educators teaching in all museums, but provided for the readers a glimpse at science instruction in two museums.

CHAPTER II. LITERATURE REVIEW

Introduction

This chapter reviews selected research and writings relevant to this investigation into teaching science in museums. Organized into three sections, the first section examines museums in America as learning and teaching environments. It begins with a glance at the historical roots of education in American museums and emergence of the education agenda. The section transitions into the learning potential in museums, and offers a perspective on the role of learners in these free-choice learning environments, and considers how the novelty, curiosity, and attention that they incite can be advantageous to educators. This section concludes with a discussion on the relationship between the two most dominant educational institutions in American society, schools and museums. It delves into research on field trips to science museums and elements the literature has identified as most influential on student learning, and proposes an element that seems to have been overlooked, the museum educators.

Section two explores the potential influence educators responsible for teaching in museums may have on student learning. This section addresses the dearth of literature on the value, purpose, and role of museum educators and relies on the bountiful research on effects of schoolteachers' attitude, beliefs, and behaviors on student learning for further support. The section concludes with a review of a few inquiries on the learning potential from instructional programs at museums offer further support for museum educators. The final section is an overview of the literature on the data collection and analysis methods employed in this investigation.

Section 1. Museums are Learning and Teaching Environments

Education in Museums

Education Agenda

Museums in America have recognized and debated their responsibility to educate the public since their inception in the 18th century, despite their roots as European transplants of privately owned cabinets of curiosity for the elite and privileged upper class (Orosz, 1990; Roberts, 1997). The first American museums were established in Charleston, Philadelphia, and Boston as cabinets of curiosity. These cabinets housed unorganized collections of objects owned by and exclusively opened to the plutocrats. The American Revolution incited museums in America to move towards a style that distinguished this new nation from its mother country, "… one open to all and useful to all" (Orosz, 1990, p. 25). The museums that emerged during the late 18th and 19th centuries admitted their role and responsibility to educate the public and be accessible to all, while at the same time, struggled to establish and maintain their commitment to scholarly research and intellectual contributions to their respective disciplines. This professional struggle, however, was hindered by the reluctance of returning museums to the exclusive and elitist attitude indicative of its European counterparts. Thus the American compromise in the 1870s officially embraced American museums as both educational and scholarly institutions, and has been marked as the starting point of the museum movement in America (Hein, 2000; Orosz, 1990; Roberts, 1997).

The education agenda in museums was initially lessons on morality and religious piety, and then focused on civic improvement and modeling of appropriate social behavior (Roberts, 1997). Historian Joel Orosz (1990) wrote that both agendas were driven by the plutocrats to maintain control of American society in response to the socio-political changes taking place around them, first was the decline of the respectability and then emergence of a middle class. The education agenda transitioned towards popular education with Charles Willson Peale leading the way, and has remained so as the middle class grew stronger and more socially and politically influential (Orosz, 1990). Peale and his sons' conception of popular education emphasized

> … the presentation of supposedly objective facts to the people so that they could make their own decisions. For those who would not or could not learn, the museum would at least provide 'rational amusement' that would reduce the need for frivolous pleasures or vices. The museum would thus be simultaneously a school in which the sovereign people could learn to make wise choices and a place of wholesome diversion for the thoughtless (Orosz, 1990, p. 81).

Peale knew the value of education while sympathetic to its need to be entertaining. He realized that for museums to be truly useful, they needed to accommodate both the serious scholars searching for knowledge and casual visitors in pursuit of amusement. He was the first to grasp the essence of the modern American museum, "an institution that promotes scholarly research, provides popular education, and offers an acceptable form of entertainment" (Orosz, 1990, p.83). Thus emerged the education agenda of American museums.

Over the next century and a half, that agenda struggled between education and entertainment with world expositions and sideshows that showcased nature's anomalies playing an integral role in how and what museums communicated to the public. The struggle continues today with television, theme parks, and the Internet challenging museums. Furthermore, what was to be learned and how it was learned progressed from the hands of the museum proprietors and curators to those of the visiting public (Roberts, 1997). The change towards more inclusive exhibit design teams to comprise of specialists in design, education, and content area was intended to "… develop exhibits with more popular appeal and effectiveness and move away from the elitist, exclusive, rarefied atmosphere that many collections-based exhibits seemed to have" (Bitgood, Serrell, & Thompson, 1994). Interestingly, this correlates with the thoughts and research on learning and role of the learner that gained popularity and acceptance in schools with perhaps each educational institution influencing the other.

Learning Potential in Museums

Learner roles and the lifelong learning perspective.

Museums are environments where learning can occur. They are free-choice, non-evaluative, non-threatening, social environments that are conducive to nurture learning. Csikszentmihalyi and Hermanson (1995) suggest that these same characteristics drive the intrinsic motivation of learning. They contend that humans, especially children, have an innate desire to learn. All the structure and bureaucracy of schools may dampen this desire in some children, meanwhile the casual, self-paced nature of museums may spark that same passion. Learning in museums is accessible throughout an individual's lifetime, while K–12 schooling is available within the first two decades of ones life and requires enrollment. Moreover, learning in museums extends beyond meaning making and conceptual change, the measures indicative of school. It includes "outcomes like an expanded sense of aesthetic appreciation, the development of motivation and interest, the formation and refinement of critical standards, and the growth of personal identity" (Schauble, 1996, p. 24). While school may promote and desire such outcomes, they are not the central objectives on which students and teachers are measured and held accountable.

Learning is “multifaceted and unbounded by time, institution, or social context” (Anderson, Lucas, & Ginns, 2003, p. 178). Reflecting on the burgeoning learning literature that extend beyond school, Rennie and Johnston (2004) identify three characteristics of learning. It is a personal process of building an understanding of one’s world as one continually remembers and connects new experiences with those in the past. It is a contextualized process of making sense of one’s experiences in terms of extant knowledge within social and physical contexts. It is a lifelong process that develops over time. Thus when it comes to learning, time, place, and mental state matters. Learning is viewed beyond the comprehension and memory of singular incidences, information, and thought irrespective of time and place as if occurring in a factory.

Learners construct an understanding of their world as they engage in mental, physical, and social activities, connect them with past experiences and thought, and continually add to this throughout their lifetime. The information that learners already hold and the way in which this information is transformed and organized in their mind play an important role in what and how they learn. Piaget argued that “no behavior, even if it is new to the individual, constitutes an absolute beginning. It is always grafted onto previous schemes and therefore amounts to assimilating new elements to already constructed structures” (p. 707, Piaget, 1983). Thus, learners are active participants in constructing an understanding of their world, rather than empty vessels waiting to be filled.

Novelty, attention, and curiosity.

Novelty is a hindrance and a helper for learning. In the early 1980s, John Falk and his colleagues introduce the novelty phenomenon to the museum learning literature

(Falk & Balling, 1982; Falk *et al.*, 1978; Martin *et al.*, 1981). Their findings reveal that the familiarity of a location influences student learning. On field trips to an outdoor environment, students familiar with that kind of environment engage in learning activities planned by the educators while those unfamiliar with the environment are consumed with exploratory behaviors. The novelty incited a curiosity that impeded participation in the intended lesson. These investigations and the volume of others that follow offer empirical data to the discussion above about the role of place and mind-state on learning, and will be examined in further detail below. They also show how novelty can hinder learning.

Conversely, novelty can attract attention and curiosity, and can be advantageous to educators during limited teaching and interaction time with students. Taken to the extreme, this is perhaps the premise underlying showcasing and exploiting nature's anomalies as museums competed with sideshows for patrons a century ago (Orosz, 1990; Roberts, 1997), and the criticism for perception of museums' focus on entertainment over education (Neighbour, 1997; Roberts, 1997; Shortland, 1987). However, in the process of impeding participation in the intended lesson, the novelty of the outdoor environment mentioned above promoted exploration to satisfy the incited curiosity. This exploration could lead to learning something of interest to the students, not the adults. Koran *et al.* (1984) tested and found evidence supporting the attention attracting and curiosity evoking power of novel objects in a museum gallery. In their investigation of rehearsal and memory recall, Phaf and Wolters (1993) report that novel input elicited attention and allowed faster learning of new information while strengthening existing representation. Although their study tests memory recall of information out of context and is more consistent with the information processing perspective, it is useful data for explicitly linking novelty, attention, and memory. “The perception of novelty both increases our attention level and activates our ability to think and concentrate” (Carson *et al.*, 2001).

The potential connections between novelty, curiosity, attention, and learning have far reaching implications for educators in museums. The nature of the singular lessons educators teach, which are under investigation in this study, is novel partly because it is a change in the usual routine of school. There is also novelty in the location even if the students have visited the museum with family or friends because this visitation is with their teacher and classmates, thus the social and physical contexts are different. The educator leading the lesson is a different instructor, and may trigger tremendous curiosity and attention from the students, which in turn can influence learning (Carson *et al.*, 2001; Iran-Nejad & Cecil, 1992; Phaf & Wolters, 1993). Furthermore, students’ perception of their learning environment is important because it can influence their cognitive and affective learning outcomes (Fraser, 1994; Moos, 1991; Raviv, Raviv, & Reisel, 1990).

Teaching the Public

As part of their education responsibility, museums have offered visiting scholars and laymen more than access to their collection. Museums like the Peale Museums and Academy of Natural Sciences in Philadelphia and American Museum in New York offered lectures to anyone willing and able to pay the fee (Orosz, 1990). The lectures were offered as early as the 1820s and topics ranged from appropriate social behavior to recent scientific thoughts and discoveries. The lectures were conducted by museum members and trustees, which included naturalists, physicians, scientists, and philanthropists. Other public outreach programs, such as interpretive materials, exhibit techniques, and professional publications, emerged at the turn of the century (Roberts, 1997). By the end of World War I interpretive mechanisms standard in most museums today, including school tours, loan programs, brochures, and labels, were in place. Bierbaum (1988) reported museums offered an average of 13 education programs. The science museums in this study provide a glimpse of what are available to schools. The term NC Museum refers to the museum in North Carolina and MD Museum refers to the museum in Maryland.

NC Museum, located in North Carolina, is a regional science and technology center established in the 1946. School groups from all over North Carolina and neighboring Virginia and South Carolina visit the museum. However, NC museum establishes special arrangements with the local community, such as free public admission during specified times and free classroom programs for all teachers in the local public school district. The museum features interactive exhibits in biology including live animals, physics, astronomy and space exploration, meteorology, and geology. There is gallery space for two separate traveling exhibitions. The main building has three enclosed discovery rooms featuring biology, physics, and early childhood exploration, respectively. There are also five classrooms dedicated to school programs, but are also used as multi-purpose rooms
as needed.

NC Museum also has outdoor exhibits. These include a music and water playground, a maze, a farm animal zoo, a working train that circled a wooded area behind the main museum building, and enclosures that house two species of large mammals and three species of predatory birds. A separate building on the museum campus features butterflies and other arthropods. The butterfly room simulates a South

American rainforest with native plants and hundreds of butterflies all year round. There is also a seasonal extension that highlights butterflies and plants native to North Carolina. The arthropod room showcases insects, arachnids, and their relatives in their respective glass terrariums. NC Museum is in the design phase for expansion of its outdoor exhibits. A web site details all the exhibits featured at the museum along with directions, membership information, descriptions of all the education programs described in Table 1, and field trip tips for teachers. There are also two gift shops, a cafeteria, and indoor and outdoor eating areas on site.

MD Museum in Maryland is a state science museum established in 1797. The museum has been relocated several times in its long history and was near completion of an 18-month renovation and expansion of its entire facility during the time of data collection (reopening occurred on the last day of data collection). School groups from all over Maryland and neighboring Virginia and Pennsylvania visit the museum. MD Museum offers special arrangements to schools in the local community, such as free admission to school groups. Only two exhibits, the planetarium, and an IMAX theater are open to the public at the time of construction and data collection. Since there is limited exhibit space open to the public, all classes are required to schedule at least one education program during the 2003–2004 school year in order to be permitted to visit the museum.

The renovated MD Museum features interactive exhibits in biology, physics, earth and environmental science, and astronomy and space exploration. This museum has a planetarium, a rooftop observatory, and an IMAX theater. There is one traveling exhibition space and a discovery room for early childhood exploration. MD Museum has three classrooms and one auditorium designated for school programs, which are used for other purposes as needed. This museum also has a web site that details all its exhibits along with directions, membership information, descriptions of all the education programs described in Table 1, and field trip tips for teachers. Additionally, there are a gift shop, a new cafeteria, and an indoor eating area on site.

Table 1. Types of education programs each museum offers to teachers and school groups extrapolated from the 2003–2004 published and distributed teachers' resource guide.

	NC Museum	MD Museum
PROGRAMS FOR SCHOOL GROUPS	*Number of different lessons available*	
Off-site Programs[1]		
Science lessons[2]	12	8
StarLab programs[3]	3	6
Auditorium programs	None	9
On-site Programs[4]		
Classroom programs (capacity ≤30)		
Science lessons	24	7
Exhibit hall lessons	None	7
Discovery room[5]	2	1
Observatory & Simulator[6]	None	9
Multi-class programs (capacity >30)		
Auditorium programs	8	None
Planetarium	None	11
IMAX	None	8
PROGRAMS FOR TEACHERS	*Availability*	
Pre-trip resources		
Open house	No	Yes
Free admission w/o students	No	Yes
Teaching ideas & resources		
Special workshops on content & inquiry teaching strategies	Yes	Yes
Consultation & free phone advice	Yes	Yes
School loan kits	Yes	Yes
Science education resource center (free)	Yes	No

[1]Off-site programs refer to programs that travel to school campuses. Educators bring all necessary materials and conduct one or more lessons.
[2]Science lessons are the one-hour, one-time lessons examined in this study. The lessons are advertised for 50 minutes at NC Museum and 45 minutes at MD Museum.
[3] StarLab is a mobile planetarium that can accommodate one class of students at a time and is set up on the school campus for a pre-determined amount of time.
[4]On-site programs refer to programs offered to school groups during field trips to the museum.
[5]Discovery room is a self-contained, free-discovery room available to school groups. An educator is assigned to remain in the room to help the students and teachers. The rooms focus on biological or physical science, and contain objects, artifacts, and equipment for students to explore related concepts. Time in the room is free and for one hour, but requires reservation.
[6]The simulator is a full-immersion, virtual reality experience that accommodates a class of students at a time.

Schools Use Museums as Resources

The first recorded partnership in America between schools and museums for the purposes of popular education is credited to Charles Willson Peale in 1821 (Orosz, 1990). Peale extended the educational programs of his museum beyond public lectures and access to his collection by offering free admission to schoolteachers when accompanied by their students who paid 12.5 cents each (half the regular admission price). In 1834, Peale’s son modified this arrangement to a school admission for all its students at the annual price of seven dollars. By 1936, field trips to museums were a standard part of museums’ and schools’ education programs (Melton, Feldman, & Mason, 1936). Educational resources for schools today extend beyond reduced admission, as suggested in Table 1. Reporting exclusively on science centers, the Association of Science-Technology Centers (2001) reveal that 89% of science centers offer classes and demonstrations to visiting field trip groups and 75% provide outreach programs to schools worldwide. Eighty three percent of science centers worldwide reported offering workshops for teachers. In addition, the number of schoolchildren museums serve is phenomenal. A nationwide survey conducted by the American Association of Museums (1994, AAM) reported that museums served 49 million children in school groups in 1988, compared to the U.S. Census Bureau estimate of 49.1 million children ages 5–18 for that year.

Museums are important resources to schools. This is established in endorsements to supplement and complement school science and increased research and funding for such research. The National Research Council (1996) recognized museums as a resource to supplement and complement school science in the *National Science Education Standards*. The National Science Teachers Association (1998) echoed this sentiment in its position statement two years later. Furthermore, increased research interest and refined methodologies in the last 25 years have resulted in greater understanding of the factors most influential to learning during school field trips to museums (Feher & Rennie, 2003; Griffin, 2004). Current literature acknowledges the affect of teachers and students with emerging recognition of value and importance of other individuals, such as chaperones and museum staff (Griffin, 2004).

Teachers Affect Student Learning

Value of teacher preparation.

Classroom teacher knowledge of how to use informal settings in their curriculum and their use of informal settings both contribute to student learning. Science educators and researchers find that teaching classroom teachers how to use museums can affect teacher attitude towards teaching science, student learning, and taking field trips. Olson, Cox-Peterson, and McComas (2001) examine teacher educator preparation of in-service and pre-service teachers to incorporate museums into their lesson plans, while Smith, McLaughlin, and Tunicliffe (1998) and Chesebrough (1994) review the impact of teacher preparation by museum educators. Pre-service teachers are initially unsure of their own ability to take students out of the classroom, and find the task overwhelming (Olson *et al.*, 2001). However, aid from their cooperating teacher help reduce that fear. Olson *et al.* conclude that the task of taking students on field trips to museums is less intimidating if teachers are provided experiences modeling effective field trip strategies and receive guidance from their cooperating teachers and university faculty.

Teacher preparation by educators from museums also has positive impacts on teachers. Smith *et al.* (1998) reveal that providing teachers with ideas and examples to teach science concepts in their classrooms via brief professional development in a museum can have a positive effect on the teachers' instructional practices. Trained teachers are better able to incorporate their lesson plans into zoo-related instruction, which affect the students' zoo experiences later in the school year. Results from interviews immediately following their viewing of a zoo exhibit indicate that students of both trained and untrained teachers made low level irrelevant, descriptive, or identification comments about their experiences at the exhibit. However, students of trained teachers are able to apply concepts learned in classroom, and make observations and comparisons about animals studied in the classroom and those viewed at the zoo.

Furthermore, Chesebrough (1994) reports a positive attitude change towards science and science teaching by pre-service elementary teachers as a result of a science methods course taught at a museum by museum educators who a held masters degree in education. The course focuses on pre-service teachers engaging in and conducting hands-on activities, observing children engaging in free-choice science activities, and interacting with the museum's scientists, exhibits, and other special features. These experiences give the teachers a chance to explore scientific concepts. Thus they develop a more positive attitude towards science, which leads to a more positive attitude towards teaching science.

These findings are consistent with preliminary results from a focus group study investigating elements that characterize a quality field trip (Falk & Storksdieck, unpublished data). Teachers, museum educators, museum administrators, and science education researchers, in separate focus group sessions, are asked to discuss elements that contribute to a quality field trip for students. All four groups insist on the need for classroom teachers to be prepared to lead a group of students on a field trip. This include mental preparation in regards to comfort level in leading groups of students off-site, logistical preparation in terms of agenda, chaperones, and awareness of facilities features, scholastic preparation pertaining to integration of the field trip into the classroom curriculum, and student preparation.

Value of student preparation.

The evidence for classroom teachers to prepare their students prior to a field trip and debrief with them afterwards in an attempt to place the whole experience into context and thus make the learning meaningful is increasing. Pre-visit strategies for enhancing learning during school field trips to museums (Gennaro, 1981) include reducing novelty of the environment (Anderson & Lucas, 1997; Kubota & Olstad, 1991; Orion & Hofstein, 1994). Additionally, Anderson and his colleagues (Anderson *et al.*, 2003; Anderson *et al.*, 2000) report value in post-visit activities to help students make meaning out of their field trip experience.

Activities prior to visiting a museum are valuable to student learning during field trips, and these activities range from instructional material to reducing the novelty of the informal setting itself. Gennaro (1981) tests the effects of carefully designed advanced organizers on student cognitive gains from a visit to a science center, and finds pre-visit instructional material about the concepts to be learned at the museum valuable to student learning from the field trip experience. Kubota and Olstad (1991) study the effects of novelty to a museum as a link between exploratory behavior and cognitive learning. They conclude that pre-visit orienting to a novel museum reduce distracting exploration and increase on-task behavior and cognitive gains. Anderson and Lucas (1997) report similar findings when they investigate the effectiveness of orienting students to the physical features of a science museum prior to the actual visit. These findings correlate with investigations of student factors that influence student learning from museums.

Anderson *et al.* (2003; 2000) examine students' knowledge construction of scientific concepts before, during, and after a visit to a museum. Their studies report that prior knowledge have a powerful influence on how students interpret their field trip experience and construct understanding from new information. Post-visit activities are crucial for students to further develop understanding, incorporate their informal science experience, and identify alternative conceptions. The learning experience as a whole (before, during, and after the field trip) is a synergism between home, school, and visits to the museum. Thus they conclude that it is important that teachers conduct post-visit activities in order to give students the opportunity to synthesize the experiences and construct their understanding.

Year-long, multi-visit studies on student memories of their field trip experiences further support the need for classroom teachers to embed field trips within the school curriculum (Wollins *et al.*, 1992) and make connections between classroom learning and field trip experiences explicit to the students (Anderson *et al.*, 2002). Wollins *et al.* (1992) analyze interviews inquiring about student recollection of memorable moments from their field trip experiences during a school year. They identify three variables that make museum experiences memorable to students: higher personal involvement for an individual child, links with the curriculum, and multiple visits to the same institution. Via similar research methods, Anderson *et al.* (2002) also finds that student recall of memorable moments are diverse and highly individualistic. In addition, live facilitated, and lecture-based theatre-type programs are prominent in student memories.

Students Affect Student Learning

Learners actively build knowledge through interactions and experiences with objects in the learners' world. Since this is a lifelong, continuous process, the learners' pre-existing knowledge contributes immensely to their construction of understanding (Driver, Asoko, Leach, Mortimer, & Scott, 1994; von Glasersfeld, 1989; Wheatley, 1991). In reference to student learning from informal science settings, student pre-existing knowledge is not limited to prior knowledge with concepts or content. Research suggests that student prior knowledge and experience with the scientific concepts (Rix & McSorley, 1999), with a particular informal setting (Falk & Balling, 1982; Falk *et al.*, 1978; Martin *et al.*, 1981), and with field trips as a whole (Gerber, Cavallo, & Marek, 2001; Orion & Hofstein, 1994) can all contribute to student learning. Rix and McSorley (1999) report that more children who had previously been taught about static electricity understand how an exhibit communicating this phenomenon work compared with students who had no previous knowledge of this area. Additionally, Gennaro (1981), finds that students who receive instructional material prior to their science center visit achieve higher cognitive gains pertaining to the intended scientific concept.

Falk and his colleagues (Falk & Balling, 1982; Falk *et al.*, 1978; Martin *et al.*, 1981) propose that novelty to an informal science setting can affect student learning itself. Falk *et al.* (1978) and Martin *et al.* (1981) experiment with the "novel field-trip phenomenon" by comparing conceptual gains and exploratory behaviors of students who were familiar and unfamiliar with an outdoor environment. Both studies find that students familiar with the setting are able to learn more about the setting and related concepts, while students unfamiliar with the setting tended to engage in more exploratory activities. The familiar students benefit from the structured class program at the informal setting, but unfamiliar students engage in behavior that interfere with learning. Conducting a similar study, Falk and Balling (1982) also compare the novelty phenomenon with different aged students, specifically third and fifth grades. They find that effect of the location is influenced by the students' developmental level. Fifth grade students at a novel setting and third grade students at a familiar setting show significantly greater cognitive gains and on-task behavior than their counterparts, i.e. other fifth grade students at the familiar site and other third grade students at the novel site. Nonetheless, they conclude, "single-visit field trips can promote cognitive learning and retention" (p. 26).

Student prior experience with excursions to museums as a whole can also affect student learning. Gerber, Cavallo, and Marek (2001) question whether exposure to museums affect student scientific reasoning ability. They find students with learning experiences outside of school, e.g. after school or with their family, exhibit higher reasoning abilities. Controlling for the teaching method and field trip location factors, Orion and Hofstein (1994) determine that student novelty to the subject matter, field trip location, and excursions as a whole all affected student learning outcomes. In this study, they vary the amount of preparation on instructional material, novelty to setting, and psychological novelty for field trips. The authors conclude that students who receive extensive pre-visit activities that include exploration of the content and concepts and hands-on manipulations of related objects exhibit more on-task learning behaviors and achieve higher cognitive gains than students who do not receive similar preparations. They argue that all three-novelty factors, i.e. cognitive, geographic, and psychological, affect student learning on field trips, and refer to these factors collectively as students' *novelty space*.

Do Educators Affect Student Learning?

There remain two groups of individuals who are part of the field trip experience but have scantily been recognized in the literature, chaperones and museum staff. Museums generally require adult chaperones to accompany visiting school groups with students to adult ratio varying according to age of students. MD Museum requires one chaperone per 10 students, but prefers a ratio of 2 to 10. NC Museum requires one adult chaperone per eight students grade K–12, and one to five for preschool children age 5 and younger. Museums' work force includes part- and full-time paid staff and volunteers. AAM (1994) report that museums employ approximately 150,000 people, two-fifths of whom work part-time, and attract the services of 377,000 volunteers, nine-tenths of whom volunteer part-time. MD Museum employs 211 full- and part-time staff, and receives services from part-time 150 volunteers. NC Museum has 72 full- and part-time paid staff and part-time 350 volunteers (American Association of Museums, 2002).

Parsons and Muhs (1994) investigate the interactions between chaperones and students during self-guided exploration of the Monterey Bay Aquarium. They find mostly positive interactions between chaperones and students that resembled family groups, while worksheets tend to hinder discussions and time looking at exhibits. Conversely, Cox-Peterson, Marsh, Kisiel, and Melber (2003) study volunteer-led guided tours through the Natural History Museum of Los Angeles County. They observe that tours tend to be lecture-oriented and volunteer-driven with the volunteer providing the content, asking the questions, and directing movement through the gallery. Ninety-two of the students interviewed (n=85) comment that they liked touring the gallery with a museum volunteer. However, observer comments suggest that there is a lack of overarching concepts connecting the information, questions and opportunities for interaction require low levels of learning based on complexity of responses, and questions are asked without follow up, elaboration, or probing.

Schauble *et al.* (2002) conduct a two-part study of parents' and museum staffs' perception and use of the learning potential of a science exhibit at the Indianapolis Children's Museum. Interviews for one part of the study query parents and museum educators about their opinions on the educational strengths and weaknesses of the target gallery and how adults might work with a child to enhance the learning potential of the target gallery. They find that both parents and educators are challenged and sometimes puzzled about how to help children learn in the exploratory gallery. Parents and educators cherish children's fascination and engagement with the exhibits, but are not sure how to determine whether children really learn and how they can help children learn without getting in the way. Educators, however, report this is the interesting challenge of the job. The authors comment that "unless careful attention is paid to helping the helpers, the energy and resources devoted to deepening museum learning may be wasted, or at best, underexploited" (p. 449).

There are a few studies that examine the effects of science lessons in museums. While they are not designed to directly examine teaching methods that the educators use, their studies suggest lecture is the predominant teaching style and these one-time lessons can effect what students learn from their field trip. Flexer and Borun (1984) assess the effectiveness of participatory museum exhibits and lecture-style lessons at the Franklin Institute Science Museum in Philadelphia in communicating science content and facilitating subsequent classroom learning. They find that teaching a structured lecture-style lesson designed specifically for the study and in congruence with the exhibits at the museum is a more effective brief learning experience than the exhibits alone. While interaction with the exhibits only is superior to the control (no exhibit, no lecture) for conveying science concepts, museum experience that includes the structured lesson is more effective at communicating vocabulary and application. Parks (1985) examine student cognitive achievement and attitude towards science from a one-time lesson at the Red Mountain Museum in Alabama. The one-time lesson is a lecture-demonstration on dinosaurs that uses objects, a dinosaur video, and a question-and-answer period. Both cognitive and attitude scores are determined through pre, post, and delayed-post multiple-choice exams. She finds that there is a significant, positive difference between pre and delayed-post cognitive exam scores for students who participated in the lesson, but not for those who did not partake in the museum lesson. However, there is no difference in cognitive scores between students who had the lesson and those who did not. Furthermore, she reports no change in attitude towards science, learning science, dinosaurs, or the museum. Parks concludes that while the one-time lesson may affect student retention of content, the program alone is not enough for affecting change on scientific attitude and cognitive learning.

Melton, Feldman, and Mason (1936) conducted an extensive study of one-time lessons at the Buffalo Museum of Science with 1200 5th through 8th grade students. Comprised of a series of experiments manipulating instructional methods and student preparation, the lessons were 30-minute, docent-led lectures for visiting school groups prior to their docent guided, lecture tour of a gallery hall in the museum. Content acquisition and retention as measured through pre, post, and delayed post (conducted three months after the study) tests were indicators of student learning. They identified and tested three factors that might affect student gains from a field trip: methods for preparing students, teaching methods during the museum visit, and methods for concluding the museum visit. Melton *et al.* reported the following findings:

- Pre-visit activities had a positive effect on student learning and method of instruction most affected student scores. These were usually silent reading lessons on the topic to be studied at the museum.
- Fifteen-minute introductory lecture was more effective than 30 minutes. An additional 15 minutes in the exhibit halls where students had access with the authentic objects was more beneficial than spending it introducing students to the hall. Fifth grade students benefited more from the 15-minute introduction than did students 6^{th} grade and above.
- Method of instruction within the exhibit hall (lecture, game, or discussion) most affected student scores, and this could be related to grade level. Fifth grade students scored higher when they had a lecture-based lesson in the exhibit hall. Seventh and eighth grade students scored higher when their lesson in the exhibit hall was conducted more as a discussion than lecture. Sixth grade students benefited from the discussion as long as there was a brief summarizing lecture at the end of the museum visit.
- Teaching ability of the docent affected student scores. Teaching effectiveness of each docent was based on test scores of students that they taught. Some docents yielded high scores from students regardless of teaching method, grade level, and subject matter. Instructional effectiveness for other docents was dependent on subject matter, not teaching method.

The authors concluded that "… the teaching ability of … docents appear to be the most important consideration of all, and without an objective check of the docents, a museum may be falling far short of the degree of effectiveness of which it is capable" (p. 74).

This study explores how museum educators embrace their teaching challenge and considers what can be done to help them. Teachers and students affect student learning from field trips to science museums. Research suggests that learning is possible, but requires knowledgeable and prepared classroom teachers and students. For classroom teachers, their knowledge and comfort in using museums within their curriculum can affect student learning. Teachers putting the field trip into a learning context via activities before, during, and after a field trip also impact student gains. Students' existing knowledge of the science phenomena featured at the museum and their personal experiences at that science setting also contribute to what students do on the field trip and what they learn. The responsibility of promoting meaningful learning for millions of school children visiting museums each year, thus, stands on the shoulders of already overwhelmed classroom teachers. However, an element that is given little attention in the literature on field trips and learning in museums is the effects of those in the museums who are responsible for the teaching, program development, and curriculum design of the museum's education program. What are these educators doing or not doing? How do they influence student learning during field trips? How can they share the responsibility?

Section 2. Museum Educators

Teaching Science

Museum educators whose sole responsibility was education first appeared by World War I (Roberts, 1997). Many were schoolteachers, and this established educators' first professional niche in museums. In 1958, Robert Hellmann from the American Museum of Natural History in New York identified the presence of 20 educators in the Museum's Department of Public Instruction. Their teaching responsibilities included science lessons for visiting elementary school groups, science and pedagogy lessons for classroom teachers, and guided tours for the public. For their qualifications, he described that

> … each [educator] be as scientifically accurate as possible, even though he must be expected to teach as wide a variety of topics as 'Conservation,' 'Prehistoric Life,' 'The American West,' 'The American Indians,' and 'Plants and animals of New York State.' Furthermore it should be noted that he or she is handling children of elementary school grades from all possible kinds of background and ability. [pp. 49–50] … The [educator] must have achieved some level of specialized proficiency so that he can speak with authority to his students. (p. 51)

Thus it was recognized that educators in museums taught a broad spectrum of learners (adults and children, professionals and laymen), content area, and program type. Today, most museums have an independent department devoted to the educational responsibilities of the institution. Educators develop, coordinate, and teach programs for school groups, teachers, and the general public. And in some museums, educators are contributing members of exhibit design teams (Bitgood *et al.*, 1994; Roberts, 1997). In their 2001 statistical report, ASTC reports that more than 50% of education staff in science centers worldwide are women. Tran (2002) and Rhoads (2001) find that the educators' teaching and education backgrounds are variable with formal and informal preparation in teaching and science content.

Educators teaching one-hour science lessons to school groups visiting museums are analogous to teachers teaching in traditional schools. Both are positions at their learning environments that are responsible for teaching a group of students and nurturing student learning. This dissertation assumes that teaching is teaching regardless of where it is done. The strategies change or are modified according to the goals of the lessons, the audience, and the setting. Nonetheless, the individuals responsible for teaching are affected by similar concerns, referred to here as teaching elements. These elements include student knowledge, time, classroom climate, and educator role. Two elements, time and student knowledge, are identified as salient concerns for teaching in museums (Tran, 2002), and thus are examined in this study. A teacher's teaching rationale, or theoretical framework, is valuable to her instruction and is also considered. The plentiful research in classroom instruction provides most of the literature foundation for this section since research specifically focusing on educators is scant.

Teaching Element: Student Knowledge

The ideas on learning discussed above requires teaching to take into account what students know and how they understand it before, during, and after instruction. Educators recognize the importance as well as challenge of this element (Schauble *et al.*, 2002; Tran, 2002). If the students only enter an educator's classroom once for one hour out of their entire lifetime, how will the educator determine what and how the students know and understand prior to and as a result of the lesson? Does it really matter? The novelty discussion above suggests that student knowledge is important for the educator to assess even for such an ephemeral experience because the experience has learning potential through the curiosity and attention it incites. How this is done in museums is currently under investigation. Nevertheless, literature on student knowledge and instruction in school can offer insights for museum teaching.

Literature on learning and teaching in schools echoes the sentiment on student knowledge and teaching, and offers conceptual thoughts and empirical data for support and suggestions. The body of literature on which this discussion relies is classroom assessment. This refers to activities undertaken by teachers and students to provide information on student understanding and the information obtained "… is used to adapt the teaching to meet student needs" (Black & Wiliam, 1998b). It is proposed that assessment be integrated with instruction so that assessment results can guide instruction (Gong, Venezky, & Mioduser, 1992; Graue, 1993; National Research Council, 1996; Shepard, 2000) and in this way work towards students' conceptual development (Bell & Cowie, 2001). Teachers provide assistance as a part of assessment in order to gain valuable insights about how understanding might be extended. Meanwhile, students constructing an understanding of science concepts receive input on whether their construction makes sense and is consistent with canonical knowledge (Shepard, 2000). Bell and Cowie (2001) refer to this relationship generated through classroom assessment as the intersection of student-teacher interactions for student learning and understanding.

Black and Wiliam (1998a) and Fuchs and Fuchs (1986) review over 40 classroom assessment research studies that explore learning gains determined through quantitative measures. They conclude instruction that include strengthening classroom assessment produce significant and often substantial learning gains, which in these investigations are determined by comparing test score improvements of students involved in the innovation with typical student scores for those tests. Many studies also show greater learning gains for low achieving students with improved classroom assessment than for other students, thus reducing the achievement gap while raising overall achievement levels.

Brookhart (1997) uses national, longitudinal data of public school students in 1987–1991 from grades 7–12 to compare classroom assessment with student science achievement. She extracts students' background information (gender, socio-economic status, and general academic ability) and extrapolates the classroom assessment environment for the respective students and teachers from their survey responses to the Longitudinal Study of American Youth. She correlates this with the students' science achievement and finds that the type of assessment is important to student achievement. Some activities are more helpful than others; science projects yielded positive effects while oral reports had negative effects on achievement.

Bell and Cowie (2001) note that while there is much written about the importance and need for formative assessment, little exists regarding the process. Their two-year study with 10 classroom science teachers in New Zealand explores the purpose and ways in which these teachers conduct classroom assessment. Emerging from their interviews are nine characteristics:

- *Classroom assessment is responsive*. Teachers and students respond to the information gained in many ways.
- *Classroom assessment has many sources of evidence*. The information can take many forms and gathered through different means, such as verbal and non-verbal responses to videos or whole class discussions.
- *Classroom assessment is tacit*. The information can also be based on instincts.
- *Classroom assessment relies upon professional knowledge and experience*. Ways to gather and respond the information relies on teachers' professional knowledge and experiences with content and students.

- *Classroom assessment is an integral part of teaching and learning*. Teaching to facilitate students learning involves taking action based on information about how students understand what is taught, and includes changing teaching techniques and giving students feedback.
- *Classroom assessment involves students and teachers*. Students take part in information gathering through self-assessment.
- *Classroom assessment has purpose*. The purposes include improving learning and changing teaching.
- *Classroom assessment is contextualized*. The information gathered, how it's interpreted, and the actions that follow need to be taken in context of the situation.
- *Classroom assessment is managing dilemmas*. There may not be obvious solutions to situations emerging from the assessments. Teachers rely on their professional judgment to manage the dilemma.

These characteristics suggest there are many ways to gather information about what and how students understand, and the teacher as the professional uses her knowledge and experience with teaching and content matter to make changes to her instruction to meet the needs of the students. The last characteristic Bell and Cowie (2001) discuss that emerged from interviews with the students of these teachers is the level of student disclosure, that is, the amount and truthfulness of student understanding that is communicated to the teacher from the students. This is a challenge for both teachers and educators.

Teaching Element: Time

Time is an extremely valuable commodity in many aspects of life, and is recognized as a critical factor on learning in terms of time available, time spent on learning, and time lapsed. Cotton (1989, ¶9) lists different ways of conceptualizing time and its expenditure in education, which is based on school time and builds from the works of Lorin Anderson, Benjamin Bloom, and Charles Fischer.

- *Allocated time* is the amount of time specified for an activity or event. When educators and educational researchers speak of allocated time, they are referring to one of the following elements:
  - School time – the amount of time spent in school. When used this way, allocated time may refer to the number of school days in a year or the number of hours in a school day.
  - Classroom time – the amount of time spent in the classrooms within the school (i.e., excluding lunch, recess, time spent changing classes, etc.).
  - Instructional time – the portion of classroom time spent teaching students particular knowledge, concepts, and skills pertaining to school subjects (i.e., excludes routine procedural matters, transitions, and discipline).
- *Engaged time*, or, *Time-on-task*, refers to portions of time during which students are paying attention to a learning task and attempting to learn. This excludes time spent socializing, daydreaming, engaging in antisocial behavior, etc.
- *Academic learning time* (ALT) is a term and concept emerging from a large-scale research effort called the Beginning Teacher Evaluation Study (BTES) conducted in the 1970s. ALT refers to that portion of engaged time that students spend working on

tasks at an appropriate level of difficulty for them and experiencing high levels of success (excludes time spent engaged in tasks which are too easy or too difficult).

- *Dead time* – refers to periods of classroom time during which there is nothing students are expected to be doing; that is, time that the teacher has failed to manage in any way.

Cotton offers further clarification to distinguish between time-on-task and academic learning time. She explains that time-on-task informs one about teaching as it “reveals the teacher's skill in selecting learning activities which engage students' attention and in keeping them focused” (¶17). Academic learning time informs one about learning in that it “refers to situations in which student and learning material are well-matched and learning is occurring in a fairly ideal fashion” (¶18). The distinction emerges from time-on-task investigations as researchers realize that not all forms of time-on-task are equal in their effects. Helmke and Schrader (1988) examine student achievement and teacher supervision during independent seatwork among 39 fifth grade classes in Germany. They report that quantity of seatwork is unrelated to student achievement despite students’ engagement in the activity. Student time-on-task may be unfruitful when interrupted by lectures and questions because the activity is not within the students’ appropriate competency level. Interruptions can also be attributed to disciplinary events, which relates to the role of classroom management on learning. Thus the quality of time spent engaged in an activity is important.

With minor adjustments, these categories can be useful for examining learning time allotted to and spent at museums during field trips. Time allocated by teachers for the field trip includes travel and museum time. A museum and its educators are allotted a portion of the field trip time based on the length of time the school groups spend at the museum, which can be influenced by length of school day, teacher use of the museum, museum hours, and transportation availability schedule. The allocated museum time is the total time students spend at the museum from when they enter the museum to when they leave, which is analogous to school time. Regardless of the quality and efficiency of the teachers' planned agenda, time is allocated for students to engage in activities that includes free time in the museum, time in specific galleries, and time in the museum's education programs. These times are analogous to classroom and instructional time. Within these allotted activity times, student behavior is observed to determine time-on-task and academic learning time. Dead time includes lunch breaks, travel between galleries and programs, and any unscheduled time. It is this use and misuse of time that is the source of criticism and concern for classroom teachers using museums (Chesebrough, 1994; Chin, 2004; Griffin & Symington, 1997; Olson *et al.*, 2001). This study examines the time allocated to and used by the museum educators in their one-time science lessons, and uses findings from schools for some insight.

Overall, literature on the relationship between student achievement and allocated time (at all levels) is inconsistent or minimally positive at best (Aronson, Zimmerman, & Carlos, 1999; Cotton, 1989; Metzker, 2003). Careful analysis of how that allocated time is used reveals that only about half the typical school day is actually used for instruction and students spend half of that instructional time engaged in learning activities (Honzay, 1986-87; Karweit, 1985). While these studies are from classrooms nearly two decades ago, more recent reviews do not report changes in use of allocated time (Aronson *et al.*, 1999; Metzker, 2003). Non-instructional time during the school day includes lunch break, passing between classes, assemblies, and other non-classroom activities. Within classroom and instructional time, factors such as inefficient classroom management, disciplinary activities, ineffective instructional techniques, inappropriate curriculum and student inattention or absence reduce time available for engaging in tasks and learning. Not all time allocated for learning is used in activities that allow for learning. Aronson *et al*. (1999) propose that this is perhaps the reason for the inconsistent findings pertaining to achievement and allocated time.

This is not to say that amount of time is not important. Gettinger (1985; 1989) conducted two studies that experimented with time available for engaging in activities and measured student achievement and retention. The first study (1985) measured reading achievement and retention among 171 fourth and fifth grade students when the researcher allocated less time than needed or allowed students to self-select less time than needed for the task. In both situations, achievement and retention were lower for students who spent less time than needed for learning the content. The second study (1989) manipulated time needed with incentives for completing the task for 118 third grade students. Extra time-on-task yielded improved return for lower-ability students, but had no effect on higher-ability students. Offering incentives minimized time required for learning while improving retention for both groups of students. In both studies, the researcher determines the tasks, which are not part of students' ongoing curriculum, and learning is measured through retention of factual information. However, as acknowledged by the author, they are useful to "… ascertain the effects of maximized time spent and minimized time needed for learning on degree of learning in general" (Gettinger, 1989, p. 88). Thus enough time is needed to engage in a task, but more time does not lead to more learning if the students do not need it.

In order to learn something, sufficient time needed to be allocated for that content or task (whether at school, at a museum, or on ones own). However, how that time was used has greater influence on learning outcomes than the amount of time allotted. This referred to student and teacher behaviors during time-on-task and academic learning time, and the rationale for emergence of the latter from the former as briefly mentioned above. Dewalt and Rodwell (1988) investigated student achievement for remedial 5th, 6th, and 7th grade students when math and science instruction were extended by 30 minutes. They found improved achievement and attitude scores for science but not math. Examination of how the additional time was used revealed that extra time for math was spent on rehashing material presented during the regular lesson while in science additional instruction was different and varied. Derevensky, Hart, and Farrel (1983) observed how low- and high-achieving Canadian students in grades 1–6 use time-on-task. While both groups spent from 75–85% of their work time exhibiting on-task behaviors, the higher-achievers expended more time on appropriate, high-success tasks. McGarity and Butts (1984) and Helmke and Schrader (1988) acknowledge the importance of teacher behavior when students are on-task. McGarity and Butts showed positive relationship between achievement and teachers' on-task behaviors, such as close monitoring, providing feedback, reteaching, managing disruptive behavior, and maintaining learner involvement in lessons. Helmke and Schrader reported similar positive effects on achievement when teachers successfully managed disruptive behavior and provided feedback discretely. Thus, quality not quantity with respect to how much time was allotted and used were crucial for student achievement.

Teaching Element: Classroom Climate

Classroom climate is a construct that describes the psychological and social atmosphere for a class of students and teacher (Baker & Piburn, 1997). It develops over time as the class gets to know one another, works together, and shares experiences

(Penick & Bonstetter, 1993), and is influenced by the teacher's teaching beliefs and behaviors (Fraser, 1991, 1994; Jakubowski & Tobin, 1991). This proposes that the teacher and students contribute to the development of the psycho-social climate for the class. However, common to classroom environment inventories (Fraser, 1991, 1994) is the emphasis on teacher's actions and other characteristics in the classroom controlled by the teacher, such as task orientation, rule clarity, competition, and order and organization. This suggests that the teacher's behavior is a primary determinant in the development of the classroom climate.

Additionally, Jakubowski and Tobin (1991) report that teacher's beliefs on teaching and how students learn influence teacher's behaviors, which in turn affect the classroom climate. Teachers from four elementary schools in Florida took part in a teacher enhancement program over the summer with continued follow up during fall and spring. The program examined teachers' current teaching and learning philosophy, identified practices and trends that needed change, and introduced teachers to areas the researchers deemed salient for improving learning environments for students such as constructivism, alternative assessment techniques, and collaborative learning. The teachers developed and implemented a comprehensive plan for a science program in fall of 1989, which was observed and studied by the researchers. Students showed increased confidence, participation, and responsibility for their learning as the teachers changed expectations in their classroom from being authority figures to facilitators.

People are members of multiple social environments. Moos (1991) asserts that "individuals are profoundly affected by the social matrix in which they are embedded" (p. 29), and thus proposes the need to understand the dynamic qualities of these learning environments. He purports the psycho-social atmosphere of these social environments are not compartmentalized and can influence one another, thus suggesting that students' family environment has the potential to influence students' performance in other environments such as school. Moos reviews literature on personal growth, relationships, and system maintenance (the degree of structure, clarity, and openness to change that characterize an environment) for teachers and students in three social environments (school, work, and family), and draws attention to interactions between these environments on individuals. He points out that "non-school settings can alter the outcome of educational programs by inhibiting their effects…, by augmenting their effects…, or by compensating for their lack of effects" (p. 48). Thus, the events and atmosphere from one social environment can help or hinder learning gains from other environments.

Teaching Element: Teacher Role

The teacher should give students the opportunity to discover and make sense on their own, while simultaneously offering guidance and exploratory activities that lead towards the sense making. Even in a lesson with intended goals and objectives, students should not be free to explore and experiment without direction. While free discovery affords the opportunity to construct knowledge, literature regarding classroom practices also reveals that guidance from the teacher is a necessary part of knowledge construction. Linn and Rice (Rice & Linn, 1978) examined student learning and behavior in free-choice learning environments by comparing their performance with those students who received direct instruction regarding experimentation and controlling variables. In both studies, students were given the opportunity to engage in a set of experiments that challenged them to identify variables, describe the experimental effects on the variables, and then design their own experiments. The goals were to determine how students function, and what they learned in environments where they were only given overall instructions to complete a set of experiments with written directions for each experiment to get them initially started with the task. Students were allowed to choose the tasks and amount of time to spend on each task.

Rice and Linn (1978) investigated whether training students in experimentation or whether student prior knowledge of experimentation affected student behavior and learning in the free-choice environment. They found that direct instruction alone and direct instruction plus free-choice was more effective in teaching students to control variables than free-choice alone. Students who received instruction about experimentation were also the most task oriented. Students who had prior knowledge about experimentation, and thus did not receive direct instruction in this study, were not eager to apply their knowledge in the free-choice environment. This further supports the findings from her 1977 work that students in free-choice learning environments do not necessarily make large cognitive gains, or are motivated to challenge themselves mentally without guidance. Nonetheless, the free-choice environment had positive motivational affects. Linn (1980) further strengthened these findings with a study that compared students' cognitive gains with direct instruction, in the form of a lecture/demonstration about identifying variables, criticizing experiments, and designing controlled experiments, before, during, or after the free-choice learning opportunity. She found that students profited and tended to be more task-oriented during the free-choice experience after having had direct instruction. The lecture/demonstration provided them with concrete illustrations with which to mentally manipulate during their free-choice time.

While knowledge cannot be passively received (von Glasersfeld, 1984; Wheatley, 1991) or "…transmitted directly from one knower to another…but is actively built up by the learner" (p. 5, Driver *et al.*, 1994), the teacher cannot merely disseminate information with the expectation that students will understand. In their review of science teaching strategies, Tobin *et al*. (1994) describe that critical components of the teacher as mediator role are to "monitor learning and concentrate on providing constraints so that student thinking is channeled in productive directions" (p. 49). This suggestion requires the teacher to be aware of students' understanding and prior knowledge, and guide students' knowledge construction in making sense of their world within the parameters of canonical understanding. The teachers' responsibilities require her to interact with the students to establish a dialogue that can reveal student thinking (Mintzes & Wandersee, 1998; Tobin *et al.*, 1994).

The literature on student knowledge, time, classroom climate, and teacher discussed above is derived from the bountiful school learning literature. The time and student knowledge literature emphasizes content acquisition and retention. They are used here merely to gain insight on how these teaching elements have been found to affect learning in one dominant educational institution in American society. Furthermore, the literature on time primarily explores achievement in terms of content acquisition and treats the relationship between time and learning as momentary events rather than a lifelong process. This can be viewed as a reflection of the difficulties of studying and measuring a concept as complex as learning. Nonetheless, these findings offer useful insights to understanding the potential influence that student knowledge and time have on one aspect of learning. The current investigation contributes evidence from museums with respect to these elements through observation and self-reflections of behavior exhibited by educators during their instruction.

Section 3. Methodology Review

This was a participant observation study of teaching science in museums, and involved interviews and direct observations of instruction. The study intended to explore one aspect of the teaching culture in museums, thus two research questions focused data collection. An inductive analysis method that incorporated elements of James Spradley's developmental research sequence (1980) and Barney Glaser and Anselm Strauss' constant comparative method (1967) was selected to analyze the data (Hatch, 2002). This analytic procedure generated understanding through examination of specific elements (units of analysis) and finding connections among them. The use of these data collection and analysis methods in education were borrowed from anthropology and sociology (Wilson, 1977). Their procedures prescribed rigorous techniques to establish validity and reliability from themes that emerged from the data.

Participant Observation

This participant observation study used Amos Hatch's (2002) classification that the research method "… place researchers in social settings but do not have the broad purpose of capturing the cultural knowledge that insiders use to make sense of those settings" (p. 22), which is indicative of ethnography. It was narrower in scope, involved less time in the field, and was driven by specific research questions. Concordant with ethnography, the researcher maintained the dual roles as a participant and an observer, valued the significance of the natural setting, and included the perspectives of the research participants (Hatch, 2002; Spradley, 1980; Wilson, 1977). The researcher attempted to understand the participants through their perspective and refrained from imposing a priori hypotheses and assumptions. This was not to say the researcher might not operate without such a framework, but that the researcher was aware of its existence and cultivated the skill of suspending preconceptions. Consequently, “a researcher seeking to understand behavior must find ways to learn the manifest and latent meanings for the participants, and must also understand the behavior from the objective outsider perspective” (Wilson, 1977, p. 253).

Planned data collection schedules, habitual introspection, and explicit awareness of details in the observations are components of participant observation. Fieldwork includes interviewing, collecting artifacts, and direct observations. Interviews are used to reveal how participants organize their experiences and make sense out of their world that is concealed from direct observation and taken for granted by participants (Hatch, 2002; Patton, 1990). However, they are limited by the participants’ perspectives and perceptions of what has happened, which are subject to distortion such as lack of awareness, state of mind, personal intent, and memory (Patton, 1990). Direct observation better enable the researcher to understand the subject in context, be open and discovery oriented without relying upon text and explanations, and see things that may routinely escape participants. On the other hand, the researcher may affect the situation in unknown ways like altering behavior of participants, selective observation of events during the situation or aspects of the situation as a whole, and limited to external behaviors exhibited by the participants. However, observations and interviews used together can balance these limitations. “Observations provide a check on what is reported in interviews; interviews, on the other hand, permit the observer to go beyond external behavior to explore the internal states of persons who have been observed” (Patton, 1990, p. 245). Interviews used in conjunction with observations enable researchers to probe more deeply into participants' perspectives on actions that the researcher observed (Hatch, 2002).

Inductive Analysis

The data for this study were analyzed with a model proposed by Hatch (2002) that was intended to provide a framework to novice researchers through basic inductive analysis steps based on two well described inductive approaches in the literature, grounded theory (Glaser & Strauss, 1967) and developmental research sequence (Spradley, 1980). Grounded theory is an inductive process with specific data collection and analysis procedures that are firmly rooted in the people and situation being studied (Mann, 1993). Analysis begins as soon as data is collected, influences collection of proceeding data, and constantly compares new data with existing data in order to determine consistency and precision of analysis (Corbin & Strauss, 1990), and thus grounds the emerging theory in the data. The developmental research sequence is also an inductive process with specific procedures "… designed to reveal the components of a social phenomenon, the relationships among components, and their relationships to the wider social contexts involved" (Hatch & Freeman, 1988). It prescribes a cycle of observation, analysis, more focused observation, and more analysis.

Hatch explains that "inductive analysis begins with an examination of the particulars within data, moves to 'looking for patterns across individual observations, then arguing for those patterns as having the status of general explanatory statements' (Potter, 1996, p. 151)" (2002, p. 161). His model emphasizes using specific elements extracted from the data to develop a general understanding and offers a systematic approach to process this that is based on procedures in grounded theory and the developmental research sequence. Theory evolves from careful study of the phenomenon within context, rather than directing developing hypotheses to be tested and thus is well suited for studies that emphasized discovery of cultural meanings from data sets that include observation and interview data (Hatch, 2002).

Summary

The literature review for this study delved into research and writings investigating the history and learning potential of school field trips. It discussed the agenda of museums to educate and entertain as well as be accessible to scholars and casual visitors. Among the audiences were schools, teachers, and students. The relationship between museums and schools began by the 1820s, interpretive mechanisms to educate visitors were all in existence by the first World War, and by the 1930s researchers were experimenting with effects of the museums' instructional programs. Research investigations progressed and dug deeper into the factors that influenced learning in museums, and eventually identified the importance of the teachers' and students' knowledge and preparation. Interestingly, Melton *et al.* reported on the positive effect student preparation had on cognitive gains in 1936. They also recognized the potential influence of educators and teaching methods in cognitive gains from one-time museum lessons, a factor that has not been extensively investigated in the literature. The review then transitioned into discussion on teaching science in museums, and used findings from science teaching in schools as foundation. It specifically focused on how teachers addressed student knowledge and time limitations in their instruction.

Museums in America have an extensive history as educational institutions established for teaching and learning the public, and hold a relationship with schools that date back to the early 1800s. This study explores one aspect of one type of program intended for school groups, the instructional process of one-time science lessons. This chapter has reviewed the literature in which this study is situated, and the next chapter elaborates on the methodology used in this investigation.

CHAPTER III. METHODOLOGY

Introduction

A participant observation study situated in the post-positivist research paradigm (Glesne, 1999; Hatch, 2002), this research explored how four educators taught one-hour, one-time lessons offered to school groups visiting two museums during February to May 2004. The post-positivist paradigm proposed that “reality can be approximated but never fully apprehended” (Hatch, 2002, p. 14), thus data collection attempted to capture an approximation of reality while maintaining an objective position in relation to the phenomena being observed.

The study was informed by Hatch’s definition of a participant observation study as a qualitative study “… that place[d] researchers in social settings but [did] not have the broad purpose of capturing the cultural knowledge that insiders use[d] to make sense of those settings” (Hatch, 2002, p. 22). Thus this study examined one specific aspect of the teaching culture in informal settings, that is instruction during short-duration science lessons. The investigation focused on instruction and asked educators to reflect upon their actions. It required the educators to discuss the lessons and provide rationales for their teaching behaviors. As mentioned in Chapter II, in this study, “educator” or “museum educator” refers to those teaching in museums and “teacher” or “classroom teacher” references those teaching in schools. Chapter III describes the museums and educators, the interview and observation protocols, data collection process, and analysis procedures.

Study Sample

Research Settings

The Science Museums

Two science museums, one in North Carolina (NC Museum) and the other in Maryland (MD Museum), were selected non-randomly for this study based on their accessibility to the researcher, reputation in their community, and education services they provided. The researcher developed a rapport with the educators at NC Museum over the years as a seasonal, part-time educator for the museum's summer science camp program for 2002 and 2003. Researchers at the Institute of Learning Innovation, a free-choice learning research and consulting organization in Annapolis, MD, introduced the researcher to educators at MD Museum.

Both MD and NC Museums are prominent informal science education institutions in their community and offer a myriad of educational programs to schools and resources for classroom teachers. McManus' (1992) classification descriptions identify them as third generation museums with their main aim as public education rather than scholarly research into collections. These museums are "concerned with the transmission of scientific ideas and concepts rather than the contemplation of scientific objects or the history of scientific developments. … [Their] emphasis is usually on contemporary science or technology, and they use interactive exhibits requiring visitor thought and manipulation as vehicles for communication" (McManus, 1992, p. 161).

The museums offer education programs for teachers and school groups. For teachers, the museums offer free and fee-based resources that can be used to prepare for field trips (pre-trip resources) or to generate lessons and curriculum in the teachers' own classrooms (teaching ideas & resources). They offer programs to school groups visiting the museum on field trips (on-site) as well as send educators to school campuses (off-site). These programs are all fee-based with time limitations ranging from 30 to 50 minutes and accommodate 20 to 130 students, depending on the program. Table 1 in Chapter II inventoried these programs in detail. Table 2 and Table 3 (below) listed the general information about the museums' statistics and features offered at their facilities.

Table 2. Information about governance, education staff and annual visitation each museum in this study.

	NC Museum[1]	**MD Museum**[1]
General information		
Year established	1946	1797
Governing authority	Non-profit organization	Non-profit organization
Visitors served		
General public (2003)	300,000	700,000
Students[2]	31,267	Not available
For science lessons	18,373	Not available
For other programs	12,894	Not available
Personnel Profile		
Full-time paid	58	98
Part-time paid	14	113
Part-time volunteer	350	150
Interns	4	10
Education staff		
Year round	30	19
Teaching staff[3]	15	17
Development & Support	15	2
Seasonal staff[4]	80	26+

[1]Information gathered from museums' web sites, teachers' resource guides, communication with education staff, and American Association of Museums (2002); [2]Numbers for students refer to 2002-2003 school year.; [3]Seven full-time and eight part-time.; [4]Additional staff is hired to teach and manage summer science camp programs.

Table 3. List of objects featured in collection and activities offered for both NC and MD Museums.

	NC Museum[1]	MD Museum[1]
Features		
Hands-on science exhibits	Weather Communications Physics Geology Paleontology Aerospace Animal habitats Biology	Chesapeake Bay Space Structures Energy Mathematics Hubble Space Telescope Science arcade
Live animals	North Carolina flora & fauna Large mammals & birds Exotic & native butterflies Arthropods & amphibians Farm animals	(live animals are new additions to museum after renovation, but were not listed in 2003 Directory)
Facilities	Small railway Butterfly House & Insectarium Farmyard Nature park & playground Outdoor maze Cafeteria Discovery rooms Gift shops Classrooms	Laser theater Full-immersion Motion Simulator Planetarium IMAX theater Observatory Discovery room Gift shops Classrooms
Activities		
For general public[2]	Lectures Demonstrations Special events Summer science camp	Lectures Films Informal workshops Science excursions Demonstrations Traveling exhibitions
For schools[3]	Classes (on & off site) Science-in-a-suitcase loan After school programs Teacher training	Classes (on & off site) Student science seminars Teacher hotline & workshops

[1]American Association of Museums (2002); [2]Programs available to general public but also accessible to school groups; [3]Programs exclusive to teachers and school groups. A more detailed listing is found in Chapter II (Table 1).

The Science Classrooms

In both MD Museum and NC Museum, all lessons observed for the study were conducted in self-contained rooms designated for school programs, and classes met the educators at the assigned rooms. NC Museum designated five rooms as classrooms used primarily for the one-time science lessons investigated in this study. However, these rooms were used for other purposes when no lessons were scheduled, such as fee-based birthday parties and staff meetings. For the one-time science lessons, topics were taught in specified rooms. All objects and supplies for each lesson topic were stored in their respective rooms. Consequently, multiple lessons of the same topic scheduled on the same day were taught consecutively. For the lesson topics observed in this study, *Simple machines* and *Forces in motion* were taught in the same room and *Adaptation advantages* was taught in another room. The rooms were across the hall from one another and had similar floor plans and interior design. One was decorated with a physical science theme and the other with a biological science theme (Figure 1). The rooms had windows along the top quarter of the wall opposite the doors.

Each lesson was assigned a five-sided, wood cart with wheels and two shelves used to store most of the artifacts, objects, and materials needed for the lesson. Objects too large to fit in the cart were stored elsewhere in the room. For all lessons, the educators greeted the students outside and instructed them on where to sit before allowing them to enter the room. Chaperones and teachers were asked to sit at or near the tables with the students. The educators started the lessons at the diamond marker indicated on Figure 1 and stayed on the carpeted area when addressing the whole class. The researcher remained at the star marker indicated on Figure 1 throughout the entire lesson.

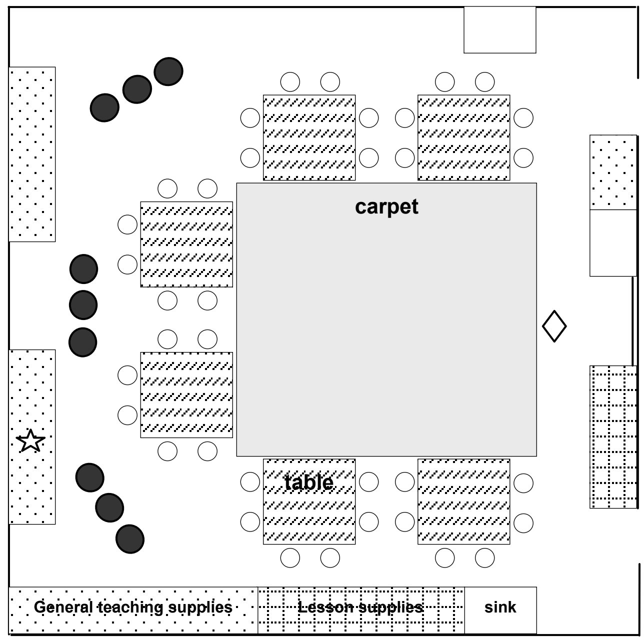

Figure 1. Floor plan for both classrooms in NC Museum.

(Diamond = educator; Star = researcher & camera location; Circle = chairs, students sit on open circles, chaperones & teacher sit on closed circles); Thick line = chalkboard.)

MD Museum designated three rooms as classrooms for the one-time science lessons examined in this study (Figure 2). Due to renovation at the time of the study, one classroom was converted into an animal care station for animals used in all school programs and the auditorium on the third floor was used as needed. The classrooms were circular because they were located below the planetarium. Lesson topics were not assigned to specific classrooms, thus lessons could be taught simultaneously and in any room. All necessary materials were stowed in the storage room adjacent and accessible to all the classrooms, and were brought into the room depending on the lesson taught. Classroom A had bare walls, no decorations, and no windows. Classroom B also had no windows, but science posters were hung on the walls. It was used to store materials not for any of the education programs such as large wood boxes along one wall, two refrigerators, and some construction supplies for the renovation. This classroom also had lighting that cast a noticeable yellow tint over the entire room. In both classrooms during all lessons observed in this study, students remained on the carpeted floor. The educators reported that the classrooms were scheduled for remodeling after the 2003–2004 school year and would be equipped with computers, SmartBoard ®, and other high technology communication equipment. Students were greeted outside of the classroom and given instructions on where to sit before entering the room. Chaperones and teachers were asked to sit on the chairs or join the students on the floor. Similar to educators at NC Museum, MD Museum educators started all lessons and addressed the whole class at the diamond marker. The researcher remained at the star markers (Figure 2) throughout the entire lesson.

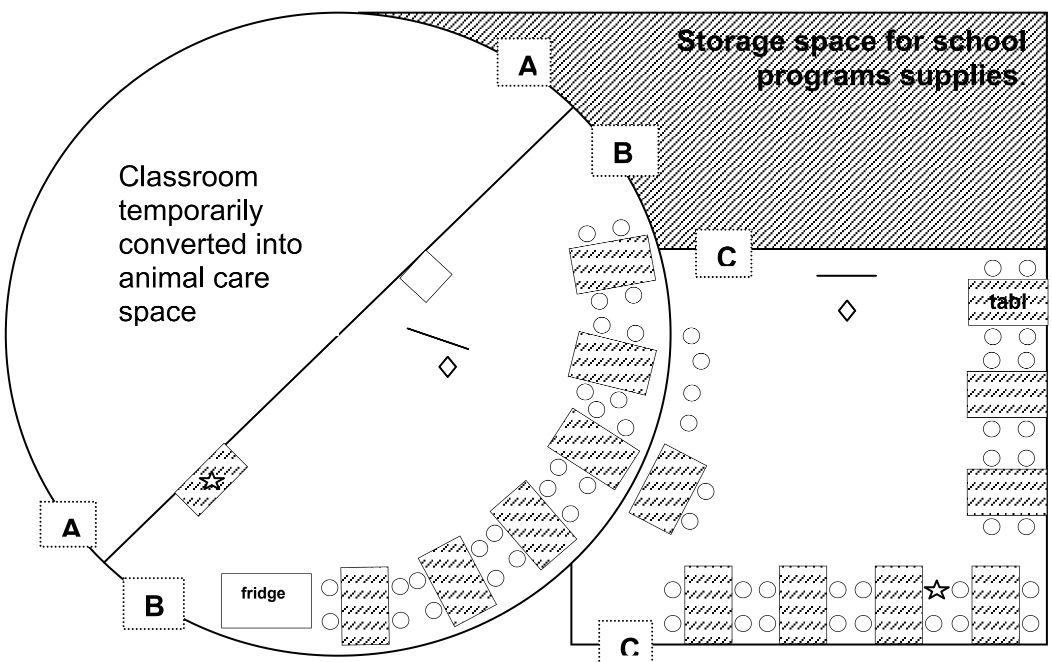

Figure 2. Floor plan for classrooms in MD Museum.

(Due to construction, only Classrooms B and C are used for instruction. Classroom A is currently used as animal care space. Diamond = educator; Star = researcher & camera location; Circle = chairs, students sit on floor in front of educator, chaperones & teacher sit on chairs; Thick line = chalkboard.)

Research Participants

Two full-time paid educators from each museum were asked to participate in this study (Appendix A). Selection was based on teaching background and experience and work status as full-time, paid educators with teaching school group programs as a primary job responsibility. To maximize on what could be learned from the four educators, educators with distinct science and teaching background and teaching experiences were selected (Patton, 1990; Stake, 1995). In NC Museum, the researcher relied on the program supervisor's knowledge of the museum's teaching staff to recommend two educators from among the staff of 15 educators dedicated to teaching all their education programs (Table 4). In MD Museum, there were only three educators responsible for teaching the museum's on-site school programs, two full-time and one part-time. Fortunately, both full-time educators had contrasting teaching backgrounds and experiences (Table 4).

Table 4. Education and teaching experience of educators in this investigation.

Educator	Degrees & Certification	Teaching Experience
NC Museum		
Janet	BS in animal science. Pursuing elementary teaching credentials & MA in elementary education	3 years summer science camp & birthday party @ NC Museum; 1.5 years full-time teaching @ NC museum
Sally	BA in elementary education & teaching credential (expired)	20 years K–6 grades in private schools in North Carolina; 10 years full-time teaching @ NC Museum
MD Museum		
Gary	BA in elementary education & elementary teaching credential. Pursuing MA in elementary education with a minor in early childhood development	1 year in science at sea program; 2 years full-time teaching @ MD Museum
Julia	BS in biology	6 years full-time teaching school and public programs at another museum in Maryland; 17 years full-time teaching @ MD Museum

General Procedures

Data Sources

Data for each educator came from a one-on-one, semi-structured interview prior to any observations (Appendix B), four to six videotaped classroom lessons at their respective museums, researcher field notes, and post-lesson interviews (Appendix C) immediately following the lessons. Additionally, the published and distributed 2003–2004 teacher resource guide and official web site for each museum provided details about the museums' exhibits, special features, and education programs. The initial semi-structured interviews were conducted immediately before or a few days prior to the first observation, to accommodate scheduling restrictions for the educators or researcher. They were 45 to 60 minutes in duration, and focused on the educators' teaching experiences, beliefs, and goals.

The lessons observed were all pre-planned science lessons taught to 2nd through 5th grade students. Lesson duration was advertised for 50 minutes at NC Museum and 45 minutes at MD Museum. The educators could not control availability of lessons since schools scheduled the field trip activities and agenda. The extent of teacher involvement in the scheduling and planning of the field trips was not queried. Furthermore, at the museums, a staff member other than the educators had the responsibility of communicating with the schools during scheduling. Thus educators were scheduled to teach lessons convenient to their personal schedules or the museums' staffing needs each week, and it was not possible to examine the same lesson for all observations. There were some similarities in the science concepts featured at both museums, which allowed for two overlaps in science lesson topics (states of matter and live animals). Due to the lack of control in scheduling mentioned above, it was not possible to observe those overlapping lessons in the two museums. Table 5 lists the published description and targeted grade levels for lessons that were observed at each Museum.

Table 5. Descriptions of observed lessons as published in 2003–2004 teacher resource guide.

Lesson title	Targeted grade level	Description of lesson as written In teacher resource guide
NC Museum[1]		
Forces in motion	4 – 8	What makes things move? Explore friction, gravity, and energy in this hands-on physics experience.
Simple machines	4 – 8	What is an incline plane, a lever, and a pulley? How can these simple machines make hard work not so difficult? Creatively problem-solve ways to use simple machines to meet challenges.
Animal adaptations	4 – 6	What are adaptations and how do they help living things survive? Spin the “Wheel of Misfortune” and see if you have what it takes to stay alive!
MD Museum		
Creepies & Crawlies	Pre K – 4	From feathers to fur, scales to slimy skin, the animal kingdom abounds with diverse creatures. Meet, observe, and touch a variety of amazing vertebrates that inhabit our world while comparing their differences and similarities and learning about adaptations.
What’s cold, what’s hot, what’s solid, what’s not?	Pre K – 2	See matter change before your very eyes, become a bouncing gas molecule, feel the chill of cold liquid nitrogen as it boils at room temperature, and discover how making (and eating!) ice cream becomes a savory science lesson!
Snap, crackle, pop!	3 – 6	Investigate the nature of static electricity as you move charges, have a hair-raising experience with Robert Van de Graaff’s most famous invention, and learn how to protect yourself from the hazards of lightning. Become “charged up” under the ultimate of shocking circumstances.

NOTE: [1]Following each description is a listing of objectives in the North Carolina Standard Course of Studies (North Carolina Department of Public Instruction, 2004) that the lesson addresses.

The following criteria determined selection of lessons observed at NC Museum. First, lessons were scheduled for 2nd through 5th grade classes. Second, the same lesson was scheduled at least twice in one day for the same grade level from the same school. One educator taught both lessons on each day. Third, this schedule occurred for at least two days so that the other educator could teach the same lesson to students in the same grade level from the same school. These criteria were chosen because lessons were taught in designated classrooms, thus the same lessons were taught consecutively at NC Museum. Also, different schools were scheduling different lessons, thus selecting lessons from the same school ensured that both educators were teaching the same lessons, which allowed for comparisons between educators. For each educator, two lessons for students from three separate schools were observed during February 2004 (Table 6, p. 66). Observing consecutive lessons offered discussion points for the educators during the post-lesson interviews. Each set of lessons was treated as one data point since there was only one post-lesson interview conducted.

Two reasons prompted inclusion of a second museum. First, preliminary analysis of data revealed that more observations and post-lesson interviews were necessary to strengthen emerging themes. Second, there were not enough lessons scheduled after February at NC Museum to provide adequate data. Additionally, the researcher relocated to Annapolis, Maryland for a 12-week internship at the Institute for Learning Innovation, therefore, it was more convenient to find a second museum in Maryland. Institute researchers introduced educators from MD Museum to the researcher who then asked them to participate.

Scheduling at MD Museum differed from NC Museum. The same lesson scheduled on the same day could be taught simultaneously, so it was not possible to observe consecutive lessons from the same school for each educator. Since different schools were scheduling the same lessons during April and May 2004, the same lesson was observed for both educators on three separate occasions. However, in the case of School 2 for Gary and School 5 for Julia (Table 6, p. 66), the classroom teachers scheduled two lessons per class. Class A had one lesson while at the same time Class

B was attending a different lesson with a different educator in the classroom next door. At the conclusion of the first lesson, the two classes switched rooms and all the students participated in a second lesson of a different topic. As a result, the students received two different lessons with two different educators in two hours time while each educator taught the same lesson consecutively. Table 6 lists the data collection schedule, including actual duration of lesson and number of students, teachers, and chaperones present.

Table 6. Observation schedule for all videotaped lessons with post-lesson interview immediately following.

Educator	Lesson title	Date	Grade level	Lesson Duration (minutes)	# of Students, Teacher, & Chaperones
NC Museum[1]					
Janet					
School 1[3]					
Class C	*Forces in motion*	2/11/04	5th	50	16 Ss, 1 T, 0 Chs
Class D			5th	50	15 Ss, 1 T, 1 Chs
School 2[3]					
Class C	*Simple machines*	2/13/04	4th	50.5	24 Ss, 1 T, 3 Chs
Class D			4th	50.5	25 Ss, 1 T, 0 Chs
Class E			4th	51	24 Ss, 1 T, 2 Chs
School 3[3]					
Class A	*Animal adaptations*	2/24/04	4th & 5th	49.5	24 Ss, 1 T, 1 TA[4]
Class B			4th	51.5	23 Ss, 1 T, 1 TA[4]
Sally					
School 1[3]					
Class A	*Forces in motion*	2/10/04	4th	40	15 Ss, 1 T, 0 Chs
Class B			4th	36	19 Ss, 1 T, 0 Chs
School 2[3]					
Class A	*Simple machines*	2/12/04	4th	46	23 Ss, 1 T, 2 Chs
Class B			4th	45	25 Ss, 1 T, 6 Chs
School 3[3]					
Class C	*Animal adaptations*	2/25/04	4th & 5th	48	22 Ss, 1 T, 0 Chs
Class D			4th	52	23 Ss, 1 T, 1 Chs
MD Museum[2]					
Gary					
School 1	*Snap, crackle, pop*	4/15/04	4th	50	22 Ss, 1 T, 11 Chs
School 2[3]					
Class A	*Creepies & crawlies*	4/16/04	2nd	47	11 Ss, 1 T, 2 Chs
Class B			2nd	49	10 Ss, 1 T, 3 Chs
School 3	*Snap, crackle, pop*	5/12/04	3rd	51	30 Ss, 1 T, 6 Chs
School 4	*Snap, crackle, pop*	5/28/04	3rd	48.5	21 Ss, 1 T, 6 Chs
Julia					
School 5[3]					
Class A	*What's cold, What's hot*	4/15/04	2nd	47	15 Ss, 1 T, 6 Chs
Class B			2nd	49	18 Ss, 1 T, 8 Chs
School 6	*Snap, crackle, pop*	4/21/04	4th	55	28 Ss, 1 T, 10 Chs
School 7	*Snap, crackle, pop*	5/3/04	5th	58	27 Ss, 1 T, 8 Chs
School 8	*Snap, crackle, pop*	5/11/04	3rd	57	28 Ss, 1 T, 6 Chs

NOTES: Due to the way schools chose to schedule their lessons: [1]The same school brought classes to NC Museum on more than one day. School 1 for Janet corresponds with School 1 for Sally, but each educator taught 2 different classes. [2]Classes observed for each educator at MD Museum were from different schools. [3]These lessons were taught consecutively and one post-lesson interview was conducted following the last lesson. Thus each set of lessons was analyzed as one data point. [4] TA = teacher's assistant.

Data Collection

This investigation was a participant observation study. The researcher conducted all interviews with the educators individually in the museums' classrooms. Throughout all lessons, the researcher remained a passive participant (Patton, 1990), and was present during each lesson to videotape and take field notes but not participate or interact with other people. The researcher set up the videotaping and note taking stations in the back or off to the side of the room 15 to 20 minutes prior to the start of class, and remained there during the entire duration of the lesson. The video camera focused on the educator or on the wall at the front of the room when the educator mingled with the students, voiding the need to obtain parental consent forms from all the students participating in the lesson. Researcher field notes of lessons were later supplemented with review of videotapes and excerpts of transcribed dialogue from the lesson.

If possible, the classroom teacher was informed of the purpose of the researcher's presence and video camera. However, sometimes the teacher blended in with the chaperones and it was more distracting to walk around and search for the teacher since the educator started instruction as soon as the students were seated. None of the teachers or chaperones objected to the presence of the researcher or the video camera. The researcher decided not to interview the classroom teachers for two reasons. First, there was not sufficient time to talk with the teacher between the first and second class at NC Museum since there was only a 10-minute break between the lessons. Talking with the teachers during the lessons was impossible and inappropriate as the researcher was busy collecting field notes and videotaping and the teachers were watching their students and the lesson. Since this data would not be available for half the classroom teachers at NC Museum, the researcher chose not to collect them for any of the observations. Second, without prior warning, the researcher did not want to disturb the teachers as they led their classes on a field trip. Researchers' prior experience with other classroom teachers on field trips influenced this hesitation.

The researcher conducted post-lesson interviews with the educators in private immediately following each lesson or set of lessons when the educators taught consecutive classes on the same topic to the same grade level. A list of questions helped to guide the post-lesson interviews (Appendix C), but they were conducted as a conversation that prompted the educators to reflect on their instruction, compare their instruction with previous lessons, and discuss rationale for their actions. Additionally, post-lesson interviews in MD Museum included questions testing preliminary ideas that emerged from educators in NC Museum. These interviews lasted 25 to 40 minutes depending on the educators' eagerness to reflect and talk. All interviews were audio taped and then verbatim transcribed by the researcher or a paid transcriber.

Initial interpretations of the educators' teaching beliefs and goals and teaching behaviors and reflections were submitted to each individual educator four or five months following data collection. The educators were asked to review the written material and respond in writing with comments, critiques, questions, or concerns. These responses were compared with the researchers' interpretations for inconsistencies, which prompted the second round of analysis.

Validity and Reliability

Themes that emerged from the data must be valid and reliable so as not to be mislead or draw inappropriate conclusions (Stake, 1995). As Stake suggested, this was addressed through several triangulation protocols. First, a methodological triangulation was used. Multiple data sources, such as observations, interviews, and researcher field notes were compared to confirm descriptions and the educators' reflections. Second, data sources were triangulated through comparison of emerging themes in the two museums to see if the phenomena remained the same in other places. Third, researcher observations and interpretations were submitted to each respective educator for them to critique and comment on analyses in writing for member checking (Glesne, 1999). Finally, data were analyzed in search of inconsistencies and negative cases that challenged initial observations and interpretations.

Data Analysis

Observation field notes with transcripts of selected lessons, interview transcripts, and educator written responses offered a manageable set of data, which could be used to document and interpret the instruction. An inductive analysis model (Hatch, 2002) incorporating elements of constant comparative (Glaser & Strauss, 1967) and domain analysis (Spradley, 1980) methods were used to analyze and compare all the data. This process involved individual analysis of data to search for categories that organized and described the situation. The categories were then compared across data sets to determine their resiliency and validity, and identify themes among them. Emerging themes were compared between the two educators within an institution and then across institutions.

The researcher followed the nine steps described in Hatch's inductive analysis model (2002, pp. 161-179), dividing them into three rounds of data analysis. Interview data were analyzed first, and were used to guide analysis observation data. Steps taken for the analysis process were listed below. Number and italicized text refer to steps as written by Amos Hatch. Subsequent bulleted text described details specific to this study.

Before Analysis

1. *Read the data and identify frames of analysis* (or units of analysis).
    - For interviews, a unit of analysis was defined as a complete thought. Once the educator began talking about another topic (whether self-initiated or interviewer-initiated), a new unit was marked. (Appendix D)
    - For observations, a unit of analysis was defined as a distinct segment of the lesson. Researcher's field notes and educators' post-lesson interviews revealed that the lessons were comprised of segments of activities and discussions that could be lengthened or shortened, reordered, or omitted. (Appendix E)

Analysis Round 1

2. *Create domains based on semantic relationships discovered within frames of analysis*.
    - The units of interview data were grouped into categories based on the topic the educator discussed. This helped the researcher become familiar with the data and find semantic relationships within the units of analysis.
    - Hatch listed the nine semantic relationships identified by Spradley (1980, p. 93) and provided relationship examples specific to education (Appendix F). The researcher reviewed each interview in search of one semantic relationship at a time.
3. *Identify salient domains, assign them a code, and put others aside*.
    - A list of domains was generated for post-lesson interviews and initial interviews individually. Salient domains were those semantic relationships

that addressed the research questions and were common within and among educators. (Appendix G)

- Corresponding interview units that supported the domain were marked and listed with the domain.

Analysis Round 2

4. *Reread data, refining salient domains and keeping a record of where relationships are found in the data*.
   - Salient domains from post-lesson and individual interviews were compared within individual interviews, among all interviews for each educator, and then between educators. Salient domains were organized into an outline (Appendix H).
   - Observation data were examined for domains that emerged from interviews. Units of observation were compared between the same lesson topic taught by the same educator, the same lesson topic taught by different educators and different topics by the same educators. Length and order of observation units were analyzed for all lessons observed. Only *Forces in motion, Simple machines,* and *Snap, crackle, pop!* were verbatim transcribed, and analyzed for details in what was said during each lesson. Limited time and funds influenced this decision. Only *Snap, crackle, pop!* was taught by both educators in MD Museum. *Simple machines* and *Forces in motion* were lessons assigned to the same classroom in NC Museum. (Appendix I)
5. *Decide if your domains are supported by the data and search data for examples that do not fit with or run counter to the relationships in your domains*.

- Interview and observation data were reviewed for negative cases, i.e. examples that did not fit within current domains. Domains were refined or abandoned.
- Searching for domains derived from interview data among observation data also served to determine whether domains were supported by all the data.

6. *Complete an analysis within domains*.
    - Elements within the domains generated from interview and observation data were revisited in search of other possible ways to organize them or relationships between elements. A new outline was generated along with support units. (Appendix J)
    - Outlines were submitted in writing to educators for review.

Analysis Round 3

7. *Search for themes across domains*.
    - Researcher looked for connections across the domains in search of major themes to understand how all the pieces fit together.
    - Educators' written comments, if any, were reviewed and incorporated.
    - A diagram was created to show the domains and how they were connected to one another (Appendix K).
8. *Create a master outline expressing relationships within and among domains*.
    - Pulled together all the domains into one comprehensive outline. (Appendix L)

After Analysis

9. *Select data excerpts to support the elements of your outline*.
    - Data excerpts came from units that supported the domain and required the least inference from the rest of the interview or field notes were selected.

Some text before and after the unit was included when necessary to put the excerpt in context and help it make sense to the reader.

CHAPTER IV. FINDINGS

Introduction

This study sought to answer two major questions and two sub-questions: 1) How do educators teaching one-hour, one-time lessons in museums adapt their instruction to the students that they teach? How does perceived variability in entering student knowledge affect instruction? How do time limitations affect instruction? 2) What is an appropriate theoretical framework to describe and understand instruction in informal settings? A total of 23 observations and 18 interviews (14 post-lesson interviews and 4 initial interviews) provided data. Each of the four educators in this study was observed teaching short, one-time science lessons on five to seven occasions, depending on scheduling. Initial interviews focused on the educators' teaching philosophies and practices, and post-lesson interviews explored reasons for their actions during the previously observed lesson(s). The results presented are organized in three sections. Section 1 describes the lessons. Section 2 describes the data from the educators and addresses the research questions. Section 3 describes the educators' goals and philosophies that underlie their instruction.

Section 1. Describing the Science Lessons

Characteristics of the Lessons

All science lessons observed in this study were comprised of segments classified as Talk, Demonstration, or Activity (Table 7). The level of physical participation for the students characterized the primary differences between the segments. As the descriptions in Table 7 depicted, Talk segments required the least amount of physical participation from the students and Activity segments required the most.

Table 7. Descriptions of the three types of segments that made up the lessons observed in this study.

Segment type[1]	Description
Talk	An educator-led verbal interchange between the educator and students during a lesson. This was a distinct segment when it involved the educator and students asking and answering questions, sharing past experiences, or telling about content related to the demonstration, activity, or topic of lesson. There was no physical participation. However, it was not part of the dialogue needed to carry out an activity or demonstration. This meant omission of *Talk* from a segment did not interfere with doing an activity. Consequently, giving instructions was not part of *Talk* since directions were necessary for carrying out an activity.
Demonstration	An educator-led whole class activity that involved using objects, role playing, and/or student physical participation. Students participated individually, or as a whole class. Not all students got the opportunity to physically participate although their attention and verbal input was needed.
Activity	Student tasks were classified as *Activity*. During an *Activity*, the educators assigned the task, gave instructions and materials, and decided length of available time. However, groups of two to four students worked together to complete the task while the educator wandered throughout the room talking with groups or individual students. The need for students to record data varied depending on the task.

[1]Level of student participation was the primary distinguishing characteristic between the segments.

Detailed descriptions of each segment in the lessons were derived from observations of those lessons during this study at NC Museum (Table 8) and MD Museum (Table 9)[1]. The table detailed the events in the lessons that were common among observations of that lesson. Dialogue after an activity was not included as part of the activity for two reasons. First, the dialogue was not necessary for completion of the task, and second, educators sometimes omitted the follow-up dialogue or used it to segue into another segment. While the objectives and procedures for the activity

[1] For the remainder of this dissertation, the segment type and number designated in Table 9 is used to reference specific segments within the lessons. To illustrate, when discussion focuses on the first demonstration in the *Forces in motion* lesson regarding the imaginary bicycle, the text in the discussion refers to that segment as Demonstration 1.

remained consistent, there was potential for variability in what educators said after the activity. Thus, this was treated as a separate segment. Sub-segments were identified for demonstrations at MD Museum where the format and purpose of the tasks remained the same, while details of the procedures changed such as the Styrofoam, hair standing, and charge line sub-segments in Demonstration 2 for *Snap, crackle, pop!*. These sub-segments provided different ways to demonstrate electrons traveling through objects and repelling from the charged student volunteer.

The number, length, and order of segments varied between lesson topics (Table 8 & 9). Each lesson had at least two of the three types of segments, and could have more than one of the same type of segment, such as six demonstrations in *What's cold, what's hot, what's solid, what's not?* at MD Museum. All lessons began with a Talk segment that introduced the students to the museum and lesson topic, but not all ended with a segment that formally closed the lesson. The introduction began as soon as all the students arrived and the doors were closed. The educator remained the primary instructor who decided transition points, lengths of tasks, flow of activities, and discussion topics.

Table 8. Descriptions of the lessons based on observations at NC Museum. Lessons were made up of three different segments.

(E = educator, S = student, Ss = students) [1]

Lesson observed	Lesson plan description based on observations
Title: Forces in motion *Target grades*: 4–8 *Grades observed*: 4th and 5th *Educators observed (frequency)*: Janet (2) and Sally (2) *Seating plan*: Students seated at table during TALK and DEMONSTRATION. Rolling took place on carpet during ACTIVITY 1 and 2, but materials remained on tables. *Published description*: What makes things move? Explore friction, gravity, and energy in this hands-on physics experience.	**TALK 1**. *Introduction*. E welcomed Ss to the museum and introduced topic of lesson. **DEMONSTRATION 1**. *Imaginary bicycle*. E led role playing of rolling down a hill on an imaginary bicycle example. Discussion focused on elements that influenced the speed of the rolling (wind, tire, and ground). **ACTIVITY 1**. *Examine full and empty cans*. E presented Ss the task of determining which can would roll farthest down a ramp (empty or full versions of each: small 8 oz. tomato paste can, medium 15 oz. refried beans can, or large 24 oz. coffee can filled with cement). Each group was given a set of these six cans, and instructed to make observations of each can and decide which would roll farthest down the ramp. **DEMONSTRATION 2**. *Compare empty and full cans*. E collected cans after Ss made their observations, and tallied votes on the board (one vote per S) with all six options pre-written on board. E rolled one can at a time down ramp made from a piece of wood and 10” deep plastic tub. A different S was asked to place a paper marker to indicate where each can stopped. Discussion focused on gravity as a force that caused rolling, friction reducing rolling energy of can, and potential and kinetic energy as ways to define energy at different stages of roll. **ACTIVITY 2**. *Canister experiment*. Each S was given a 5” cardboard canister with plastic lids and a worksheet of a data table (three columns record contents in the canister, S’s hypothesis on how the canister would roll down ramp, and canister’s actual rolling behavior; six rows for six trials). Ss at tables shared materials to fill canister (dried pinto beans, three sizes of metal washers, and different shaped foam pieces). E set up three ramps on the carpet area. Ss were instructed to fill their canister with any combination of materials provided, roll the canister down the ramp, and fill in the data table. They were asked not to push their canisters down the ramp in order to keep results consistent among all experimenters. E challenged Ss to come up with content combinations to make the canister roll down the ramp in different ways, and revealed a list of suggested rolling behaviors written on a poster board. (roll to the left or right, slides down ramp, rolls down and stops at the bottom of the ramp, wobble down the ramp, rolls very far, and stops on ramp after rolling a little). **TALK 2**. *Review activity*. E asked Ss to report whether they met the challenges and the contents of their canister for each challenge. **TALK 3**. *Review lesson*. E reviewed and reiterated vocabulary introduced during lesson, and described run away truck ramps as a real-life example of concepts in lesson. E suggested that the teacher could continue this at school.

Table 8 *Continued* Descriptions of the lessons based on observations at NC Museum[1]. (E = educator, S = student, Ss = students)

Title: Simple machines *Target grades*: 4–8 *Grades observed*: 4th *Educators observed (frequency)*: Janet (3) and Sally (2) *Seating plan*: Students remain seated at table throughout lesson, except when asked to help in DEMONSTRATION. *Published description*: What is an incline plane, a lever, and a pulley? How can these simple machines make hard work not so difficult? Creatively problem-solve ways to use simple machines to meet challenges.	**TALK 1**. *Introduction*. E welcomed Ss to the museum, introduced topic of lesson, and asked Ss to define simple machine. **DEMONSTRATION 1**. *Simple machine examples*. Examples of simple machines were placed on top of a wood cart at the center of the room (manual eggbeater, screwdriver, nutcracker, door wedge, hammer, scissors, bottle with a screw top, and paper towel tube with strings and washer attached to make a pulley). E picked up one object at a time, and showed Ss how it was a simple machine. Discussion focused on listing the six types of simple machines (inclined plane, pulley, wedge, wheel and axle, screw, lever and fulcrum). **DEMONSTRATION 2**. *Construction worker.* E presented Ss with task of lifting a "construction worker" (three liter plastic drink bottle filled with sand) up to the top of a "building" (wood cart). Ss were asked to come up with a simple machine (an inclined plane or ramp) that would reduce the work to lift the worker. Work was measured using a spring scale, and measurements were recorded into pre-written statements on board. (effort to lift worker, effort to lift worker up short plane, effort to lift worker up long plane, effort to lift worker and friction fighter, effort to lift worker and friction fighter up short plane, and effort to lift worker and friction fighter up long plane) E challenged Ss to reduce the work even more. This led to increasing the length of the ramp and introducing a toy truck to pull the worker up the ramp in order to reduce friction. Discussion focused on gravity and friction as forces that needed to be overcome. **ACTIVITY 1**. *Inclined plane*. Ss were given replicas of the inclined plane demonstration (16 oz. plastic drink bottle filled with sand, wood car, two sizes of wood planks, data table, a spring scale, and a meter stick clamped to a stand so that it could stand upright on the table). Ss were instructed to measure the effort needed to lift their worker up the ramp at three given heights (10, 20, and 30 cm) using the two ramp lengths. **TALK 2**. *Review activity*. E asked groups to report their recorded measurement from the spring scale for each height and ramp length. Differences in the measurements due to different heights and ramp length were the focus of discussion. **DEMONSTRATION 3**. *See saw*. E presented Ss with the task of lifting her with one foot. Ss were asked to come up with a simple machine (lever and fulcrum) so that a S could lift E with one foot. The lever and fulcrum were presented and the selected S was asked to set them up in a way that would lift the E if she sat down on one end of the lever. Classmates were allowed to help. Discussion focused on gravity as a force that helped and hindered lifting the person when using the lever and fulcrum. **ACTIVITY 2**. *Lever and fulcrum*. Ss were given replicas of the lever and fulcrum demonstration (three 2" long dowel sticks of varying diameters, three 2" wide pieces of wood of varying lengths, a sponge cut out of a person, and a plastic 6 oz. container). Ss were instructed to use their levers and fulcrums to flip the sponge person into the plastic container and determine which combination they prefer. **TALK 3**. *Review activity*. E asked groups to report on their experiments and their preferred combination.

Table 8 *Continued*. Descriptions of the lessons based on observations at[1]. (E = educator, S = student, Ss = students)

Title: Adaptation Advantages *Target grades*: 4–6 *Observed grades*: 4th and 5th *Educators observed (frequency)*: Janet (2) and Sally (2) *Seating plan*: Students remain seated at tables throughout lesson. *Published description*: What are adaptations and how do they help living things survive? Spin the "Wheel of Misfortune" and see if you have what it takes to stay alive!	**TALK 1**. *Introduction*. E welcomed Ss to the museum, introduced topic of lesson, and asked Ss what adaptation meant. Ways in which animals were adapted to their environment were listed. **ACTIVITY 1**. *Yes or no*. E presented Ss with the task of identifying the adaptation features of their animal (a stuffed toy camel, rattle snake, tortoise, tarantula, or lizard per table). They were given index cards with descriptions of animals' adaptation features and a 'yes' and 'no' sign. Ss were instructed to read the descriptions, decide as a group whether their animal had that feature, and place the description on the appropriate sign. **TALK 2**. *Review activity*. E asked one group of Ss at a time to introduce their animals and report on the adaptation features that they believed their animals possessed. E commented on, confirmed, or corrected their decisions. **DEMONSTRATION 1**. *Dress up for desert*. E asked for a S volunteer. Ss were asked to pretend that their classmate was about to trek through the desert, and they needed to come up with objects that s/he required in order to survive. E pulled out some of these objects as they were recommended and placed them on the volunteer (water bottle, sun block, hat, loose clothing, sandals, and sunglasses). **TALK 3**. E led discussion about the many objects that people needed to bring with them when they traveled to the desert. Discussion focused on how different animals were adapted to their physical environment in order to survive. **ACTIVITY 2**. *Wheel of Misfortune*. E presented Ss with a game, *Wheel of Misfortune* (3' diameter wood divided into 10 sections mounted to a stand upright so it can be spun; each section had a natural event: predator, cold, heat, sandstorm, and hunger). Ss were given another stuffed toy animal (scorpion, peccary, jackrabbit, desert tortoise, roadrunner, armadillo, or coyote) along with a set of cards that described adaptation features the animal possessed. Groups were given score chips. A different S each time was asked to spin the wheel. Using the descriptions given and what might know about the animal, groups were instructed to come up with ways their animal would survive the natural event on which the wheel landed. E gave groups time to confer and then walked from one group to the next and listened to their explanations. Successful explanations convinced the E the animal would survive that particular natural event, and thus received a score chip. Unsuccessful explanations cost a score chip. **DEMONSTRATION 2**. *Live animal*. E presented a live animal (animal used depended on availability that morning; bearded dragon from Australia, chinchilla from Andes Mountain, and gecko were used in the lessons observed). Before bringing the animal out, the E told Ss they had the opportunity to touch the animal if they wanted, modeled the appropriate way to touch the animal, and reminded them of acceptable behaviors. E held the animal, asked Ss what adaptation features they thought the animal possessed in order to survive in its environment, and commented on Ss' comments. E walked the animal around to each S (and interested adult) and gave them a chance to take a closer look and touch. E told Ss about the animal (diet, physical features, and behavior) and answered Ss' questions. Ss sat and waited until E came around to them. E cautioned Ss that these animals in the museum were used to being around and handled by people, which was uncommon among animals found in the wild. **TALK 4**. *Review activity*. E led discussion about the animals in the *Wheel of Misfortune* game. E revealed to Ss the animals that they received.

[1] Lessons consisted of three types of segments: Talk, Demonstration, and Activity. Refer to Table 7 for description of segments

Table 9. Descriptions of the lessons based on observations at MD Museum.

(E = educator, S = student, Ss = students) [1]

Lesson observed	Lesson plan description based on observations
Title: Creepies and Crawlies *Target grades*: Pre K–4 *Observed grades*: 3rd *Educators observed (frequency)*: Gary (2) *Seating plan*: Students seated in semi-circle on carpeted floor. *Published description*: From feathers to fur, scales to slimy skin, the animal kingdom abounds with diverse creatures. Meet, observe, and touch a variety of amazing vertebrates that inhabit our world while comparing their differences and similarities and learning about adaptations.	**TALK 1**. *Introduction.* E welcomed Ss to the museum, introduced topic of lesson, and asked Ss what they know about it. E asked Ss to share what animals they feel were creepy and crawly. E told Ss about appropriate ways to behave when the animals were brought out and ways to touch the animal. **DEMONSTRATION**. *Live animals*. E had four animals (Eastern box turtle, White's tree frog, chinchilla, and ball python) and brought them out one at a time. Animals not in use were stored in their carrying cases that were hidden behind chalkboard. Before bringing out the animal, the E told Ss a clue about the animal and asked them to guess what they thought the animal would be. E brought out the animal and told Ss about the animal (physical features, geographic distribution, animal group like reptile, amphibian, and mammal, diet, and behavior). Ss asked questions and shared comments and personal experiences with the animal. E asked and answered questions about the animal. E walked around the room and gave each S (and interested adult) the opportunity to take a closer look and touch the animal. E reminded Ss that these animals in the museum were used to being around and being handled by people, which was uncommon among animals found in the wild. **TALK 2**. *Review lesson*. E asked Ss if they had any questions or comments about the animals they just saw.
Title: What's cold, what's hot, what's solid, what's not? *Target grades*: Pre K–2 *Observed grades*: 2nd *Educators observed (frequency)*: Julia (2) *Seating plan*: Students seated in semi-circle on carpeted floor. *Published description*: See matter change before your very eyes, become a bouncing gas molecule, feel the chill of cold liquid nitrogen as it boils at room temperature, and discover how making (and eating!) ice cream becomes a savory science lesson!	**TALK 1**. *Introduction.* E welcomed Ss to the museum and asked Ss whether they knew the topic of the lesson. **DEMONSTRATION 1**. *Phases of matter*. E showed examples of three phases of matter (solid rock, liquid water, and gas in air) and talked about the physical characteristics and differences between each type of matter. E told Ss there were also two other types of matter, plasma and superconductivity. **DEMONSTRATION 2**. *Molecules.* E held up a clear glass jar filled with beads along with each example of matter. Jars were the same size, but were filled to different capacities for the different phases (full for solid, half full for liquid, and nearly empty for gas). Ss were told that everything was made up of molecules, the beads in the jar represented molecules, and that the molecules in the different phases of matter had different energy levels. Ss were instructed to wave their arms above their head to simulate energy level of phases (fast for gas, medium for liquid, and very slow for solid). **TALK 2**. *Being scientists*. E reminded Ss that they needed to be good scientists today, and asked them what they needed to do in order to be good scientists (think, observe, and use senses to touch and taste). **DEMONSTRATION 3**. *Solid to liquid by heating and melting.* E presented Ss a game, *Pass but don't drop*. E instructed Ss to take the ice cube that was passed to them, rub it for four seconds, and pass it to the person next to them. The ice cube was passed all around the circle and returned to the E considerably smaller (or no longer there). The discussion focused on melting and how heat created from the rubbing hands caused the change from solid to liquid.

Table 9 *Continued*. Descriptions of the lessons based on observations at MD Museum. (E = educator, S = student, Ss = students)

What's cold, what's hot (CONTINUED)	**DEMONSTRATION 4**. *Ice cream*. E presented Ss with a pitcher containing a white colored liquid. She told Ss there were three different things in the mixture (cream, vanilla, and sugar), and challenged them to determine what those things were using their eyes and nose (seeing and smelling) as she brought the pitcher to each person for closer inspection. Ss were asked to be good scientists by keeping their guesses to themselves until everyone had a chance to make their observations. E asked Ss to share what they thought were the things in the mixture, what could be made with those things once they were revealed (ice cream), and how this could be done (freeze it). E brought out a cold ice cream making cup and poured mixture into it. A chaperone was asked to bring the cup around to each S so they each got a chance to turn the crank to make the ice cream. Everyone got to eat the ice cream at the end of the last demonstration. **DEMONSTRATION 5**. *Feeling phases of matter*. E presented Ss with a game, *Feel but don't squeal*. This game was played on two separate occasions. E brought out the game piece made from a 4" diameter, T-shaped PVC pipe. One end was sealed shut and the opposite end had a black fabric sleeve attached at the opening, the top was also sealed shut. Ss were told that an object was placed in the tub (air for the first round, a candle in the second round), instructed to stick their hand in the container as the E brought the tube around, feel the object, and determine what it could be. Ss were asked the type of matter for the object and then what the name of the object. This game was played a second time as the last demonstration, and the E focused discussion on reviewing how to change phases of matter from solid to liquid to gas by adding heat. **DEMONSTRATION 6**. *Liquid to gas by boiling*. E introduced liquid nitrogen to Ss. E told Ss about nitrogen in the air, and asked Ss to give examples of the coldest things they knew. E gave safety precautions that Ss needed to follow when she poured out the nitrogen (remain seated and do not reach for the nitrogen). Discussion and demonstration used liquid nitrogen at –320 ˚F in a room at 75˚F to explore boiling and change from liquid to gas. Ss watched as E manipulated different objects in three segments of this demonstration. Ss made comments about what they saw. E asked Ss about what they saw and related observations back to phase changes. • E placed a glass beaker on the floor and poured some liquid nitrogen into it. They observed and discussed the liquid nitrogen boiling in the beaker. • E challenged Ss to come up with a way for her to get an inflated balloon into the bottom of an empty beaker without popping or untying the knot. Within this segment, Ss were asked to role play movement of gas molecules by waving their arms above their head really fast. Discussion focused on using temperature (cold and hot) to change movement of molecules, condensing and expanding. E placed the balloon at the opening of the beaker and poured liquid nitrogen over the balloon. The balloon appeared to deflate and sink into the beaker. The E pulled the balloon out and it inflated back to the original size. • E poured liquid nitrogen on to the carpet at the center of the circle. Discussion focused on the cloud formed by water molecules in the air condensing due to extreme cold from liquid nitrogen. Safety precautions were reiterated. Once all the nitrogen evaporated, Ss were allowed to reach out and touch the floor, which was now cold.

Table 9 *Continued*. Descriptions of the lessons based on observations at MD Museum. (E = educator, S = student, Ss = students)

Title: Snap, crackle, pop! *Target grades*: 3–6 *Observed grades*: 3rd–5th *Educators observed (frequency)*: Gary (3) and Julia (3) *Seating plan*: Students seated in disorganized rows on carpeting floor during TALK and DEMONSTRATION. Students clustered into groups, but remained on the floor during ACTIVITY. *Published description*: Investigate the nature of static electricity as you move charges, have a hair-raising experience with Robert Van de Graaff's most famous invention, and learn how to protect yourself from the hazards of lightning. Become "charged up" under the ultimate of shocking circumstances.	**TALK 1**. *Introduction*. E welcomed Ss to the museum, introduced topic of lesson, and asked Ss what they knew about it. E asked Ss to give examples where they experienced static electricity. **ACTIVITY**. *Rod and material*. E presented Ss task of generating static electricity with different rods and materials (12" rubber, plastic, and glass rods, 4" squares of raw silk, Mylar, and wool, a data sheet with a 3x3 table of rods and materials, and container of Styrofoam ground into pieces). Ss were shown how to generate static electricity with the materials (rubbing the rod on the material) and check whether they generated electricity (moving rubbed end of rod near ground up Styrofoam piled on the carpeted floor; presence of static electricity was indicated by Styrofoam pieces sticking to rod). Ss were instructed to try combinations of rod and material to determine which generated static electricity enough to lift the ground up Styrofoam, and record 'yes' or 'no' responses on the data sheets. **TALK 2**. *Review activity and charges.* E asked groups to report on their findings and recorded this on a similar 3x3 table already drawn on the chalkboard. Discussion focused on the most successful combinations (the rod or material combination that best generated static electricity), and possibilities for data discrepancy between groups. E led discussion on charges (proton, electron, neutron, negative, and positive) as a cause for static electricity. **DEMONSTRATION 1**. E asked two Ss to help demonstrate how charges repelled and attracted using magnets as a visual example. Diagrams were drawn on the board to support the explanation of charges generated from the rubbing of the rod on the material. **DEMONSTRATION 2**. E introduced the 125,000 volts Van de Graaff generator and explained the safety precautions (no electronic devices like cameras and cell phones when on machine, no electronic medical devices like pace maker and insulin pump, and no pregnant women). Ss also needed to stay seated and not reach for the machine or person standing near machine. E demonstrated static charges and transferred the charges onto her or himself to show that it did not hurt. E asked for different Ss to help with the next two sub-sections of the demonstration. • S stood on plastic stool, held ground up Styrofoam closed in one hand, and placed other hand on dome of generator. E turned on the generator and charged up S. When the E signaled, the S opened her/his hand and the ground up Styrofoam flew out of the S's hand. • S stood on plastic stool and placed one hand on the dome and other by her or his side. S's hair started to stand up as generator charged the S. • E offered all Ss, chaperones, and teacher the opportunity to participate in the last sub-section, and reiterated the safety precautions. All participants were asked to hold hands and form a line that curved around the room. E stood on the plastic stool and placed one hand on the dome and held the other in a fist. The person at one end of the line stood near the E with her or his empty hand in a fist. When the E signaled, the S brought her or his fist up to the E's fist. The charge that built up in the E jumped to the S and was carried down the line to everyone else. This gave everyone a small static electric shock. **TALK 3**. *Review generator*. E explained the mechanism of the generator and related this with the Ss' activity with rods and materials. **TALK 4**. *Review lesson and lightning*. E asked Ss if they had any questions about static electricity. E told Ss what to do during a lightning storm.

[1] Lessons consisted of three types of segments: Talk, Demonstration, and Activity. Refer to Table 7 for description of segments

In all the lessons, there were no long or consecutive segments of Talk, but there were long and consecutive segments of Demonstration (Figures 3 & 4). Figure 3 displayed time intervals and order of each segment for all classes observed at NC Museum according to the educators and lesson. Figure 4 displayed the same type of data for Gary and Julia at MD Museum (discussed further in *Repetition Develops Consistency*, p. 89). The educator directed dialogue during both Talk and Demonstration segments.[2] For example, in Julia's School, *Snap, crackle, pop!*, Talk 1 welcomed students to the museum and asked them to share personal examples with static electricity. Julia followed each student example with a comment and elaboration.

> Educator, "What do you think goes snap, crackle, pop?"
> Student, "Rice Krispies."
> Educator, "Oh, everybody says that. Rice Krispies. Think about snap, crackle, pop. What else do you think about besides Rice Krispies? Anything else?"
> Student, "The TV."
> Educator, "Oh."
> Student, "Has static in it so you can watch TV."
> Educator, "Oh ok, so sometimes when you go close to the television screen you might sometimes feel that little static charge. You're right, there's static there too."
> Student, "Your clothes."
> Educator, "Yes. Think about when you pull clothes out of the dryer. Sometimes they stick together. When you fold them, you get a little zap."
> Student, "When you go down a slide."
> Educator, "Oh the slide, excellent. We used to have a slide in our kid's room upstairs and I could never figure out why when the little guys got off the slide they always went, "ooh". They were getting a static charge. On the way down, they touched a metal rim on the sides, they were really getting a charge. So static is all over the place. We've probably got some other great examples of static but first let's talk about what static is. Static is actually a collection of charges that like to sit in one place. It's kind of like what you're

[2] For excerpts from transcripts of the lessons, "Educator" refers to the educator teaching the lesson and "Student" refers to any student in the class. The student comment could be from the same student or a different student. The researcher did not distinguish between student comments because regulations prohibited capturing students' images on video, thus making it difficult to accurately and consistently distinguishing between students.

doing right now. W hat would happen though if I opened the door and we let a whole bunch of other charges in? If maybe we let the other two school groups that were with you today inside here. What would you have to do to make room for them?"

Student, "We would have to squish."

Educator, "Well you might get closer together or you'd have to move somewhere else. You'd probably move out the back door here. So static, when it builds up to a certain point, begins to move. Sometimes it's your hand or another object that gets that static when it starts
to move."

Julia, School 8 Lesson Dialogue, 11 May 04, lines 77–107

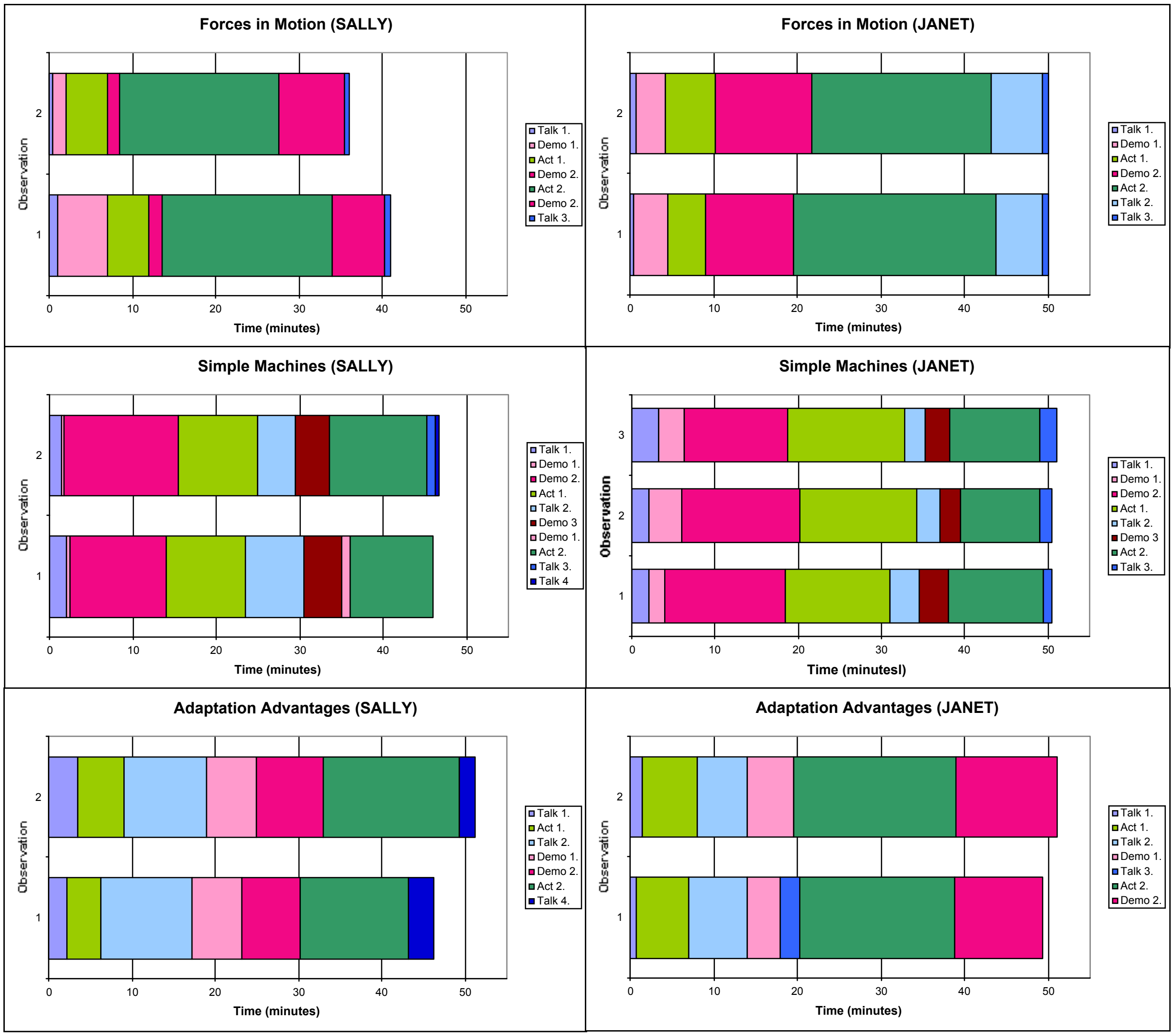

Figure 3. Order in sequence and amount of time for segments in lessons observed at NC Museum.

All classes for each lesson were taught consecutively, for example, Class 2 was taught immediately after Class 1 for Sally's *Forces in motion*. (Blue shades = Talk; Green shades = Activity; Red shades = Demonstration).

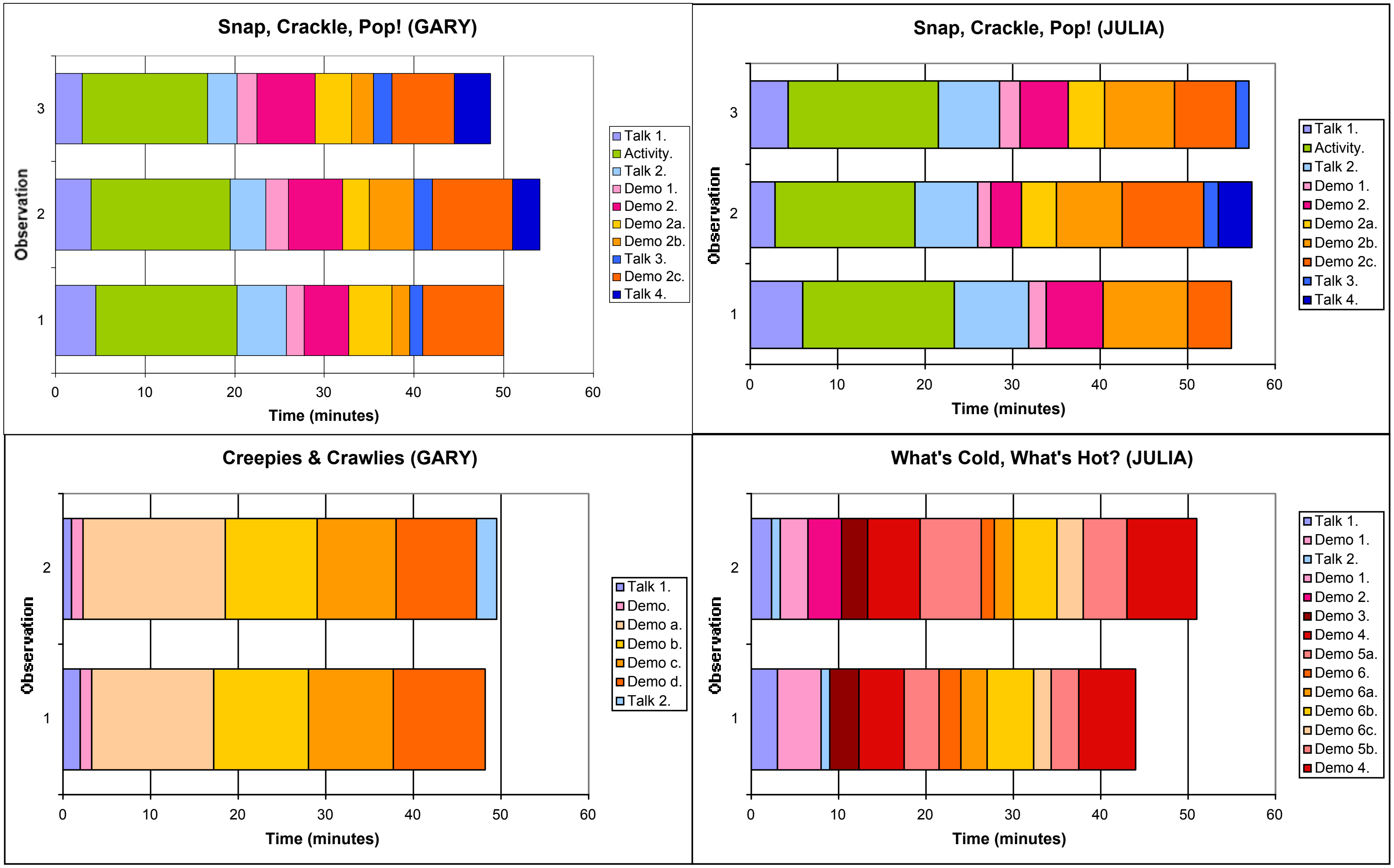

Figure 4. Order in sequence and amount of time for segments in lessons observed at MD Museum.

For both educators, all *Snap, crackle, pop!* classes were taught on separate occasions. Classes for *What's cold, What's hot?* Were taught consecutively. (Blue shades = Talk; Green shades = Activity; Red & Orange shades = Demonstration)

Julia directed this discussion on examples of static electricity and used it to segue into her definition of static electricity. The students answered questions and listened. In Demonstration 2B, Julia directed the discussion but this was part of a whole class activity where one student volunteered to charge himself up with the Van de Graaff generator. In this excerpt from Demonstration 2B, a student was charged with the generator until his hair stood straight up. Julia then turned off the machine, asked the volunteer to remain on the plastic stool, and addressed the class.

> Educator, "Well James, let's see what happens here. We're going to try this out. Let me turn it off. (turns off and discharges machine) You take your hand off [the dome of generator] but stay on the stool. Ok, stay right there on the stool. Now James, I still see a few hairs up there. It's kind of interesting. Do you see that? (asking rest of class) He's got some hair standing up. They're real fine. They're real small there. Why are the hairs still standing up? He doesn't have the machine producing the charge anymore. What's going on here? Why are they still standing up? Do you know?"
> Student, "Because of the machine."
> Educator, "Ok. We turned the machine off but the charge is not leaving his body. That reminds me of something that happened over here on the chart."
> Student, "Electricity."
> Educator, "You got it. Electricity is a hard word."
> Student, "Static electricity."
> Educator, "Yes. It's still there on his head but I want to find out why. Let's see if we can get someone else to answer. You've got the answer, I know you do. Let's see if we can get somebody else."
> Student, (inaudible)
> Educator, "It's still on the surface of his body but what's keeping it there? Let me ask you a question. Is James normally this tall?"
> Student, "No."
> Educator, "All right. Think about that. What's happened here?"
> Student, "He's close to the ball."
> Educator, "No the ball is actually discharged. There's no longer a charge there. I did that when he got off (when he took his hand off dome). But he's standing on something we worked on earlier."
> Student, "He's standing."
> Educator, "A stool made out of …"
> Student, "Plastic."
> Educator, "Plastic. Look at that. The plastic is acting like an insulator. It's keeping the charge from getting to the ground just like it did over there on our rods. Now James I bet if you step down that charge is

> going to go real quickly down into the floor. Go ahead and do that, let's see. Yes most of his hairs are down. Now do you feel any charge any longer? Let's shake hands to see if you're still charged. Nope. He's gotten rid of the charge. The charge became grounded when he got off that insulator. Good job James. We're going to try this again."
>
> Julia, School 8 Lesson Dialogue, 11 May 04, lines 537–585

Plastic acting as an insulator was interjected as part of the demonstration. Julia led the students towards the answer she wanted, and used the answer to talk about plastic as insulators and related this back to what they did in the rod and material activity. The excerpts illustrated typical ways the educators led discussion during both types of segments. There were opportunities of physical participation during a demonstration and discussion focused on that participation.

Closure of lessons at MD Museum involved asking students whether they had questions regarding the topic or activities from the lesson. At NC Museum, the educators concluded the lessons in different ways. For *Forces in motion*, both educators reviewed the vocabulary words that were introduced and emphasized in the lesson. In *Adaptation advantages* and *Simple machines* there was no separate segment that asked for questions or reiterated content or vocabulary. On all occasions at both museums, the educators thanked the students for coming and reminded them to listen to their teachers for directions. Students at MD Museum remained seated until the educators made this announcement to dismiss them. On 3 of the 13 lessons at NC Museum students got up and started to leave before the educators' dismissal. All the lessons at MD Museum exceeded the advertised 45 minutes by 2 to 13 minutes (Table 6, p. 66). Five lessons at NC Museum exceeded the 50-minute limit by two minutes or more. Not including the classes that arrived at the museum 15 minutes late, four were less than 50 minutes.

Repetition Develops Consistency

There was consistency in the general content and activities among the lesson topics overall. These were pre-planned science lessons advertised and designed to offer a learning experience to school groups during their visits to the museum. The lesson topics targeted specific grade ranges and objectives correlated with state curriculum standards (NC Museum's lessons were correlated with the North Carolina Standard Course of Study and MD Museum's lessons were in the process of being coordinated with Maryland's state standards). The activities, demonstrations, and discussions corresponded with the overall objective of the lesson regardless of educator and class, and procedure for the activities and demonstrations remained consistent (Table 9). Figures 3 and 4 showed the sequence of segments for each lesson observed and approximate time spent on each segment during the lesson. Within a lesson topic, the order as well as time spent on the segments was more consistent for a single educator than between educators. For example, in *Adaptation advantages*, Sally conducted Demonstration 2 before Activity 2 for both classes, while Janet taught Activity 2 before Demonstration 2. In *Snap, crackle, pop!* Gary conducted Talk 3 before the last sub-segment of Demonstration 2, while Julia omitted Talk 3 in all three observations. Julia embedded elements of Talk 3 throughout Demonstration 2. The educators had different reasons for teaching the same lesson topic in a different order (detailed discussed in section *Lessons Comprised of Segments: Rearrange the segments*, p. 122). Nonetheless, the objectives, content, and the procedures for the segments did not change.

Educators reported that consistency was part of the lesson design and developed through repetitious use of the lesson plans. Reflecting on how she taught her two *Adaptation advantages* lessons (School 3) differently, Janet said,

> Janet, "I think they were pretty similar. …The program's pretty blocked (referring to segments), like blocked through this, blocked through that, blocked through this, so there wasn't really too much that I think that I changed. I mean I'm sure I said different words just because you know different words come out. But other than that I think that the classes were very similar. I think the second class though was a little slower at the start on thinking what an adaptation is (referring to student knowledge). I don't really think they understood what the word meant because some were coming up with like, 'when they're in a new place' or like, 'their climate' or something like that. So they were a little less informed about adaptation and what that means."
>
> Researcher, "So did your teaching or what you said change in regards to the second class?"
>
> Janet, "Not really, I gave a definition more clearly like you know, 'an adaptation is something that an animal has to live in the habitat'."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 50–63

The segments in the lesson design kept the two classes similar. Janet changed a detail in her discussion in the second class to accommodate her assessment of students' knowledge, but noticed minimal difference in how she taught the lessons since she included all the segments in the same order for both classes. Figure 1 showed that except for inclusion of Talk 3 in Class A but not in Class B, the sequence of events between her two classes were identical. This omission was not noticed at the time of data collection, thus Janet was not asked to discuss her reasons for this change. Sally's *Adaptation advantages* classes included the same segments, objectives, and procedures, however, she intentionally changed the order of segments (discussed further in *Manipulate Controllable Elements: Rearrange segments*, p. 122).

The educators commented that repeating the lessons helped to develop consistency so that every class of students received similar experiences regardless of when and with whom they had a particular lesson. It appeared the educators gained comfort and insight with a particular lesson as they taught the same lesson to different groups of students, which enabled them to refine their explanations and instructions.

Comfort with lessons.

Comfort with lessons referred to developing familiarity with the lesson plan and content through teaching the same lesson over and over again. This was helpful in articulating explanations and directions concisely and efficiently, as well as responding to class tardiness, seamlessly and without stress. *Simple machines* was a newly developed lesson and taught for the first time in September 2003. Sally had only taught it a couple of times before School 2. When asked whether she taught the two classes any differently,

she said,

> "You know why it was different? Because every time I do it I think of other things to add or other things to say or different ways to say it, and I still forget things. But I think, 'oh why didn't I think of saying that last time,' and each time I adjust it a little bit. It doesn't have anything to do necessarily with the level of the [students], it has to do with it dawning on me, 'oh I could say it clearer' or 'I could connect this a little better way' or 'I haven't taught it very many times'. …So yeah I haven't taught it very much. The more you teach it the more you realize what works and what doesn't work and the less you forget to give them the more explicit directions."
>
> Sally, School 2 Post-lesson Interview, 12 Feb. 04, lines 61–74

Sally was comparing differences between the two classes for School 2, and realized some of the differences were based on revelations she made during the lesson on how to explain content or give directions in a clearer and more concise way. She attributed this to her lack of familiarity with this lesson since she had not taught it very often.

Similarly, Gary talked about refining his directions for Demonstration 2C during School 4 *Snap, crackle, pop!*.

> Gary, "…The biggest thing right now is the charge line. With the air conditioning on, it's not building up that good of a charge and that's a challenge. And I've just started to break them in half lately. Like these past maybe three weeks. I'm still trying to work out the wording for that and how to do it the best way."
>
> Researcher, "What do you mean?"
>
> Gary, "Like I count them off but trying to explain it and have one group stand up while the other one's kind of further back. To do it in a way that doesn't cause confusion. …Normally the first group is okay but then when I switch them out, sometimes the first group wants to sit where they were before, which is normally in front of machine. And that's why I'm like I've changed my wording a little bit where I'm a little bit more aware of it like, 'you need to take a seat further back where the other group was.' But then sometimes when we get a great charge we can do all thirty people at once and it just doesn't matter. But right now it hasn't been that way."
>
> Gary, School 4 Post-lesson Interview, 28 May 04, lines 236–254

This was not a new lesson for Gary, but the building's air conditioning system was causing a new problem (MD Museum was under massive renovations). Gary conducted Demonstration 2C as a whole group for School 1, but for Schools 3 and 4, he divided the class into three groups to do the charge line with fewer students at a time as a result of the reduced charge build-up on the generator. In the latter two classes, there was confusion as the groups switched. Gary divided the class into groups of eight to ten students according to where they were seated. He took the group closest to the generator first and asked the remaining students to stay seated. During the switch, students in the first group returned to where they were sitting, which was near the generator. This crowded the second group of students at the charge line, and reduced the strength of the shock as charges jumped from the line to the students sitting nearby. By the second switch for the third group, everyone was standing and crowding towards the generator as the excitement and noise level in the room rose tremendously. Gary talked over the screaming and cheering for the students to not get too close to the machine or those in the charge line, while at the same time, his mobility was restricted because he was charging himself up with the generator for the demonstration. At the moment, he was testing out the best procedures and directions that would help him manage the class while conducting the demonstration.

Julia reported that the familiarity she gained from these repetitions gave her flexibility. In talking about how her time was divided up during School 6 *Snap, crackle, pop!*, she said,

> "After you've done these classes hundreds of times too, you're either looking at the clock saying, 'ok if you've got a lot of questions on this, spend an extra five minutes, I can slowly take it out of two other places and you won't even notice it because you're doing another activity so it works.' It tends to work out. This is one of those classes where they hardly ever get out of the door without everything that the last hundred groups got because it's very easy to adapt it to their needs."
> Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 183–189

Knowing the lesson plan and how long it took her to get through different segments, she was able to be flexible. She seamlessly compromised time in one segment for the sake of another, nonetheless, the experiences these students received were similar to those of previous classes.

Sally provided evidence for this explanation in School 1 *Forces in motion*. The school arrived at the museum 15 minutes after class was supposed to begin. Sally waited in the room for the students, and checked her voicemail for a call from the school or teacher. When the school arrived, another museum educator greeted the classes and directed them to Sally's room. At the start of their classes, both teachers informed Sally the time they had to leave. Sally taught the lessons without appearing rushed, confused, or flustered. She omitted and shorted segments to accommodate for the reduced time (discussed further in *Manipulate Controllable Elements*, p. 115), but did not make a big deal of the changes in front of the students. With only 45 or 50 minutes, the educators had to make quick judgments. Repeating the same lesson plan with different groups of students developed comfort and familiarity with that lesson so that the educators could respond quickly and smoothly.

Insight for future lessons.

In addition to familiarity with the lesson plans, repeating lessons also developed insight for current lessons. Each time the educators taught the same lesson, it was to a different group of students even if the schools, grade levels, or teachers were the same. The educators used what they learned from previous classes to anticipate students' responses and reactions in current classes. Comparing how he taught School 1 *Snap, crackle, pop!* with what he did in previous classes, Gary explained his reason for emphasizing the variability in results for Activity during Talk 2.

> Gary, "…When this group can't do it (referring to lifting Styrofoam with static built up through rubbing together rod and material) … it seems like they did something wrong because theirs all vary (referring to differences in results between groups). And sometimes it turns into, 'well you know we did it right, you did it wrong.' That's why I always try to point out 'yes, we did the same experiment but we all did it differently. This is what's affecting the experiment. There's not a right or a wrong. There are just lots of variables here.' And so sometimes I'll say [this] to get them thinking [that] you should probably do it more than once. That one time isn't really a good example of whether or not it's going to hold true in the future."
>
> Researcher, "So you're learning from how students in past classes responded to the fact that not everybody agrees with each other."
>
> Gary, "Yes because I have noticed in the past, like I said one group will turn around and say, 'well you must have done it wrong.' But some groups are very competitive. And there are so many factors involved. I mean even humidity is going to affect what happens."
>
> Gary, School 1 Post-lesson Interview, 14 Apr. 04, lines 83–97

Gary anticipated from previous classes that dispute could arise between students due to discrepancy in their results for Activity in *Snap, crackle, pop!*, which could be attributed to many other factors including the humidity in the room. Thus as soon as he finished filling in the table in School 1, he brought attention to the inconsistencies and asked students for reasons why.

This was the same rationale Gary used to let students pick their own groups for Activity in this same lesson for School 3. He said,

> "The reason I let them pick their own groups is, again some of this is trial and error. I have found that I don't like to be the one to separate the friends because sometimes that ends up being more of a distraction. 'Ok you three together, you three', then I always have a group complain, 'can't I be with so and so?' And sometimes it works as more of a distraction. Where if I let them pick their own groups and then I let them work in groups next to their friends to begin with, then sometimes it alleviates some of the 'I want to work with my best friend' because their best friend is in another group but they're right next to you."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 206–212

Again Gary learned there was a potential cause for distractions in forming groups for the rod and material activity and tried to address it before it could start. However, there was still possibility for conflict to arise. Six students had trouble forming groups during School 3, and while Gary noticed their quandary, he waited for the students to resolve it. Their teacher interjected and helped these students resolve the dilemma, which Gary appreciated (teachers' role in student management discussed below in *Taking Advantage of Others: Classroom teachers as student managers*, p. 143). Nonetheless, Gary took precautionary measures to reduce chances for distractions, and neither solution changed the objectives and procedures of the lesson.

Julia pointed out that this was also a way to manage students' behaviors without having to rely on the teachers. As she talked about the presence of the teacher in School 6 *Snap, crackle, pop!*, Julia said,

> "I think for this class particularly, probably [Gary] and I both don't tend to rely on [the teachers] a whole lot because we know where [the students are] going to get excited and where we really have to tell them that they have to be quiet and give directions and things. So the teacher's nice to have along but if she is not there, we still can do it."
>
> Julia, School 6 Post-lesson Interview, 21 Apr 04, lines 390–393

Julia anticipated when and how students responded to parts of her lesson based on how other students responded in past lessons. Therefore, she was ready for changes in students' behaviors in different parts of the lesson, which minimized her need to rely on the teachers for class management. For observations *of Snap, crackle, pop!*, a noticeable changed in student behavior occurred during Demonstration 2C for the charge line. The educator charged him/herself up with the generator while students and adults held hands in a line wrapping around the room. When the educator felt charged enough, s/he reached for the students at the start of the line and transferred the charge from the educator to the line. This gave everyone a static shock. After the first attempt, all the students were cheering, laughing, and standing, and the noise level rose considerably. Meanwhile the educators' mobility was restricted since s/he was holding on to the generator. Despite the appeared commotion and chaos, the educator remained calm and collected. S/he had to raise her/his voice or repeat her/himself to be heard, but did not appear frustrated or impatient with the students.

Previous classes also offered educators insight on student knowledge, which helped them determine what to expect from students they did not know. Sally suggested that teaching consecutive lessons offered her immediate indication of student knowledge. For School 2 *Simple machines*, when asked whether the first class affected the second class, Sally said,

> "Oh it did because I was pretty sure even before they walked in that they would've had some instruction already on simple machines. I was pretty sure that this was something that was pretty much grade-wise. …I knew it

wouldn't necessarily be on the same level but I knew they would have already been familiar with some of it. So there were times when I asked them for instance, 'what do you think a simple machine is?' They could figure it out that it was long and narrow and all that stuff. And I never would have asked children who hadn't heard of simple machines anything like that. So I was just curious to see what they would say and most of them gave me a reasonable answer. Even if it wasn't right, it was a reasonable answer."

Sally, School 2 Post-lesson Interview, 12 Feb. 04, lines 139–153

Considering the dialogue at the beginning of both classes for School 2, Sally asked students "what is a machine?" and Talk 1 involved deriving a definition of simple machine with the whole class.

(Class A)

Educator, "Can someone tell me what a machine is?"
Student, "You mean a simple machine?"
Educator, "No, I mean a machine."
Student, "Umm, (inaudible, parts)."
Educator, "Okay that's a good start. What do you want to tell me?"
Student, "It's a device."
Educator, "That's a good start too. We can put those two together. We've got a device of something that has a lot of parts, something that is made of lots of small parts. Can you add to it?"
Student, "It helps you do work."
Educator, "Yeah, that's the main thing. It's something that helps you do work. And you usually need a force to do the work. And so a machine it could be … (walks to cart at front of room and picks up an object and shows class, puts it down and picks up another object, shows class, and puts back on cart. Does not say anything about the objects). Or it could be something that you're thinking of that is made of hundreds and hundreds of parts. But you said I needed a simple machine, and what do I have listed up here (points to list of words on board)?"
Students, "Simple machines."
Educator, "Have you talked about any of those?"
Students, "Yes."
Educator, "And they all help you do …"
Students and Educator, "Work."
Educator, "So we have some challenges today." (Begin Demonstration 1)

Sally, School 2 Class A Lesson Dialogue, 12 Feb. 04, lines 12–46

(Class B)

Educator, “So we are going to talk about simple machine. We are going to have a couple of challenges today to see if we can make our work easier. What’s a machine?”

Student, “Like an easier way of doing things. Like an easier way of like (student stops)”

Educator, “Oh you’re real, real close. Anybody want to add to that?”

Student, “Something to make something that you’re doing easier.”

Educator, “You have the same idea, you just said it in a different way. You have something to add to that? (points to student)”

Student, “If you were doing something hard and you wanted to do something easy, like those measuring things then you would … (inaudible).”

Educator, “Sometimes it’s very, very simple. That’s why they call it a simple machine. It’s just one little thing. Sometimes it’s a whole lot of pieces put together (holds up object from cart to show class). This is a machine that helps makes work easier. Usually it helps you use more force than you could use by yourself. I think I would still even give you this challenge. This is a construction worker.” (Begin Demonstration 1)

Sally, School 2 Class B Lesson Dialogue, 12 Feb. 04, lines 4–23

Sally asked students to define a machine at the start of both classes. In Class A, she focused on a general definition of machine and worked towards defining a simple machine, but students appeared ready to define a simple machine. Due to students’ performance in the first class, Sally anticipated that students in Class B were familiar with simple machines. Thus she did not hesitate to question the second class with the same rigor, and accepted their definitions of simple machine right away.

Similarly, in School 3 *Adaptation advantages*, Sally challenged the students in Class B a little more due to the competency of students in Class A. At the start of Class A, Sally asked students “what does it mean to adapt?” A student responded, “changing the way you live to fit your needs.” Sally offered that humans were adapted to breathe air and asked students what body part let humans breathe air. Their performance throughout the lesson demonstrated to Sally that they had studied animal adaptation in school prior to the museum visit. She asked Class B if they had studied adaptation like

Class A and they answered “yes,” and she also asked them “what does it mean when you’re adapted to something?” Student responses included, “you have to get used to a different environment” and “animals have to learn to live in that kind of place.” Instead of offering that humans were adapted to breathe air, she asked, “are you adapted to breathing in water?” Students responded, “no, but fish are,” and Sally followed with more questions, “what do you have to do since you are not adapted to breathing in the water, what do you have to do if you want to go in the water?” Talking about how she started the classes, Sally said,

> “I repeated what [students in Class A] told me adaptation was and I don’t think that I said a whole lot of other explanations. …In [Class B], I did decide to try and see how they understood it as far as getting, if they were adapted to something like to being in water, to breathing in water. So I was curious,
> I thought I’ll just see if they can understand that that way and then they had no trouble.”
>
> Sally, School 3 Post-lesson Interview, 25 Feb. 04, lines 24–28

Students’ competency in Class A suggested to Sally that students in Class B were at least familiar with adaptation, thus she was confident to challenge them at the beginning of class. Instead of telling students that humans were adapted to breathing air, she asked students whether humans were adapted to breathe in water and continued with questions asking what humans needed in order to be adapted to breathe in water.

Janet reported similar sentiments about using consecutive classes to predetermine student knowledge. However, she found that she could not rely on her judgment all the time. When asked whether the previous classes affected the later classes in School 2 *Simple machines*, she said,

> “Right, definitely the previous classes prepared me for their knowledge which then shocked me for the third one because they didn’t know as much because I was expecting the third one to know just as much as the first and second and they didn’t really know that much. So that was kind of false information or false guessing on my part. So definitely the first

groups helped me out just in reviewing the material and doing the order of everything and getting it all back up to speed with the third group, which I guess actually works out well because it was the third group who didn't know as much. So by the third group I was ready to go, so it was perfect that they came in as the third group."

Janet, School 2 Post-lesson Interview, 13 Feb. 04, lines 244–251

Since students in Class A and B were familiar with simple machines and competent in the activities and demonstrations, Janet assumed students in Class C would be comparable. She admitted that this judgment was incorrect in this observation. She used previous classes to offer a glimpse of student ability in later classes, but found that this information was not always reliable. Nonetheless, student knowledge in Class A was useful for Class B, and the first two classes allowed her to gain familiarity and get into a rhythm with the lesson plan for the third class.

Teaching the same lesson topic to different groups of students in the same grade level also gave the educators insight on what they could expect. For School 6 *Snap, crackle, pop!*, Julia talked about discussion during Talk 2,

"…When you're actually doing the chart and trying to explain how the charges vary between the material of the rod and the Styrofoam, if they don't really catch on to that, then they won't really understand how the machine works when it transmits charges to you. So I try to do that as complacently as possible but at the same time make sure they get that electron and proton word. It's interesting because fourth graders usually know electron and proton. I wasn't sure at this point [since] these classes are still at the end of third grade, but it didn't sound like they had talked a lot about electricity. They usually say, 'oh we learned that in school' and oftentimes too no matter what the charge is they'll say, 'neutron.' And that's your opportunity to say, 'well there's other types of particles too but neutrons are not really charged' and they didn't give that opportunity so I was assuming at that point that they hadn't talked about much of anything related to static."

Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 162–172

Julia learned from previous classes that if students did not understand the discussion on charges during Talk 2, they would have a difficult time understanding how the machine worked in Demonstration 2. Also through repetitions with different grade levels, Julia knew what to expect from fourth graders and looked for verbal indicators to suggest whether they had studied the subject matter in school or not. When she asked these students about charges, they did not offer the word proton or electron like previous fourth grade classes. Nor did they make comments that suggested they studied this in school. Therefore, Julia assumed they were less familiar with static electricity (how this affected her instruction in this segment is discussed in section *Manipulate Controllable Elements: Ways of Modifying the Dialogue*, p. 127).

Comfort and Insight Summary

The one-time science lessons examined in this study were available to multiple grade levels, and each lesson used the same lesson plan regardless of grade level. The educators developed comfort and insight with the lesson plans as they repeated them to different groups of students so that they could respond to unexpected events quickly and without stress. Table 10 summarizes these findings with their respective observation and interview data.

Table 10. Summary of findings and excerpts from *Repetition Develops Consistency* section.
(PL=post-lesson; LD=lesson dialogue)

Findings	Evidence Summary	Evidence Referenced
Comfort with Lessons		
Educators develop comfort and familiarity with the lesson plans as they teach the same lesson plans to different groups of students. They refine what and how to say explanations and directions, and learn to compromise time seamlessly and without stress in one segment for another.	• Sally compared how she taught Classes A & B. She said it was different because she thought of other things to say, other ways to say them, or realized what worked & didn't work each time she taught the lesson. She admitted that this was still a new lesson for her, and that she's only taught it once or twice before this observation.	• Sally, School 2 , 2/12/04 *Simple machines* PL Interview (lines 61–74)
	• Gary explained the need to refine his instructions for the new way of conducting Demonstration 2 so that they were understandable and enabled him to continue managing the class. He acknowledged the need to conduct it differently due to changes in the room. Observations showed Gary was talking over the students for their attention as the demonstration progressed while students cheered and moved toward the generator.	• Gary, School 4 , 5/28/04 *Snap, crackle, pop!* PL Interview (lines 236–254) Researcher field notes
	• Julia talked about how she divided up her time in her classes. She said after teaching it hundreds of times, she knew she could spend extra time in one segment and takes it out of others while ensuring similar experiences as previous classes.	• Julia, School 6, 4/21/04 *Snap, crackle, pop!* PL Interview (lines 183–189)
	• Sally's classes arrived at the museum 15 minutes after their lesson was to start. Sally found out the amount of time she had per class, and taught the lessons without appearing rushed or flustered. Segments flowed from one to the other despite changes she made to accommodate the reduced time (see *Manipulate Controllable Elements*, p. 107)	• Sally, School 1 *Forces in motion* Researcher field notes
Insight for Future Lessons		
Educators anticipate students' behaviors in different segments of their lessons based on responses from previous classes, thus reducing the need to rely on classroom teachers for behavior management.	• Gary clarified his reason for emphasizing student results from the activity. He said when there were discrepant results for the activity students from previous classes accused each other of doing things wrong so he preempted possible accusations by proposing the possibility of many other variables.	• Gary, School 1, 4/14/04 *Snap, crackle, pop!* PL Interview (lines 83–97)

Table 10 *Continued*. Summary of findings and excerpts from *Repetition Develops Consistency* section. (PL=post-lesson; LD=lesson dialogue)

Insight for Future Lessons (continued)	• Gary explained his reason for allowing students to pick their own groups for the rod and material activity. He did not want to break up friends because he noticed that was sometimes more distracting to the students. Observations showed Gary watched six students squabble over picking groups, but did not address them (see *Classroom teacher as student manager*, p. 132). Neither solution appeared to change the objectives or procedures of the activity or lesson.	• Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 206–212) Researcher field notes
	• Julia rationalized not needing to rely on the teacher since she knew where in the lesson students were usually excited and required more management. Her and Gary's calm and composed demeanor during dramatic changes in student behavior Demonstration 2C support this.	• Julia, School 6, 4/21/04 *Snap, crackle, pop!* PL Interview (lines 390–393) Researcher field notes
Previous lessons offer insight on what to expect students to know based on grade level or school, but their assumptions are not always correct.	• Sally compared how Class A affected her in Class B. She knew students in Class B were at least familiar with simple machines due to performance of students in Class A. Lesson dialogue showed Sally asked students in both classes to define a machine. In Class A, she focused on defining a machine in general and worked towards defining a simple machine, but students appeared ready to define a simple machine. In Class B, she accepted students' definitions of simple machine right away.	• Sally, School 2, 2/12/04 *Simple machines* PL Interview (lines 139–153) Class A LD (lines 12–46) Class B LD (lines 4–23)
	• Sally compared how she started her classes in Classes A & B. She repeated students' definition of adaptation in Class A but in Class B she wanted to see if students understood the concept if she posed the question another way. Observations showed Sally told students in Class A that humans were adapted to breathe air, but asked students in Class B whether humans were adapted to breathe in water and what would be needed to do so.	• Sally, School 3, 2/25/04 *Adaptation advantages* PL Interview (lines 24–28) Field notes
	• Janet discussed how she assumed students in Class C would know about simple machines due to performance of students in Classes A & B, but she realized her assumption was incorrect. However, Class A & B gave her opportunity to become familiar with the lesson and get into a rhythm by the third class.	• Janet, School 2, 2/13/04 *Simple machines* PL Interview (lines 244–251)
	• Julia talked about how students from past classes helped her draw conclusions about students' knowledge in her current class. She said student comments and recognition of vocabulary words revealed to her whether they had studied and were familiar with the lessons' concepts.	• Julia, School 6. 4/21/04 *Snap, crackle, pop!* PL Interview (lines 162–172)

Section 2. Describing Nuances in Instruction

Distinct Reasons for Making Changes in Lessons

The educators maintained consistency in the content topics, activities, and procedures of the lessons, but there were subtle differences between the lessons. Educators commented that students' behaviors and knowledge prompted modifications. While time was always a concern in the sense that educators only had 45 or 50 minutes to complete a lesson, it became more critical when students were late. Finally, the educators' professional judgment, comfort with the lesson plan and content, and memory also affected the subtle differences between lessons, which were addressed, as educators became familiar with the lessons (discussed above in *Repetition Develops Consistency*, p. 89).

Students Influence Changes

Educators reported making changes in their lessons for the classes observed in this study as they took into account the students' knowledge and behavior. Students' prior knowledge influenced what the educators said and did during a lesson (discussed further in *Manipulate Controllable Elements*, p. 115). Talking about how student knowledge affected his instruction for School 3 *Snap, crackle, pop!*, Gary said,

> "Well [with] this group, since I felt like they had some basic knowledge of electricity and just the structure of things, I did mention atoms more. With some groups, I go right to charges and don't mention atoms much. Especially maybe if I don't have a feeling that … they have some basic concept of an atom or if they haven't at least heard the term before, … I don't mention it. I go more into charges more than saying, 'when we rub atoms together.' Because I felt with this group that they had some understanding that there's atoms out there and like rubbing them…like I was trying to explain that rubbing them together can produce charge. Where other times instead of saying atoms I'll say, 'rubbing different materials together will produce a charge'."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 75–82

Gary decided to elaborate on atoms because he perceived these students were knowledgeable of the content and thus could understand more in-depth content (discussed further in *Manipulate Controllable Elements: Ways of Modifying the Dialogue*, p. 127). He explained he would not do so if the students did not appear to be familiar with atoms.

Similarly, Janet changed her use of Demonstration 1 in School 2 *Simple machines* because she determined students were familiar with simple machines. Talking about her assessment of student knowledge from Talk 1 for Class A, she said,

> "The first one, the first one caught me off guard the most just that they knew everything because I didn't know they'd come in knowing everything. And just the way they were like, 'I know this and I know that.' So instead of showing them that each item up on the table was a simple machine, I asked them to tell me what type of simple machine it was. Because like if the class didn't know anything I would be like you know, 'is this a simple machine?' or I would like kind of tell them, 'this is a screw.' Whereas them (students in Class A)
> I would ask them to tell me instead. So I did change that."
> Janet, School 2 Post-lesson Interview, 13 Feb. 04, lines 30–36

The students volunteered information and their comments suggested that they knew about simple machines during Talk 1. Thus Janet asked the students to tell her how the objects in Demonstration 1 were simple machines rather than the other way around in situations when students were less familiar with simple machines.

Julia used students' facial expressions and response behaviors to determine their knowledge. As she talked about the knowledge level of the students in Class B School 5 *What's cold, what's hot, what's solid, what's not?*, she said,

> "Usually if the teacher has gone over anything to do with matter with them, the first group of questions was about solids, liquids and gases they answered pretty quickly. And then when you get to molecules, if they are looking at you kind of funny when you say the word molecule you know they haven't gone over that far. And that's usually the point where I either introduce the concept of molecule or wait until later on to put it into more

> of the conversation so you're not hitting them with three things right away. By the response, just the time that it took them to respond too, I had the idea that they had probably gone over this some but they weren't quite as familiar as that second group was. The second group was much more familiar than the first group was."
>
> Julia, School 5 Post-lesson Interview, 15 Apr. 04, lines 15–23

Julia decided students in Class B were more familiar with states of matter and molecules than those in Class A based on the way the students responded to her questions. Students' facial expressions and the speed in which they responded to the word molecule suggested to her that they might have studied it before this lesson. Consequently, Julia introduced molecules to the discussion and conducted Demonstration 2, which she did not do in Class A.

This strategy was echoed in her thoughts on teaching during her initial interview. Julia said,

> "…you can watch and you can tell with kids' behaviors, you can tell if they're enjoying it or not or if they're getting something out of it or not. And I think that's probably the best thing we do [here]. …If I see a child, who's not functioning well with the others in using equipment, I'll go over and give them a set by themselves and say, 'here you can do this while the other group is doing that.' And I kind of think it usually helps quite a bit. A lot of it is just minute by minute, you know you're doing the program. You do the program so many times, it's pretty much cemented in your head. So you're looking around at the kids going, 'ok, are you doing ok over here? Yep, ok but this person over here's not.' Trying to draw them in is probably one of the best things that we do."
>
> Julia, Initial Interview, 14 Apr. 04, lines 333–342

Julia pointed out that watching the students and making quick assessments about their interests and comprehension was a part of her teaching. She made adjustments in her lessons as they came up like offering extra equipment to students who were having trouble working together. Being familiar with the lesson plans enabled her to be more attentive to the students' needs.

Sally commented that she forgot to talk about deserts as a natural habitat in the first class for School 3 *Adaptation advantages* since the animals, examples, and activities in this lesson topic focused on animals adapting to live in the desert. While she intended to discuss it before Activity 1 in Class B, she commented,

> "…like this part in general when they looked at the stuffed animal and answered yes or no to the adaptations I felt like that was pretty easy for them. It wasn't as easy for some of the other classes I've done. So I guess I was just thinking, 'oh let's just go ahead and get that done. That'd be easy, they won't have trouble with it.' And actually they did [finish], like I told you before they really did know pretty much about the desert so they weren't at a total loss."
>
> Sally, School 3 Post-lesson Interview, 25 Feb. 04, lines 74–78

The students in Class B demonstrated they were familiar with adaptation, so Sally decided that the students could carry out the activity without having to describe a desert environment first. Thus she decided to continue with the activity and discussed deserts afterwards despite her intentions to do it the other way around before the class started. These examples suggested the educators modified what they said and did based on their assessments of student knowledge, which they determined through student comments and body language such as facial expressions and eagerness to respond, to communicate their understanding.

Student behavior also influenced modifications in the lessons. Sally talked about an intentional change in her action during School 3 *Adaptation advantages* based on how students behaved in the previous lesson. Sally said,

> "… I did not put the little life circles or what-in-the-world they are, I did not put them in. Everyone was supposed to have two or three to begin with and all they did was fight over them so I didn't put them in to begin with. It didn't make any difference and they didn't know the difference. And you're supposed to take them away if they make a mistake and I don't like that part. They don't get one if they don't have anything and if they have something they get one. I try not to make too big a deal out of it, but I'm sitting here thinking if there wasn't some other thing we could use that

> wouldn't be so absolutely fascinating, this really is not the important part of what we are doing."
>
> Sally, School 3 Post-lesson Interview, 25 Feb. 04, lines 104–111

As a part of the *Wheel of Misfortune* game, groups received score chips and the winner was the group with the most chips at the end of the game. The chips were multi-neon-colored foam pieces approximately 3" in diameter. Each group was given two chips at the start of the game. Students in Class A became preoccupied with the chips before the game began and were reluctant to return them at the end of class. Sally felt the chips distracted the students from the game, and decided to not bring them out until after the game began for Class B. Also, changing a rule of the game such that chips were not taken away was based on her preference irrespective of the students. Sally felt her changes were legitimate since neither of the changes affected the whole experience and the students would not know the difference.

Student behavior also prompted Janet to consider making a change in School 3 *Adaptation advantages*. However, her revelation did not come soon enough. She said,

> "There was something while I was teaching that I thought 'oh yeah I would do that differently if I had a third class.' And I think it was just showing the wheel. Like I wouldn't have shown the wheel until like a segment later. I showed it too early and they just focused on the wheel. So I think what I would have had them do in the third class is read over what their animal is capable of and not tell them why. Just tell them they need to learn about the animal that's at their table and that they need to learn it really well. So they wouldn't be more focused on the wheel they would be more focused on their animal. That's what I would have changed for the third class."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 82–89

In both classes, Janet revealed the wheel and the game before giving groups their animals and instructions for the game. She felt the students became preoccupied with the wheel and did not focus on the animals they were given. This revelation did not come soon enough to make the change in the second class, but she thought that if she had a third class she would attempt that change.

Time Influences Changes

Time was a factor in these lessons because they were short, one-time lessons. There were 45 or 50 minutes to complete the planned activities and work towards meeting the intended objectives, and there were no opportunities for the educators to "continue tomorrow" or "come back to it later." Comparing the differences between teaching in museums versus schools, Gary said,

> "You never get to know the students, not with a forty-five minute class. And because of that, that's the difference (referring to teaching in schools versus museums) that can be challenging because there is no follow-up. You do some questions and answers, you review with them what they learned. But you can't go back to them the next day to make sure it made it into that long-term memory [or that] they didn't see something else at the museum that they found so much more interesting."
>
> Gary, Initial Interview, 14 Apr. 04, lines 314–318

Comparing his teaching experiences in school and museums, Gary reported that his lessons were singular experiences that needed to be completed in his allotted time. There were no opportunities for him to continue the lesson later or follow up with students afterwards. Janet commented,

> "… yeah, time influences it because how long should I give them to do this activity? I mean every one of those programs went over their 50 minutes."
>
> Janet, School 2 Post-lesson Interview, 13 Feb. 04, lines 178–179

Time affected her lessons because it influenced her judgment on the amount of time that she allocated to different segments of the lesson. An extra few minutes in one segment meant she lost a few minutes in another segment, consequently, she had to decide carefully.

Julia clarified that there was flexibility to accommodate the time factor and that punctuality affected this. She said, "Oh time is always a factor. We schedule so that every program is about 45 minutes long because you're watching the clock because they're going to the 11:00 o'clock IMAX or the 12:00 o'clock Kids Reading. So yes, you have to be very careful with that. There's ways of speeding up and cutting down if you have to, and pretty much all of our programs is flexible like that. You have to be because a lot of times you don't even get them arriving here on time. Luckily these groups were here at the door when they were supposed to be."

Julia, School 5 Post-lesson Interview, 15 Apr. 04, lines 86–91

Time was a familiar factor in the lessons because classes could have other programs scheduled or be late to their lessons. Julia admitted that there were ways built into the lessons' design that could accommodate needed changes (discussed further in *Manipulate Controllable Elements*, p. 115). The lessons were designed to be flexible to the needs of the classes, and the educators developed familiarity with the lessons through repetition of the same lesson plan so that they could accommodate for it seamlessly and without stress. However, on time arrival of a class was necessary for the educators to maximize on the

time available.

Talking about whether time affected her lesson in School 8 *Snap, crackle, pop!*, Julia said,

"Not really. I'm confident enough with this program. I've done it enough that I can pretty much get everything in no matter what amount of time I have. I might not do three kids on the machine (referring to Van de Graaff generator). I might do one or two and then skip on to the activity or you may not do the charge line. If they're really bordering out of control I usually don't do the charge line because that's only going to make it worse. And then the teacher is left with them afterward to deal with them at the next place."

Julia, School 8 Post-lesson Interview, 11 May 04, lines 95–100

Julia taught the lesson often enough that she knew how to make changes to it in order to accommodate time without affecting the overall experience. She also pointed out that sometimes students' behavior prompted a change such as Demonstration 2C. In all the lessons, except for Sally's School 1 *Forces in motion*, the educators felt that they had enough time to complete their lessons (classes for Sally's School 1 arrived at the museum 15 minutes late.)

When asked whether time was a factor that affected their instruction, the sentiments were similar to Gary and Janet's responses,

> "It was good. They arrived on time so I could go at a comfortable pace. I didn't feel like I had to rush or leave things out necessarily."
> Gary, School 2 Post-lesson Interview, 16 Apr. 04, lines 45–46

> "Not really. I would prefer to have more time to have them do their challenges. They weren't done when I asked them to stop but they had done a good majority of them, and then it was based on their own personal time management. How long they spent on each challenge and how many times they rolled the same can down the ramp. But other than that, and no time was pretty good. And I think I let the second group stay an extra five minutes or so."
> Janet, School 1 Post-lesson Interview, 11 Feb. 04, lines 180–185

When the students arrived on time, the educators managed the lessons without rushing or omitting segments. While the educators appreciated more time so students had more time in the activities, they felt there was sufficient time to complete the lesson in the allotted time.

Educators Influence Changes

The educators commented that changes in the way they taught a lesson topic were sometimes not prompted by the students or time but by their own comfort in the content and lesson plan, professional judgment, and what they remembered. Their reasons and rationales were related to their familiarity with the lessons discussed above (*Repetition Develops Consistency*, p. 89). As the educators mentioned in the discussion above, they gained familiarity with lessons as they taught the same lesson plans to different groups of students, and sometimes their own professional judgment and preference prompted the changes.

Distinct Reasons for Making Changes Summary

The educators acknowledged making changes in their lessons for the students, time, and themselves. Students' behavior and knowledge influenced changes. Time was a familiar challenge that was intensified when students were late. Educators also made changes as they became familiar with the lessons and content. Table 11 condenses the findings along with the supporting observation and interview data discussed above.

Table 11. Summary of findings and excerpts from *Distinct Reasons for Making Changes* section.

Findings	Evidence Summary	Evidence Referenced
Students Influence Changes		
Students' knowledge and comprehension as determined through their verbal and non-verbal responses to the lessons prompted educators to make changes. Verbal responses included what students said and recognition of vocabulary words. Non-verbal responses included body language and facial expressions.	• Gary talked about how his assessment of student knowledge affected his instruction. He said he felt this class had basic knowledge of electricity and atoms so he went into details about the parts of atoms, which he would not do, if the students were not familiar with atoms. Observations showed he did not elaborate on atoms in Schools 1 and 4 (see *Manipulate Controllable Elements*, p. 107)	• Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 75–82) Researcher field notes
	• Janet talked about changing Demonstration 1 due to her perception of students' knowledge. She said the students in Class A started off telling her about simple machines so she asked them to tell her how the objects were simple machines instead of the other way around.	• Janet, School 2, 2/13/04 *Simple machines* PL Interview (lines 30–36)
	• Julia talked about her assessment of student knowledge and how this affected her teaching. She said the speed of students' responses and facial expressions to her questions in Class B indicated they had gone over the concepts in school and that she could discuss the topic. Observations showed she conducted the molecule demonstration with Class B, but not A. In the initial interview, she commented that she made quick assessments of student knowledge and interests based on observations of their behaviors.	• Julia, School 1, 4/15/04 *What's cold, what's hot?* PL Interview (lines 15–23) Researcher field notes Initial Interview, 4/14/04 (lines 333–342)
	• Sally admitted her planning to discuss a topic before the activity but intentionally postponed it because students' performance thus far suggested to her that they would not have trouble with the activity.	• Sally, School 3, 2/25/04 *Adaptation advantages* PL Interview (lines 74–78)
Students' disruptive behavior caused educators to make changes to their lessons.	• Sally talked about a deliberate change in Class B due to disruptive behaviors in Class A. She said the colorful score chips appeared to distract the students' attention away from the game so she distributed them after the game began in Class B.	• Sally, School 3, 2/25/04 *Adaptation advantages* PL Interview (lines 104–111)
	• Janet explained students' behaviors in her two lessons prompted her to consider changing a step in her lesson if she had a third lesson. She said revealing the wheel for the game too early seemed to distract students' attention away from the game and she would delay the unveiling until after the students had studied their animals. Observations showed students in both classes carried on conversations while Janet talked.	• Janet, School 3, 2/24/04 *Adaptation advantages* PL Interview (lines 82–89) Researcher field notes

Table 11 *Continued*. Summary of findings and excerpts from *Distinct Reasons for Making Changes* section.

Time Influences Changes The allocated 45 or 50 minutes influenced how much time educators spent on different segments of the lessons. There were no opportunities to follow up or return for further clarification. But time was a familiar challenge and lessons were designed to be flexible.	• Gary compared teaching in museums versus in schools. He said with 45 minutes, there were no opportunities to get to know the students or follow up on the lessons to review what students learned or found interesting during their field trips. • Janet acknowledged that the lessons' time limit affected her instruction because it influenced the amount of time she allotted for students to spend on activities. • Julia talked about flexibility in the lesson plan to accommodate time and that punctuality affected this. She said there were ways to speed up and cut back the lessons because classes were often late. • Julia admitted time did not really affect her lesson. She had taught this lesson often enough to know how to cut back on the lesson (like taking fewer volunteers or omitting segments) and still do everything planned. • Gary and Janet admitted there was enough time to complete their lessons. Gary said the students arrived on time so he could teach at a comfortable pace without rushing or leaving things out. Janet said she preferred having more time for students to finish their activity, but this could be due to their time management. Otherwise she felt there was enough time, and admitted letting the second class stay an extra five minutes. In both these observations, classes were taught consecutively and educators included all the same segments, but the time intervals varied slightly.	• Gary, Initial Interview, 4/14/04 (lines 314–318) • Janet, School 2, 2/13/04 *Simple machines* PL Interview (lines 178–179) • Julia, School 5, 4/15/04 *What's cold, what's hot?* PL Interview (lines 86–91) • Julia, School 8, 5/11/04 *Snap, crackle, pop!* PL Interview (lines 95–100) • Gary, School 2, 4/16/04 *Creepies & crawlies* PL Interview (lines 45–46) Researcher field notes • Janet, School 1, 2/11/04 *Forces in motion* PL Interview (lines 180–185) Researcher field notes
Educators Influence Changes Educators influenced changes in the lessons as they repeated the same lesson plans and developed familiarity and insight.	• (Refer to findings presented in *Repetition Develops Consistency*)	• (referenced in *Repetition Develops Consistency*)

Manipulate Controllable Elements, Take Advantage of Others.

Two elements emerged as ways pre-planned, one-time science lessons could be made to accommodate the reasons for change discussed above. One element, the segmented lesson, was a built-in feature of the lesson design. The other, the dialogue between the educators and students, was a characteristic of the experience and expertise of each educator. The educators modified their lessons by manipulating these elements within their control, and then taking advantage of others. In these lessons, the teachers and chaperones were available for the educators to capitalize on. The underlying rationale for their changes came from the educators' goals and teaching philosophies.

Lessons Comprised of Segments.

Length, inclusion, and order of the segments were at the educators' discretion as suggested in Figures 3 and 4 (pp. 85–86), and they manipulated them to suit the needs of each individual class. The discussion above reported that the segments in the lesson design helped to develop consistency as educators included each segment each time they taught the lesson. The educators acknowledged that design of the lessons into segments of activities and dialogues also contributed to their flexibility and customizability. Julia described it this way in her initial interview,

> "The nice thing about our programs, too that makes it very specific to that group is we follow a set of guidelines. In this program you should teach A, B, C, D and E but if you do it B, D, C and A or A, C, E and D it doesn't matter. You gave it to them and the way you gave it to them is going to encourage them to go out on their own more. So that would be our overall goal."
>
> Julia, Initial Interview, 14 Apr. 04, lines 121–125

As Julia pointed out, as long as the intended objectives were addressed in the lesson, there was flexibility in how the educators communicated this. They were able to alter time spent on segments, order of the segments, and even exclusion of segments in order to adjust to time available, student knowledge and interest, and their professional choices.

Omit a segment.

The option to omit a segment was one way segmented lessons were flexible to the needs of the educators. During School 5 *What's cold, what's hot, what's solid, what's not?*, Julia excluded Demonstration 2 and the discussion on molecules in the first class but included it in the second class. She brought up molecules in Class A towards the end of the lesson, but did not do Demonstration 2. When asked about this difference between the two classes, Julia said,

> "This class is kind of flexible because you can take the pieces, the different sections that we talked about with solids, liquids and gases and you can kind of move them around if you have to. I've often found if they're not really, really comfortable in the very beginning if you talk about solids, liquids and gases, and then you get to molecules and they don't really seem like they've heard it before, it's sometimes easier to interject that later on which I did with the first group. [With] the second group, just by the speed of their answers,
> I kind of thought this is a good concept to bring up right away in the very beginning."
>
> Julia, School 5 Post-lesson Interview, 15 Apr. 04, lines 28–34

Julia's decision was based on her judgment of how students understood the concepts, which was determined by the way they responded to her questions. As discussed above (*Distinct Reasons for Making Changes in Lessons: Students Influence Changes*, p. 104), she used students' responses from previous second grade classes as indicators against which to measure these students. The lesson's segmented design gave her flexibility to adjust her lesson to the students' knowledge without impacting the whole experience for either class.

Janet contemplated omitting a segment due to student behavior in School 3 *Adaptation advantages*, but decided she did not want to deprive the students of the experience with the animals. She said,

> "I was so tempted not to pull out the animals, the live animals I was like so close. We were short on time and they were just so loud and noisy but I feel that they shouldn't miss out on stuff like that like you know I have them up here (referring to live animals) so I might as well just show them and stuff like that you know. They actually did calm down for those pretty nicely. It went well but it was so close, but I'm not usually like that. I usually do all the special things even though they're bad. I'm like, 'well okay'."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 228–233

The lesson focused on animal features that illustrated how some animals adapted to a desert environment. Students in both classes were disruptive, and Janet struggled for their attention during Talk and Demonstration segments. For example, students continued to play with the stuffed animal from Activity 1 during Talk 2 despite Janet's request for them to put the animals away. Demonstration 2 involved showing a live animal and observing adaptation features on a living animal rather than a stuffed toy, and also offered students opportunities to see and touch a live animal. Omitting this segment would not have affected the students' experience up to this point, but it was worthwhile enough for the whole experience that she included it despite her frustration with the class' behavior.

Omitting segments also gave the educators flexibility to accommodate time. Julia rationalized that leaving out Demonstration 2A from School 6 *Snap, crackle, pop!* due to time did not take away from the students' experience as a whole. As she reflected on whether time affected her instruction, Julia said,

> "It did when I cut the one demonstration (referring to Demo 2A). … If a group is here on time, everything's flowing great, there's not an excessive number of questions or having to stop to get them quiet, [Demonstration 2A is] neat because it's a very slow transition holding these pieces of

> Styrofoam, they fly up. But the hair just kind of throws you into the exciting part of the program. So yes, I don't think they lost anything by not seeing that. I probably did the hair repelling just like the Styrofoam, when you get a charge on your head but I think they got the general idea."
> Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 272–279

This class started a few minutes late because there was confusion about which classroom students were supposed to go to when the classes entered the museum. As mentioned earlier, multiple classes were taught simultaneously at MD Museum. Both classes from this school were sent to the same classroom, so Julia spent the first few minutes of the lesson sorting out the confusion. To make up the few minutes lost, Julia omitted Demonstration 2A, but she did not feel omitting that sub-segment negatively affected the students' overall experiences. She did not appear flustered by the mix up. When students were not at her door when class was scheduled to start, she went looking for them, brought them to her class, and started her lesson.

This was also the case in the *Simple machines* lessons. On previous occasions (not for this study), the researcher observed a fourth demonstration to explore pulleys in *Simple machines* at NC Museum. Neither Sally nor Janet conducted this activity in observations of this lesson during the study. In all three of Janet's classes, there was only one minute left in the 50 minutes allotted by the time the students completed the last (Figures 3 & 4, pp. 85–86). Janet spent the remaining time on Talk 3 reviewing the students' results in Activity 2 rather than introducing a new simple machine. While the last demonstration on pulleys was another example of a simple machine, omitting it did not affect the earlier demonstrations, activities, or discussions on levers and inclined planes. Sally used this rationale to leave out the pulley demonstration. When asked whether time was a factor in her teaching, Sally said,

> "Not as much, not as much because I just didn't do the last activity. It wasn't something that, I just didn't do it. …I've never really done the

whole program anyhow because, let's see, how much time did we have? Forty, forty-five minutes out of the fifty, so it was a lot closer so I didn't change things because of time I just didn't do the last activity. It's just an entirely different thing, I think it's about pulleys. It doesn't matter if you do it or you don't
[do it]."

Sally, School 2 Post-lesson Interview, 12 Feb. 04, lines 77–83

Even though both of Sally's School 2 *Simple machines* lessons ended with five minutes remaining, she chose to leave out the pulley demonstration. She was not bothered by her choice because that demonstration did not take away from students' experiences thus far, and omitting it alleviated pressure on her to rush through the previous segments in her lessons. For Sally, the segmented lesson gave her flexibility to use professional judgment on what she thought was necessary to meet the goals of the lessons.

The lesson's design worked against her in School 1 *Forces in motion* because the segments were not broken down appropriately. Both classes for Sally's *Forces in motion* lessons arrived at the museum 15 minutes late. In discussing her reasons for omitting Talk 2 in both lessons, Sally said,

"Like I said I maybe would have skipped one little part. There's nothing to skip in here. …They still had a shorter time to roll the cans than they would have had so there really isn't a separate little section you can say, 'oh I just won't do that part.' …It's one big thing practically, rolling cans. …To roll the cans, to check that out I would just as soon not do that (referring to Demonstration 2) but it doesn't seem fair to ask them to vote and then they don't find out because its partially worth the answer. That seems kind of unfair but I mean that takes more time and I'd rather do something else but I don't think its fair. But if it were, let's see if I can think of one. If I'd done *Weather* in a very short amount of time, a shorter amount of time and it's just one activity we don't do if we don't have as much time. It's easier to take that out than it was in this one. …So then I still would have time more time to summarize up if I could have taken out a more definite piece."

Sally, School 1 Post-lesson Interview, 10 Feb. 04, lines 231–249

In this situation, Sally criticized the way *Forces in motion* was segmented. She felt it was not appropriate to leave out Demonstration 2 since the students had looked at the cans in Activity 1 and voted on the one they thought would roll farthest. Thus segments could not be easily omitted to accommodate time constraints. Sally was also reluctant to reduce the amount of time spent on Activity 2 because she believed sufficient time was needed for students to experiment with different content combinations in order to experience the task since this was the main focal point of this lesson. Even though she had less time per lesson than Janet (40 minutes for Class A and 36 minutes for Class B), Sally gave her students 20.5 and 19 minutes for Activity 2, compared to the 24.25 and 21.5 minutes that Janet allotted her classes. As Sally mentioned, other lessons such as *Weather* had a segment that could be excluded without impacting the remaining lesson but in her opinion this one did not. While segmented lessons offered flexibility, the way they were segmented was important.

Lengthen or shorten a segment.

Having the option to vary the length of time spent in each segment also offered flexibility. The educators spent approximately the same amount of time on the same segments each time they taught the lesson, but the intervals were not identical and there were occasions when the differences were minutes apart. As mentioned above, Sally chose to give her students ~20 minutes to experiment in Activity 2 for School 1 *Forces in motion,* despite the need to abbreviate the lesson. Sally felt it was important for students to have enough time to experiment in order for the lesson to be meaningful. In Class B of this same observation, the teacher notified her that she had 30 minutes for her lesson. Reflecting on that situation, Sally said,

> "I had even less time for the second [class] so I didn't spend as long a time on the … imaginary bicycle on purpose because I knew I only had like 30 minutes to try and do something for them."
>
> Sally, School 1 Post-lesson Interview, 10 Feb. 04, lines 187–189

She chose to cut back on Demonstration 1 to explore students' ideas on the factors that affected objects rolling down a hill so that there was sufficient time for them to experiment in Activity 2, which she allotted 19 minutes. Sally took minutes away from one segment for another based on her judgment that students needed more time experimenting with rolling than imagining rolling down a hill.

Time did not always shorten lessons. All ten of Julia and Gary's lessons exceeded 45 minutes. The teachers played a critical role in allowing for this extension (discussed in *Take Advantage of Others: Teachers as Timekeepers*, p. 141). When the educators felt they were not pressured by time, they extended time spent on certain segments. In School 7 *Snap, crackle, pop!* Julia exceeded the allotted time by 13 minutes. The researcher noticed that she answered more questions than in other observations of her and other educators. When asked her reason for this, Julia acknowledged the researcher's observation and said,

> "Tons more. …We usually don't get that many. I'd say the average we maybe get four, maybe three, maybe five questions tops. But I was looking at the teacher and I had already checked with one of the chaperones and she said they didn't have anything to do but lunch afterward and I figured if the interest has been generated, I'm going to answer until they tell me they have to go."
>
> Julia, School 7 Post-lesson Interview, 3 May 04, lines 233–236

Julia found out from a chaperone that this class did not have a program scheduled after this lesson. She was not pressured to finish exactly within 45 minutes, and was free to answer the many questions that the students asked until she was informed she needed to stop.

Gary also admitted that taking an extra five minutes was not a big deal since he knew his class (School 1 *Snap, crackle, pop!*) was not in a hurry to another program. When asked whether time affected his instruction in this lesson, he said,

> "Not really with this one because we were the only program they had. Because sometimes right after this they're going to an IMAX movie or a planetarium show and if it's a group public show they can't hold it so sometimes you have to help … get them onto their next presentation, where in this one [that] wasn't an issue. I knew that they were going to be in the building for at least an hour longer so if I had them for an extra five minutes it wasn't going to affect them, or at least not in a negative way."
>
> Gary, School 1 Post-lesson Interview, 14 Apr. 04, lines 130–135

Knowing the classes were not in a rush, Julia and Gary did not worry about taking a few extra minutes in the latter segments of their lessons. Since their lessons were taught simultaneously, Julia and Gary were also not under pressure to rush through the first class in order to get to the second class. It was those occasions when they had to teach two classes consecutively that they exceeded 45 minutes the least. This was perhaps the reason Sally and Janet did not usually exceed their 50 minutes limit since multiple classes at NC Museum were taught consecutively.

Rearrange the segments.

Educators occasionally rearranged the order of segments, which was attributable to their preference more so than student knowledge or time. Comparing Julia's sequence of the *Snap, crackle, pop!* lesson topic with Gary's sequence, on all three observations, Gary taught Talk 3 before Demonstration 2C. Julia did not have Talk 3 in any of her lessons, but instead embedded that content within the whole Van de Graaff generator demonstration. Reflecting on how he felt the lesson (School 3 *Snap, crackle, pop!*) went, Gary said,

> "I do feel that they walked away not knowing everything, but taking a little bit with them even if it's just how charges work because I really like to cover that, that this machine is just not magic. That, 'all right well, we've learned about charges, let's look at how this all comes together.' That this machine is producing a negative charge and because of that, Styrofoam is flying out of your hand and your hair's standing up and how all this comes together."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 281–286

This related to Gary's thoughts in his initial interview. He talked about his perspective on teaching science in museums. He said,

> "We have forty-five minutes…. We do a lot of hands on but it still involves a lot of direct instruction. And there's nothing wrong with direct instruction. Part of the reason we do it is because there's not always the background. The children don't always come with a background. And direct instruction can be very efficient when you're working within time constraints where we incorporate that with hands-on. You might start out the lesson with direct instruction to get them started and then allow free exploration and then bring them back with more direct instruction as a follow up."
> Gary, Initial interview, 14 Apr. 04, lines 403–409

Thus, Gary's rationale for this sequence of the segments in his *Snap, crackle, pop!* lessons was related to his goals for the lessons and his perspective on teaching. He felt it was important for students to learn the science behind the machine, and decided direct instruction was an efficient and effective way of doing this given the time and place of the lessons. It appeared he intentionally separated the discussion from the demonstration so that the content was obvious to the students.

Similarly, Julia's teaching perspective and goals for the lesson influenced her instructional approach. However, her background and professional experience differed from Gary. Her 17 years of science teaching were all in museums. Talking about how her teaching style changed over the years, Julia said,

> "But as I've worked here longer and longer in different areas, I think I've picked up more of the entertainment skills and I think because teachers in the classroom don't teach this way, informal education really stands out because you can be, you can joke, you can be the entertainer. You can do things that almost appear as magic at times but you explain what you're doing also."
> Julia, Initial Interview, 14 Apr. 04, lines 405–409

Julia integrated discussion on how the generator made the Styrofoam fly out or hair stand up during the demonstration to keep the experience flowing and part of the generator's allure. Julia felt since the environment in which she taught was different than a classroom, the way she taught and interacted with the students could be different.

Sally experimented with the order of Demonstration 2 during School 3 *Adaptation advantages* to search for a different way of teaching that lesson. Compared to Janet, Sally brought out the live animals in Demonstration 2 before Activity 2, the Wheel of Misfortune game. Sally admitted that this was a conscious decision to experiment with the sequence of the lesson. She said,

> Sally, "I had enough time to do what I wanted to do. They came on time and we went around about to the right time. And before when we didn't have quite as much time (referring to other times she's taught this class) I went ahead and played the game a little bit…. We didn't have as much time so they just walked by and touched the animal on their way out. So this time I spent a lot, I spent more time [on the animal]. …And I don't know if I'll always do it, but that's the way it's written. It's written with the animal in that order so I thought, okay I'll try it, see if I like it. And I'm not sure I do."
>
> Researcher, "Why is that?"
>
> Sally, "Well it takes too much time to go from table to table and it's hard for them to be quiet. …I might want to …talk about the animal and truly just have them go by and touch it on the way out rather than having to sit around and wait while I go from table to table. Ideally you should go from table to table, but that's really hard for them to do. It's because there's nothing to do. You're just sitting there waiting. You've either already touched it and you're talking about that. That's not too bad. Or you're sitting there waiting for the person to come so you can touch it and you're not doing anything else. And it's not unreasonable that you would want to talk to your neighbor. I might go back to doing it the other way but I wanted to try it like it was written. …"
>
> Researcher, "Since time was not so pressing and the students knew their stuff, do you think you had to deal more with behavior management?"
>
> Sally, "No I just thought about it more. I was freer to try some different things. I felt freer to try different things and also maybe just think about how can I manage this better instead of worrying about the time and all that. I was just freer to be able to think about that."
>
> Sally, School 3 Post-lesson Interview, 25 Feb. 04, lines 134–169

Without the constraint of time, student knowledge, and student behavior, Sally felt free to explore a different way of teaching this lesson. She rearranged the order of the segments, which according to Sally was back to the way the lesson was originally written. She did not like the flow because the students were not occupied appropriately while she walked around the room with the live animal. Janet brought the animals out at the end of her classes when she taught this lesson, but her procedure for this demonstration was the same as Sally's. Students sat and waited for her to bring the animal around like in Sally's classes. However, Janet commented that her students seemed to settle down when she brought the animal around, and did not express concern that the students had to sit and wait for her to bring the animal around.

Lessons comprised of segments summary

The lessons were comprised of three types of segments that educators could manipulate to suit the interests and abilities of the classes. Segments were identified based on the level of student physical participation (Table 8, p. 77). Educators omitted segments, changed the length of time spent on segments, or rearranged the order segments were taught. Table 12 summarizes these findings along with the supporting interview and observation data.

Table 12. Summary of findings and excerpts from *Manipulate Controllable Elements: Lessons Comprised of Segments* section.

(PL=Post-lesson; LD=Lesson Dialogue)

Findings Summary	Evidence Summary	Evidence Referenced
Omit a segment Educators omitted segments within lessons due to perceived student knowledge, students' behaviors, and reduced time. It was important that omitting segments did not affect students' overall experience, which was helped and hindered by the lessons' design.	• Julia explained omitting the molecule demonstration in Class A but not Class B was due to students' reactions to her molecule questions compared to how other students in previous classes responded. But she discussed the concept early in the lesson for Class B, and later for Class A. The segmented lesson enabled her to move the pieces around as needed without impacting the overall experience.	• Julia, School 5, 4/15/04 *What's cold, what's hot?* PL Interview (lines 28–34) Researcher field notes
	• Janet contemplated omitting the live animal demonstration due to students' behavior, but did not want them to miss out on the experience. Observations showed students were disruptive while Janet talked during discussions and demonstrations.	• Janet, School 3, 2/24/04 *Adaptation advantages* PL Interview (lines 228–233) Researcher field notes
	• Julia said she omitted a demonstration to accommodate time, but the remaining demonstrations illustrated the same ideas so the students did not miss out on anything. Despite the mix up with classes at the start of the lesson, Julia did not appear flustered or stressed.	• Julia, School 6, 4/21/04 *Snap, crackle, pop!* PL Interview (lines 272–279) Researcher field notes
	• Sally explained that time did not affect her lesson. She said she did not change her lesson due to time because she omitted the last demonstration, which was unrelated to the rest of the lesson. She felt leaving out the pulley demonstration did not take away from the rest of the lesson.	• Sally, School 2, 2/12/04 *Simple machines* PL Interview (lines 75–83) Researcher field notes
	• Sally explained how the lesson's design made it difficult to accommodate time. She said the lesson was designed in such a way that she could not easily omit or shorten a segment that did not take from the students' overall experience, unlike another lesson at the museum. Sally did not appear befuddled or stressed despite the unexpected tardiness and reduced time.	• Sally, School 1, 2/10/04 *Forces in motion* PL Interview (lines 231–249) Researcher field notes

Table 12 *Continued*. Summary of findings and excerpts from *Manipulate Controllable Elements: Lessons Comprised of Segments* section. (PL=Post-lesson; LD=Lesson Dialogue)

Lengthen or shorten a segment Length of time spent on segments were increased or decreased to accommodate time. Shortening one segment resulted in more time available for another segment. Without the rush to finish on time, educators extended latter segments. Museums' program schedule influenced whether lessons could be extended beyond allocated time.	• Sally admitted shortening Demonstration 1 deliberately due to reduction of her already shortened class. She knew she had only 30 minutes to do something for the students. Sally gave both classes ~20 minutes for Activity 2 despite the reduced time.	• Sally, School 1, 2/10/04 *Forces in motion* PL Interview (lines 187–189) Researcher field notes
	• Julia talked about the reason she extended the lesson and answered more student questions. She said she learned from a chaperone that the class had lunch after their lesson, and thus decided she could answer more questions as long as there was interest and she was permitted to do so.	• Julia, School 7, 5/3/04 *Snap, crackle, pop!* PL Interview (lines 226–236)
	• Gary explained that time did not affect his lesson since this class did not have another scheduled program afterwards. He admitted taking an extra five minutes did not have a negative effect on the students. This class exceeded the time limit by 10 minutes.	• Gary, School 1, 4/14/04 *Snap, crackle, pop!* PL Interview (lines 130–135) Researcher field notes
Rearrange the segments Segments were reordered due to educators' teaching preference.	• Gary clarified his reason for emphasizing how the Van de Graaff generator worked. He wanted students to understand how the generator worked and that it was not magic. In his initial interview, Gary pointed out some direct instruction was useful for teaching 45–minute lessons because it was an efficient way to use time and incorporate the activities. In all his *Snap, crackle, pop!* classes, Gary drew a diagram of the generator on the board to explain the mechanism before Demonstration 2C.	• Gary, School 3, 4/14/04 *Snap, crackle, pop!* PL Interview (lines 281–286) Researcher field notes Initial interview, 4/14/04 (lines 403–409)
	• Julia talked about changes in her teaching over time in her initial interview. She said she did not have to teach like classroom teachers and could be more entertaining while explaining the content.	• Julia, Initial Interview, 4/14/04 (lines 405–409)
	• Sally explained since time or students' knowledge and behavior did not constrain her, she was free to teach the lesson in a different way to see if she liked it. She rearranged the order of segments, but did not feel students were occupied appropriately during the live animal demonstration when the lesson was taught in this order.	• Sally, School 3, 2/25/04 *Adaptation advantages* PL Interview (lines 134–169)

Ways of Modifying the Dialogue

Complementing the order, length, and inclusion of the segments were the educators' words within those segments. The educators pointed out that what they said and the manner in which they said them were modified to accommodate time, students, and their professional experience and judgment. Flexible to the educators' preference was the amount of depth and detail for the content and the level of student involvement.

Student involvement in dialogue of lesson.

Educators manipulated the level of student involvement during discussions with students. Sally attributed time limitation as her reason for what she said in School 2 *Simple machines*. During Talk 2 for Class A, Sally asked each group to call out the amount of effort it took to pull their truck up the inclined plane set at 10 cm. After the groups reported their results, Sally said,

> Educator, "oh my goodness, we got 100 to 400. It was really, really not steep and it was short. I wonder why it was different. Does anyone know why it was different? (students whisper but no one speaks up or raises their hand). Do you know what, when you pull it up you need to get near the top before you read it so that might make a difference. (referring to experimenter error whether students read the spring scale when truck was halfway or all the way up the ramp) Let's see the 20 cm."
>
> Sally, School 2 Class A Lesson Dialogue, 12 Feb. 04, lines 211–214

In that same situation for Class B, Sally said,

> Educator, "We've got between 200 and 500, so there's a little bit of work, not too much. And the reason why there is a difference is where that scale started whether it started at zero or not. I had to fix one person's. Another reason why is that when you pull it, you pull the wheel a little, and that changes the number a little."
>
> Sally, School 2 Class B Lesson Dialogue, 12 Feb. 04, lines 221–224

In Class A Sally offered the students the opportunity to explain the reason for variations in their results, even though none of the students spoke up with a reason. Sally did not give the students this opportunity in Class B. Reflecting on her reason for this she said,

Sally, “I was trying to think of reasons and [standing] there telling them the reasons…I’m thinking that I really shouldn’t be telling them the reasons that they should be figuring out the reasons why. But then I didn’t have enough time to let them sit around and figure out the reasons why the answers were different. Did that come out right? Did you understand that?”
Researcher, “Okay so let me see if I can figure this out. So you’re saying that in the end, you ended up telling them why there were variations.”
Sally, “Why I thought there were variations but as I was doing it I was thinking it would really [be] better if they could figure out some reasons maybe I’d have to give them hints. But if I do that then we’ll never get to the other things you know, we’ll never get to …the other activity at all.”
Researcher, “So do you think that made a difference in what they understood, what they got out of the experience as a whole?”
Sally, “Not for the basic concept, which is you know what makes the work easier or harder.”
Sally, School 2 Post-lesson Interview, 12 Feb. 04, lines 170–187

Sally reflected that as she told students possible reasons for the discrepancies, she realized it might be better if they offered their own reasons. But she admitted not doing this because she was concerned that there would not be enough time. Nonetheless, she felt the change in her approach did not affect the students’ overall experience.

Janet also reduced student involvement from the first class to the third class in School 2 *Simple machines*. In Demonstration 2 with the inclined plane and construction worker, Janet determined the amount of effort to lift the construction worker (plastic 3-liter soda bottle filled with sand) straight up in the air. Next students were challenged to come up with a way to reduce the amount of work needed to lift the worker. In Class A, the demonstration progressed as followed:

Educator, “Four thousand five hundred grams is what our spring scale said it took to lift that worker straight from the ground straight up to the top of this building that he works at. So how can we make it a little bit easier, a little less effort to get him up to the top of his building every day? What do you think?”
Student, “(inaudible, use the scale)”

Educator, “Ok, we will use the scales to measure how much effort it takes to get him up there. But what might help us to use less effort? What do you think?”

Student, “A ramp.”

Educator, “Ok. So we have our ramp or our incline plane (brings out a short board. She props one end on the top of the cart and places the other on the floor to make a ramp), one of the simple machines. And next we are going to lay him at the bottom so he’s lying down right there (lays plastic bottle on ramp). I need another volunteer. How about that one right there? (points to a girl, she comes up to front of room) And I’m going to attach it right here again (educator hooks scale to the rope secured around the bottle) and what I want you to do is pull him right up the incline and I’ll look at the measurement. (student pulls scale & bottle up ramp and begins to lift bottle off ramp) Try and keep it so that it touches. (referring to bottle staying on ramp) Ok, wasn’t too much less. So it didn’t really help us out that much. It didn’t save us that much work. So what could we do to maybe help us out a little bit more?”

Student, “Pulley.”

Educator, “A pulley you think might help us a little bit more? Well in this example, we’re just going to work with incline planes. So what could help us out a little bit more?”

Student, “If you laid it out in front of him.”

Educator, “If I laid the ramp further down? Maybe if I get a bigger ramp?”

Student, “Yes.”

Educator, “Oh, so more distance, right?”

Student, “Yes.”

Educator, “Right make more distance. Let me move my… (removes ramp and brings out longer piece of board)”

Student, “So it’s more flat.”

Educator, “…So she said get a longer incline plane and that will increase our distance but it might help us out. So I have a longer board here (sets up ramp with longer board).”

Janet, School 2 Class A Lesson Dialogue, 13 Feb. 04, lines 134–178

In this same situation for Class C, student involvement was reduced.

Educator, “… we’re reading about four thousand five hundred grams. (calling out measurement from spring scale) Thank you, you’re very strong. So for effort to lift the worker, so we’ve just lifted the worker straight up into the air, straight up onto his work site. That was four thousand five hundred grams. That was a lot. So now I have the worker and you can sort of see some other things and clues that I might have up in my question. (referring to pre-written sentences on board) So we’re going to use an incline plane and it’s pretty much like a ramp, an incline plane. (brings out short board and sets up ramp.) And we’re going to set it up here. So now his company has come up with this little incline plane that they think is going to help him out a lot and reduce the effort that it takes to get him to the top. So, my spring scale again, and I need a very strong volunteer. (points to a girl, Student walks to front of room) I just want you to put your fingers in there and pull it up. All right. (student pulls scale & bottle up ramp, educator bends over to read scale) Keep pulling, keep pulling. It didn't reduce it by much at all. So this is effort to lift the worker up short incline plane. So it only reduced it by about two hundred grams. So it's not really that much but it helped. Two hundred grams is, I think, pretty good. We're getting there. So his company, he was really tired and he was still like, 'I just can't work when I get up to the top. I'm too tired by the time I get up there.' So his company was like, 'ok we'll get you a longer incline plane.' So, let me take this one away (takes away short board and brings out longer board) and they get him a longer incline plane. But to me it looks like it increases the distance that he has to travel. So we'll see if it takes a little more effort because I think that's a long way. That's like twice the distance. We'll see how much effort it takes. All right. How about you right there. (points to a boy, he walks to front of room) So just put your fingers in there. (student pulls scale & bottle up ramp) Three thousand five hundred. Thank you very much. So effort to lift the worker using the long incline plane,…was three thousand five hundred. Wow. So by doubling our incline plane, how much did it reduce our worker effort?"

Student, "Eight hundred."

Educator, "Yes, eight hundred grams. So first by using the short one it reduced it two hundred grams. By doubling it, it reduced it eight hundred grams."

Janet, School 2 Class C Lesson Dialogue, 13 Feb. 04, lines 159–187

When asked about this change in student involvement during the demonstration, Janet said,

"It more may have been because I thought if I asked what we could use instead they might say pulley or an answer I didn't have. So instead I said, 'they went out and purchased it.' And I kind of made it more like a story in the last one whereas in the first one it was more like, 'we have this situation. This is what is going on.' …In the last one, it's more a story, 'his company,' you know. And they laughed a lot and they got into it a little bit more, but I more offered what the company was willing to buy and provide. I guess I didn't want to confuse them with having so many material up there that they could have listed a lot of things and not really knowing what kind of question I was asking. …I just went off on a story. I just kind of started floating away. There wasn't a real reason. It was more that I had become familiar with the process of that particular section of the program and so familiar that we were now going to make a story out of it.

So it's kind of like first I kind of come up with some ideas, then I put the ideas together, and then I make a story."
Janet, School 2 Post-lesson Interview, 13 Feb. 04, lines 84–126

Janet was cognizant of the change in the way she led Demonstration 2 and attributed it to her growing comfort in the lesson by the third class and her concern that students would propose ideas, like a pulley, that she could not support in the demonstration despite their legitimacy. The purposes of Demonstration 2 were to illustrate the use of an inclined plane, the effects of varying the length of the plane, and the effects of the wheel and axle in conjunction with the inclined plane to reduce effort to bring the worker to the top of the building. After the short inclined plane, students in Class A were asked to come up with a better way to bring the worker from the ground to the top of the building. They suggested a pulley, perhaps alluding to an elevator system, rather than lengthening the plane. In the same situation during Classes B and C, Janet proposed to lengthen the plane to reduce the effort as illustrated in the excerpt above for Class C.

After the long inclined plane, Janet asked students in Class A and B for another simple machine to use in conjunction with the inclined plane to reduce effort even more. Class A suggested a wheel and axle, but students in Class B proposed a pulley. For Class C, Janet told the students a wheel and axle would reduce the effort and continued with the demonstration. Janet maintained the procedure and objective of the demonstration, but manipulated the dialogue and progressively reduced student involvement as her comfort level and experience with students from this school changed.

Gary compared the way he conducted the discussions in School 2 *Creepies and crawlies* for Class A versus Class B due to student responses. He said,

Gary, "Just the first class before I asked the question, they were telling me what they already knew. The second class, I would ask the question and they would give me the right answer but they waited until I asked the question. But that could even be the teacher and what they're used to in the classroom."

Researcher, "Did that affect your teaching?"

Gary, "A little bit. Like the first class, I didn't ask as many questions because they were telling me that they already knew a lot of it. So I mean I still did ask questions but sometimes I changed the question or if they already knew the answer, they knew it was a reptile, I didn't ask. So it did influence my questioning on what questions I asked when I asked. Things like that."

Researcher, "In reference to the first class, are you saying that the types of questions that you asked changed because they were offering more information?"

Gary, "Not maybe the types but how many questions. Since they were already giving me responses to what I would normally use as questions, …I listened to what they already knew and then tried to structure my questions around it. And I did it with both [classes]. But with the first group they just gave me more background information on what they knew than the [second] group did, like more volunteer information."

Gary, School 2 Post-lesson Interview, 16 Apr. 04, lines 10–30

Student involvement changed from responding to Gary's questions to volunteering information they already knew. He initially asked questions in Class A but as students volunteered what they knew about the animals, he listened and responded to their comments. In Class B, student comments were primarily in response to questions that Gary asked. He suggested that this could be attributable to student-teacher interactions to which students in Class B were accustomed in their classrooms at school, but also offered later that this difference in student behavior between the two classes could be due to the students' state of mind. These third grade classes participated in two science lessons consecutively with a five-minute intermission as they switched classrooms. He reflected that students could be tired by the second class and thus more reluctant to volunteer information. Regardless, Gary manipulated the dialogue and changed the level of student involvement based on the students' eagerness to talk.

Depth and detail of discussions.

The educators reported that they manipulated the amount of depth and detail in the Talk segments to accommodate the students. As mentioned above (*Distinct Reasons for Making Changes in Lessons: Students Influence Changes*, p. 104), Gary pointed out that he decided to go more in depth about atoms during Talk 2 for School 3 *Snap, crackle, and pop!*. The students' responses to his question about charges suggested to him that they were familiar with charges,

> Educator, "When we're working with static electricity, we're working with charges and we're producing a charge. There are two types of charges we're working with. Does anybody know the types of charges? Think of a battery, there are two ends to a battery."
> Student, "There's a plus side and a minus side."
> Educator, "Good. There is a plus side and a minus side. We call that something different than plus and minus in science though. You're on the right track."
> Student, "I think the minus is a negative."
> Educator, "Excellent, the minus is a negative charge. Good. And the opposite of the negative charge is this plus charge, which is?"
> Student, "Positive."
> Educator, "Good. We have positive and negative charges. When we make static electricity, that's a negative charge. So we're creating a negative charge here every time we produce static. We're creating a negative charge. And we're doing that by rubbing together atoms. Everything around us is made of atoms and when you rub atoms together they can produce a charge, a positive charge or a negative charge. (E draws diagram of rod and material from experiment) When we rub them together, we're going to rub parts of atoms together like electrons and protons. Protons have a positive charge and electrons have a negative charge. So when we rub these different parts together, they exchange parts. And if they end up with a lot of electrons they have a negative charge, if they end up with a lot of protons, they're going to have a positive charge."
> Gary, School 3 Lesson Dialogue, 12 May 04, lines 177–201

Comparing this decision with his actions in Schools 1 and 4 for the same segment, Gary did not mention protons and electrons in explanation of charges. In School 1 *Snap, crackle, pop!*, Gary felt the students' slow and hesitant responses suggested they were perhaps not familiar enough with charges for him to go into detail about the parts of atoms. Gary said,

> "Like how many hands went up, just looking at faces, if there was a bunch of blank stares, and then trying to give other examples like when I said, 'there's two types of charges out there, does anyone know what they are?' You know and two hands went up. And then I tried something else. I was like, 'we're thinking of batteries. Batteries have two ends to them.' And then it made a little bit more of a connection but everyone still wasn't, the hands weren't going up like a positive and negative. …The hands that were up, only two were like this."
>
> Gary, School 1 Post-lesson Interview, 14 Apr. 04, lines 185–191

In School 4 *Snap, crackle, pop!*, Gary sensed the students were not focused on the lesson. He observed minimal interest during the activity segment and remembered they were one of the first groups to arrive at the museum when it opened (this was opening day for the newly renovated museum). He thought their program schedule suggested they had not sat down since they arrived at 10 a.m. and it was now noon. The students' actions were more sluggish than expected. Consequently, Gary decided not to go into detail about the parts of atoms. In both of these observations, he talked about positive and negative charges but only went into detail about parts of atoms in School 3.

In Julia's Talk 2 for School 7 *Snap, crackle, and pop!*, students brought up conductors and insulators as they talked about reasons for discrepancies in the results from the rod and material activity,

> Educator, "Yes, there were some different answers."
> Student, "(inaudible, the way people rub the rod)"
> Educator, "Oh, he's got one of the ideas here. The reasons some of these answers don't match is maybe some of you were really rubbing that material hard and fast. And that's exactly what you have to do. That's how it works the best. Maybe some of you were a little slower but more deliberate trying to do it. It depends on what kind of technique you use as to how much of a charge you get. So that may be why some of you got yes, most of you got no there. Ok, good. Good answer. What about the rubber compared to the glass? How did that work?"

Student, “Well it didn’t work on anything because maybe it’s a conductor.”
Educator, “Oh that’s an interesting word. Somebody else brought that word up to me a short while ago. Very good. Well what we have here is the rubber is probably the worst because you see the largest no’s there and the smallest yes’s. So the rubber wasn’t nearly as good as the glass but the glass wasn’t nearly as good as the plastic. What are conductors? When you talk about conductors, you can also talk about something called insulators. What are conductors?”
Student, “(inaudible)”
Educator, “Very good. They allow a charge to move. These things allow the charge to move much more so than the plastic did. So we’re going to call these more like conductors. They’re acting as if they’re conductors. What is the plastic acting like? Not a conductor, a …”
Student, “An insulator.”
Educator, “Who said that? I heard it. Very good, let me know who said it so you get credit. Very good. It’s acting more like an insulator. It’s holding onto that charge, not allowing it to move. And sure enough, plastic, glass and rubber are not the best insulators or conductors. But in this case when we compare the three, plastic does act more like an insulator than the other two. Glass and rubber act more like conductors.”
Julia, School 7 Lesson Dialogue, 3 May 04, lines 283–316

Julia went along with concepts that the students brought up and related them to the lesson. Neither she nor Gary talked about conductors with the other classes. While Julia discussed insulators in the other lessons also, this occurred during Demonstration 2 as she questioned students about the need to stand on the plastic stool in order for the charging effect to work.

Referring to this incident, Julia said,

“I think I probably gave them more things. I tried to give them more things to think about. More detailed information and a couple of kids brought up to me conductors and insulators on their own without me ever asking about it. I think I elaborated a little bit more on that on the board and I talked and I tried to ask some questions as I went around to the group to you know, give them circumstances. ‘Do you think this would work as well if you tried this or if you did that?’ So I tried to come up with some more challenges for them and see what they were equipped for.”
Julia, School 7 Post-lesson Interview, 3 May 04, lines 23–28

She elaborated more during her discussion about insulators with this class than other classes observed in this study. This was a class of 5th grade students, while the other two classes were 3rd graders, thus Julia felt she could be more in depth because the students' brought up the content and responded appropriately to her follow up questions.

The flexibility in depth and detail of the lessons was also reflected in Gary and Sally's initial interviews. Gary commented about using questions and answers in his teaching, and said,

> "Sometimes just to get a feeling for where they are at the beginning [of the lesson]. …So one [lesson] will target multiple grade levels, for example, we do one on matter and we do Pre K to I think third grade on that. Starting off with a few questions to see where this group of children is, how much they understand already about matter, and then guide the lesson around that to try to figure out what you need to teach. … If they're Pre K, they might not know the term solid, liquid, or gas and you spend a little bit more time defining them. But if they're third grade, spend a little bit more time on molecules, what is a molecule, and based on how [molecules are] arranged and act together, that's going to create a solid, liquid, or gas."
>
> Gary, Initial Interview, 14 Apr. 04, lines 213–222

Gary pointed out that the lessons were available to multiple grade levels, for example a lesson on matter from pre-kindergarten to third grade. He used his questions and the students' responses at the start of a lesson to determine their understanding, which could also be revealed through the students' grade levels. The details of what was discussed could be changed to suit the ability level of the students. This sentiment was demonstrated for his *Snap, crackle, pop!* classes discussed above. Gary changed the extent to which he discussed atoms based on the students' knowledge and interests.

This was the same reason Sally asserted that she could teach the same lesson to kindergarten to fifth grade in her initial interview. She said,

> Sally, "In fact I … find now that I could almost teach many of [the lessons] from kindergarten through fifth [with] the same [lesson plan]."

Researcher, "How do you go about doing that? I mean it's kindergartners versus fifth graders."

Sally, "Use larger words, go into more detail. The further up the grades you go the older they get, and there are a lot of times I thought they wouldn't like this. And then find out differently. …I did *Amazing Air* off-site, which is mainly …things that air can do like taking up space, move things, and holding things up. And I did that from kindergarten through fifth grade."

Researcher, "So it's the same concepts?"

Sally, "The same concepts, use much larger words but once they get to fifth grade I tell people I can't explain things much beyond fifth grade. I think part of the reason that they enjoy it is because by the time they get to fifth grade, the teacher never lets [them] do anything that was playful. ... So it's a little neat to be able to do things that are more hands-on. You try things out. You just ask further questions. If there are things they have to make, you might have to make them for the younger ones and they just try it out. The older children can make their own. And you can encourage them to change it to see what happens much more than with the little ones."

Sally, Initial Interview, 24 Oct. 03, lines 286–307

Sally admitted that she varied the difficulty of the details in her lessons with older grades compared to younger grades so that the same lesson plan could be taught to multiple grade levels. The concepts were the same, but the depth and details were changed according the students' abilities. Observations suggested that there was minimal difference in the depth and details of the dialogue between the classes. But it must also be noted that grades for the observations ranged between third to fifth. All lessons observed in this study at NC Museum were taught to fourth and fifth grade classes.

Ways of modifying the dialogue summary.

What the educators said and how they said it were also manipulated. The educators varied the amount of depth and detail, as well as modified the amount of student involvement during Talk and Demonstration segments to accommodate students, time, and their own comfort and judgment. Table 13 summarizes these findings and corresponding data.

Table 13. Summary of findings and excerpts from *Manipulate Controllable Elements*: *Ways of Modifying the Dialogue* section. (PL=Post-lesson; LD=Lesson Dialogue)

Findings	Evidence Summary	Evidence Referenced
Student involvement Student involvement during Talk and Demonstration segments varied. Students were given less opportunity to explain or share information with time reduced and increased comfort in teaching a lesson plan. The way students were involved in the dialogue (volunteering the information versus answering questions) was also changeable due to student knowledge.	• Sally reduced student involvement in the discussion after an activity, and talked about her reason for doing so. Lesson dialogue showed Sally asked students in Class A reasons for discrepancy in their activity results, but did not ask students in Class B. Sally said she realized it would be better for students to offer reasons but felt there might not be enough time left to do other things. She did not think her decision made a difference in what students gained from the lesson overall. • Janet explained her reasons for reducing student involvement in Demonstration 2. Dialogue showed Janet asked students in Class A to propose simple machines that would reduce work to lift an object, and in Class C she told them the simple machines needed. Janet clarified that she became comfortable with that demonstration and did not want to turn down students' suggestions despite their legitimacy because she did not have the supplies. She progressively decreased amount of student involvement in this demonstration from Class A to C. • Gary talked about the way he changed student involvement based on their eagerness and knowledge. He said students in Class A were telling him what they knew so he did not ask many questions, but asked more questions in Class B because the students did not volunteer what they knew. He noted that this could be due to students' habits with their teacher or state of mind since this was their second lesson in a row.	• Sally, School 2, 2/12/04 *Simple machines* Class A LD (lines 211–214) Class B LD (lines 221–224) PL Interview (lines 170–187) • Janet, School 2, 2/13/04 *Simple machines* Class A LD (lines 134–178) Class C LD (lines 159–187) PL Interview (lines 84–126) Researcher field notes • Gary, School 2, 4/16/04 *Creepies & crawlies* PL Interview (lines 10–30)

Table 13 Continued. Summary of findings and excerpts from Manipulate Controllable Elements: Ways of Modifying the Dialogue section. (PL=Post-lesson; LD=Lesson Dialogue)

Depth and detail Educators manipulated the depth and detail of their discussions to accommodate students' knowledge, interests, and abilities. A lesson topic was available to multiple grade levels, and the same lesson plan was used.	• Gary went into more details because students demonstrated they were familiar with the content by answering his questions. Dialogue showed he talked about protons and electrons and related them to charges, which he did not do for Schools 1 and 4.	• Gary, School 3, 5/12/04 LD (lines 177–201)
	• Gary talked about not going into details on parts of the atom due to the students in Schools 1 and 4. For School 1, he felt the lack of raised hands to answer his questions suggested that they were not familiar with atoms and so he did not elaborate. For School 4, he thought students appeared sluggish and uninterested in the activity.	• Gary, School 1, 4/14/04 PL Interview (lines 185–191) School 4, 5/28/04 PL Interview
	• Julia discussed conductors and insulators in Talk 2 and attributed this to student knowledge. Dialogue showed that a student suggested rubber and glass did not work as well in the activity because they might be conductors, and Julia elaborated on conductors and insulators, which she and Gary did not do in other lessons.	• Julia, School 7, 5/3/04 LD (lines 283–316); PL Interview (lines 23–28) Researcher field notes
	• Gary talked about the same lesson plans used for multiple grades during his initial interview. He said since the same lesson plans were used, he started his lessons with questions to determine what students knew, and changed what he talked about based on student knowledge and grade level. This was demonstrated in the way he changed the dialogue about atoms among *Snap, crackle, pop!* lessons.	• Gary, Initial Interview, 4/14/04 (lines 213–222) Researcher field notes
	• Sally talked about being able to teach the same lesson to kindergarten through fifth grade students during her initial interview. She said she changed vocabulary and details to accommodate the students, but the same concepts were discussed. None of the lessons observed in NC Museum was taught to Kindergartners.	• Sally, Initial Interview, 10/24/03 (lines 286–307) Researcher field notes

Taking Advantage of Teachers and Chaperones

In the observations for this study, the chaperones and teachers were used as resources to aid the educators. Teachers were timekeepers and aided with student management, while chaperones were activity helpers. The educators informally assigned these roles in order to facilitate the flow of their lessons within the time allotted.

Classroom teachers as timekeepers.

As timekeepers, some teachers were up front and others were not. In her *Forces in motion* lessons that arrived 15 minutes late, the teachers informed Sally the amount of time she had for her lessons at the start of class. But sometimes this information was relayed non-verbally. Julia commented,

> "You're also looking at the teacher because you usually get a hand signal like, 'we have to get out of here now or go out the door,' so that to some degree, the time factors important too. I think they were going to get back on the bus."
>
> Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 258–261

Julia admitted to being perceptive to the teachers' unintentional, non-verbal behaviors. Gary discussed this when asked whether time was a factor that influenced his instruction in School 4, *Snap, crackle, pop!*. He responded,

> "Not too much, not really because I don't know what they're doing afterwards but I know they have another show or presentation. And sometimes I also try to look at the teacher and see if she's looking at her watch or staring at the clock. Or see if she's talking to chaperones to try and figure out if they need to leave right now. Or if the teacher is enjoying themselves and not paying attention to the time then I kind of assume I can keep going. But if they're just staring at the clock or looking at me and looking at the clock."
>
> Gary, School 4 Post-lesson Interview, 28 May 04, lines 221–228

Gary watched the teacher's behaviors for clues on how much time he had remaining.

Janet resorted to asking the teacher. As she talked about the differences between her teaching approach for the three *Simple machines* lessons, she highlighted time as a reason for the difference in Class C,

> "…plus they were five minutes late and I didn't know when had to leave so…at some point I went up and asked the teacher how long I could keep them for."
> Janet, School 2 Post-lesson Interview, 13 Feb. 04, lines 301–303

Since her third class was late, she wanted to know whether she had an extra few minutes to make up the lost time. The teacher did not approach her, so Janet asked the teacher. On some occasions, the educator could find this information out without the teacher.

Gary also used the class' agenda and his knowledge of the museum's floor plan to determine his time parameters. He said,

> "I mean time definitely affects how I teach. And I try to look at the schedule ahead of time and figure out if it's ok if I run over or if they have to be somewhere right away. And then I can also make a judgment on how close they are to the next location. Like to get from the first floor to the third floor right now, especially with a group of thirty, it's going to take at least five minutes if not more. But sometimes if they just have an IMAX movie, which is just next-door, I can kind of stretch it a little bit further and go, 'well when you leave here, just go left and you'll be right there'."
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 113–118

The schedule to which Gary referred was the museum's school program schedule. Using the class' agenda was possible if the teacher signed up for another museum program. Nonetheless, the educators used the teachers as timekeepers in multiple ways. They watched teachers' behaviors during the classes, checked the museum's program schedule, or talked with the teachers during the class. This informed educators on how much time they had, especially if the class needed to leave early, and it informed educators whether they could go over the time limit for that class. Thus, using the teachers as timekeepers was useful in that it gave the educators flexibility in a variable that was fixed.

Classroom teachers as student managers.

Teachers were also valuable for student management when they interjected to call the class' attention to the educators or handled individual student behavior problems. Even though educators could anticipate how students would respond to different activities and demonstrations in their lessons (discussed above in *Repetition Develops Consistency: Insight for future lessons*, p. 94), there were occasions when teachers' management rapport with their students were useful. The teacher interjected as Julia called the students back together after Activity to start Talk 2 in Julia's School 8 *Snap, crackle, pop!*.

> Educator, "Ok, let's go ahead and start cleaning up even if you're not finished. Finish up real quickly. (Students continue to work on activity, some students begin to place materials back in box. Educator collects the boxes.) Okay, looks to me that almost everybody is cleaned up. Here's what we're going to do. Come on back with your group. Sit with the people you worked with so you can see your chart. You want to be able to read it. (Students move around, some students still working on the activity. Students continue to talk to each other.) Ok, even if you're not done yet, we want to go ahead and start to move on."
>
> Teacher, "Third graders, I want you sitting on your bottoms with your legs crossed and facing Ms. [Julia] like you know how to it. On your bottoms facing Ms. [Julia] with your legs crossed like you know how to sit. (Students sit and quiet down, teacher waits) Thank you."
>
> Educator, "Thank you."
>
> Teacher, "And our eyes and ears are on her."
>
> Educator, "All right, thank you. I appreciate that. What we're going to do here is fill in the big chart as a group so you have to look at the chart that your group has."
>
> Julia, School 8 Lesson Dialogue, 11 May 04, lines 243–257

The teacher interjected in this same manner during Demonstration 2C as Julia tried to get the students to move along the charge line so that everyone got a chance to be shocked. When asked to talk about her thoughts on the teacher's interjections during the lesson, Julia said,

> "I was actually glad she was [there] because she knows her students better than I do. And she knew them by name and if one in particular were a little more energetic in a negative way, she would get up and do something about it. I appreciate that. So it didn't really affect how I interacted with them. It was just a relief because you know, by the end of this program you're going to lose your voice from talking so much and talking so loud and having to yell to get their attention. So that worked out well."
>
> Julia, School 8 Post-lesson Interview, 11 May 04, lines 169–174

The teacher was useful in calling the students' attention and managing the crowd. While it did not change the activities in the lesson or how Julia interacted with the students, she felt it was helpful to have someone who knew the students and had a management rapport with them intervene when needed.

In regards to calling students' attention, Gary pointed out classroom management differences between schools and museums. He said,

> "We don't use anything here to get their attention. Where in a classroom lots of times, for classroom management the teacher has little sayings or gestures or flips the lights. Something to get the class' attention, where we don't have anything like that [here]. And with forty-five minutes, they're not going to pick it up. I mean I've seen…other [educators] try and it just doesn't work. You can't set a routine in forty-five minutes. Like one [educator] a few years ago said, 'one-two-three-eyes on me,' the kids would go, 'one-two eyes on you.' It's great for a classroom, but that takes a few days if not a few weeks to get kids into that routine. You can't teach a routine in forty-five minutes. But sometimes when the teacher does have one, they will do it to get [the students'] attention. They'll snap their fingers or they'll whistle or they'll do the 'one-two-three-eyes on me' thing."
>
> Gary, School 4 Post-lesson Interview, 28 May 04, lines 298–307

Gary felt it was not possible to establish a management routine with the students in the short amount of time of his lesson. As a result, teachers' classroom relationships with their students were appreciated in these science lessons at the museum. The lack there of was noticeable and made it challenging for educators.

Janet reflected on School 3 *Adaptation advantages*,

> "They were rambunctious, very talkative. The teacher didn't have any control over them at all. Yeah for both classes definitely, I mean I thought that the second teacher would be a little bit better, but they were still talking, having their own conversations during everything. I thought that since she sat at [that] table I thought that it would be better, but no they sat with their friends and stuff like that so it definitely didn't make it any easier. Yeah they were both very challenging to get under control. And it's kind of one of those programs where there's a lot of talking that goes on at times like that but then we need to stop talking and bring it back together. That was pretty challenging."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 1–8

Janet struggled to gather students' attention during Talk or Demonstration segments in both *Adaptation advantages* classes, but neither teacher interjected. She felt the teachers did not have control over the students and later cited an incident where some students played tic-tac-toe in front of the teacher, but the teacher did nothing. This prompted Janet to contemplate omitting Demonstration 2 with the animals as mentioned above (*Lessons Comprised of Segments: Omit a segment*, p. 116), but she did not want the students to miss out on the experience so she included the segment.

To address such situations, Gary and Sally applied their own methods. Sally switched the light on and off two or three times, waited for the students' attention, and then addressed them. Gary repeated, "I need all eyes on me please," until he got all of their attention. He attributed this to his student teaching and professional preparation as a classroom teacher.

> "I try not to rely on the classroom teacher too much for behavior management and normally I feel that I have generally good control of the class. Like just saying things like you know, 'I need eyes on me right now' and trying to let…them know what I expect. …and then pausing and doing a little bit of wait time for like three seconds or so and waiting for…all of them to look at me. And then I'll say stuff like, 'you know I'm still waiting for a few pairs of eyes.' I don't go, 'well I'm still waiting for you, you, you, you and you to pay attention.' I'll just say, 'I'm still waiting for a few pairs of eyes and once I have all eyes on me, we can move on.' Things like that. But some of that is also based on my student teaching

and working in a more efficient setting to gain their attention. And then, like I'm not going to shout over them. Again some of that comes from even student teaching. Just little techniques or little sayings to gain the focus back on you."

Gary, School 3 Post-lesson Interview, 12 May 04, lines 239–250

He found that skills he developed for teaching in school was applicable in the museum. Gary noted above that some routines such as switching lights and "one-two-three, eyes on me" could not be set in just 45 minutes, but he used more explicit ways to gather students' attention. The educators were not helpless or unskilled in managing the students, but they appreciated the teachers' rapport and initiative to manage their students. Sally put it

this way,

> "Certain rules apply in every classroom. If you want to prevent chaos and promote learning, raise your hand, take turns talking, listen to educator, etc. Mainly I just let the students know that I expect them to follow general classroom rules. I may need to wait to get students' attention or may need to move someone to another seat. Most of the time the classroom teacher deals with a student who is very disruptive."

Sally, Initial Interview, 24 Oct 03, lines 45–52

Sally was asked to compare teaching in museums versus schools, and pointed out that there were some rules to student behavior that was expected regardless of the setting. In the museum, the teachers intervened when those rules were broken to the extent that they became disruptive.

Gary and Julia also commented on the need for teachers to intervene in situations that required managing student behavior. Gary said,

> "The only time that I would feel that I definitely need support from the teacher is if a student does something that just puts themselves or others at risk. …this class that's not necessarily going to happen (referring to *Snap, crackle, pop!*), but with something, like you've seen me do *Creepies and crawlies*. Like if a child can just not stay seated and they're going to keep charging at the animal or handle it inappropriately, then I'll probably have to explain to the child and make sure the teacher is aware of it, that I need to do this. 'If you can't handle an animal the way I ask,

> then I'm going to have to move on and you're not going to be able to pet this animal.' And then at that point I try to also give the teacher clues that this child is doing something that might be a safety risk or is just hindering the program and to please interject at that point. Because normally with something like that, all the teacher needs to do, even with this class if there's a problem is just have a chaperone come and sit next to the child. Because I much prefer that than trying to not have a child participate."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 258–270

Gary's preference was for the teacher to intervene and handle individual student behaviors that could disrupt the whole class. He would address the disruptive student and hint to the teacher to interject. Gary noted that this might not require the teacher to do much more than ask a chaperone to sit with the disruptive student, and he preferred this rather than excluding the student from participating.

To illustrate, in Gary's School 3 *Snap, crackle, pop!* lesson, a group of six girls had trouble deciding on groups. They wanted to make three groups of two rather than the instructed groups of three. Gary noticed the girls, but did not approach them. The teacher interjected before Gary said anything to them. He checked in on the status, but the teacher informed him she had it under control and told the six girls to form two groups or she would pick for them. In talking about what the teacher did, Gary said,

> "Where I did appreciate it when all the girls wanted to work together that she did step in and help alleviate the problem. If not, I would have just done it myself but I was very appreciative that she took the initiative to do it and that she also perceived it as a problem. Because I did notice it when they were forming groups…I wanted to give them a few seconds to see what they were going to do. How they were going to resolve it themselves before I stepped in. And it seemed like they were all satisfied in the end. No one seemed upset or concerned."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 233–239

As Gary mentioned earlier (in *Repetition Develops Consistency: Insight for future lessons*, p. 87), he did not want to break up friends because past classes suggested that this could be distracting. He watched and waited for the students to resolve the situation on their own, but their teacher intervened. While he did not make it a habit to rely on the teacher for classroom management, he appreciated her presence and initiative when the situation arose. In this way he was able to continue the lesson and attend to the other students who were working together. Similarly Julia said,

> "Generally their presence for any of our programs really doesn't affect what we do. What affects us is kids behavior. If the kids are older and they don't see the teacher there, a lot of times we do have trouble. They're thinking they can do whatever they want."
> Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 378–381

Julia acknowledged that the teachers' presence did not affect the activities and what she did during the lessons, however, their potential influence over students' behaviors made their presence valuable.

During Demonstration 2 of Janet's Class B School 1 *Forces in motion*, a student yelled, "shut up!" The teacher walked over, pulled his chair aside, and reassigned the student. Janet did not pause her demonstration. A few minutes later in that same demonstration, the teacher walked over to a group of students and took papers away. The students were busy writing something on the papers that the teacher did not approve. She managed the student behaviors without interrupting the lesson. As Janet began Talk 2 in Class C School 2 *Simple machines*,

> Educator, "Ok, let me get everybody's attention up here. So we're going to go around the room and I want you first to tell me how much, how many grams it took to lift your friction fighter and your worker just straight up into the air without any of the incline planes. So tell me how much for your top line?"
> Student, "800."
> Educator, "Eight hundred? All right…"
> Teacher, "I need heads off tables. It's not naptime."
> Educator, "Ok, about a thousand. Thousand?"
> Student, "1000."
> Educator, "Ok. A thousand."
> Janet, School 2 Class C Lesson Dialogue, 13 Feb. 04, lines 281–296

This teacher continued to manage her class despite Janet's presence and role as instructor during the lesson. She called students out on behavior that she felt were not appropriate in this learning experience. Janet continued asking students for their results without a pause despite the teachers' interjections. More disruptive student behaviors were observed in Janet School 3 *Adaptation advantages* lessons. For example, students continued to play with the animals from Activity 1 during Talk 2 even though Janet asked them to put the animals aside.

When asked how she handled student behavior problems that appeared to arise in her lessons, Janet said,

> Janet, "Yeah I'm not really one of those because I don't feel it's my job. My job isn't to discipline the children. That should be their teacher. I've definitely had classes where the teacher leaves the room for a second and the kids just go nuts. I mean, so definitely there are teachers that have control over their students because when the teacher leaves the room, the children are just different beasts. But it's hard for me because that shouldn't be my job to stop what I'm doing and discipline them. It should be for the teacher to stop the program and discipline them because you know what's it going to matter to the kid if I say you know, 'go sit in the corner. You're going to have [to talk to] your parents,' you know I can't call the child's parents. They know I don't have that control over them."
>
> Researcher, "Okay, so it's kind of a two-part reason. One being that it's not necessarily your job to do that and second thing is just you don't have that kind of relationship with the students to really have an impact even if you did discipline them."
>
> Janet, "Right, …I mean if they're really doing something bad like, I'd move the camel onto the floor (referring to incident in Class A when students continued to play with the toy from Activity 1 so Janet moved the stuffed camel onto the floor). I mean if they're really not listening, I will do things but not anything drastic like send them out of the room. You know anything like that that's not, I'm sure a teacher would get very upset if I told one of their students to go sit in the hallway. And also I don't like to effect the other students that are behaving well and ruin their time and stuff like that."
>
> Researcher, "What do you perceive to be your job when you're up here doing a lesson?"
>
> Janet, "To inform the students of new information and to make sure that they're having fun and understanding the material and to work with the teacher and helping them grow in whatever they're studying at their school, because I don't know what they learned already. So sometimes you know the teacher like she just said, 'we'll go downstairs and we'll look at the animals and look at specific adaptations' and stuff like that. So just to work with the

> teacher helping the children learn whatever it is because the teacher comes here for a purpose. She wants the children to learn a specific thing. So I'm here to make sure the kids learn that specific thing not discipline and yell."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 10–45

Thus Janet had defined roles for herself and the teacher, and she taught her lessons within those parameters. Her job was not to discipline nor did she feel she had the relationship with the students needed for disciplining, therefore, she left that task for the teachers. She was there to provide the information and experiences that the teachers sought for their students.

The other educators were not as explicit with their distinctions. However, they shared her sentiments on the teachers' role and responsibility as disciplinarian with their classes even at the museum. Despite the brevity of their time with each class, the educators were attentive to the relationship the teachers had with their students, and it appeared this was what the educators capitalized upon since they did not have this relationship. Gary verbalized this during the post-lesson interview for School 2 *Creepies and crawlies*,

> Gary, "In all two classes, all of the teachers participated and they asked questions and encouraged the students to. That has a direct impact on the way I'm going to teach."
>
> Researcher, "Ok. How so?"
>
> Gary, "It lessens, well it lessens my anxiety level a little bit, especially at the beginning of the class. Because, when they enter with some chaos and some confusion and it takes a few minutes to calm them down or to get them on track I guess. It does take away from the lesson a little bit, or we might move slower at the beginning than the end. So having the teacher's support and encouragement with students helps keep them on track, which helps me progress smoothly through the lesson. … and I think it also influences the students which again that influences my teaching because the teachers' behaviors, the students are going to pick up on the teachers' behaviors. And it's going to affect their behavior."
>
> Gary School 2 Post-lesson Interview, 16 Apr. 04, lines 80–107

Gary recognized that the teachers' preparation prior to and behavior during his lessons affected the students' behaviors, which in turn affected his teaching. He noted that it took time from his lesson to calm the students if they arrived flustered. The teachers' presence and behavior could help to refocus the students and move the lesson along. Thus teachers' relationship with their students persisted in the science classrooms at the museums, and the educators relied upon this to develop and maintain a suitable learning atmosphere.

Chaperones as activity helpers.

In addition to classroom teachers, educators took advantage of chaperones' presence during their science lessons. Both museums required chaperones to accompany visiting school groups, however, this did not always occur for the lessons observed (Table 14). All classes at MD Museum exceeded the teacher to student ratio, while only 5 of the 13 classes at NC Museum met the required ratio. Five classes at NC Museum were not accompanied by additional chaperones. Nonetheless, in all the classes, the educators asked adult chaperones to sit behind the students at the start of the lesson, but were encouraged to join the students during activities or participate in demonstrations that had opportunities for everyone to participate. These whole class participation demonstrations occurred in Demonstration 2C (charge line) for *Snap, crackle, pop!* and all demonstrations that offered the chance to touch live animals.

Table 14. Number of chaperones and students per lesson.

Educator	Lesson title	# of Students	# of Chaperones	Meet required adult:students ratio?[1]
NC Museum				
Janet				
School 1	*Forces in motion*			
Class C		16	0	No
Class D		15	1	Yes
School 2	*Simple machines*			
Class C		24	3	Yes
Class D		25	0	No
Class E		24	2	Yes
School 3	*Animal adaptations*			
Class A		24	1 TA	No
Class B		23	1 TA	No
Sally				
School 1	*Forces in motion*			
Class A		15	0	No
Class B		19	0	No
School 2	*Simple machines*			
Class A		23	2	Yes
Class B		25	6	Yes
School 3	*Animal adaptations*			
Class C		22	0	No
Class D		23	1	No
MD Museum				
Gary				
School 1	*Snap, crackle, pop*	22	11	Yes
School 2	*Creepies & crawlies*			
Class A		11	2	Yes
Class B		10	3	Yes
School 3	*Snap, crackle, pop*	30	6	Yes
School 4	*Snap, crackle, pop*	21	6	Yes
Julia				
School 5	*What's cold, what's hot*			
Class A		15	6	Yes
Class B		18	8	Yes
School 6	*Snap, crackle, pop*	28	10	Yes
School 7	*Snap, crackle, pop*	27	8	Yes
School 8	*Snap, crackle, pop*	28	6	Yes

[1]Required adult to students ratio at NC Museum is 1:8 and MD Museum 1:10.

Commenting on why she elaborated more in Talk 2 for Class B than Class A during School 1 *Forces in motion*, Janet attributed it to the presence of the chaperone. She said,

> "When there's more adults in the room to help the students out and actually encourage them and have them figure out ways [to fill the canister,] it's a lot easier for me because I can't make it around to every child. So with that table, the father had gone through with them why it would work this way and if you flipped it over it would work the completely other way. (referring to behavior of canister rolling down the ramp based on position of contents) And I thought that was neat and I would at least tell the other kids about that. So that was more why because he had made a specific point about it. 'You could just flip it over,' and I was like yeah this is an easier way of saying it [and decided to] just tell that to the class. And they were all excited because that was their thing."
>
> Janet, School 1 Post-lesson Interview, 11 Feb. 04, lines 267–273

In this class, there was only one chaperone, aside from the teacher, and he sat and worked with one group of students for the duration of the lesson. Janet noticed the discovery the chaperone prompted and made a point to discuss it during Talk 2. She suggested that the chaperone helped her by giving students more personalized attention. Julia and Sally both made similar comments in this regard,

> "And also the parents were helping with that too. The parents were not letting them just do the activity. They were letting them do it themselves but they were saying how come his worked and yours didn't? Where were you sitting? What were some of the factors involved here?"
>
> Julia, School 8 Post-lesson Interview, 11 May 04, lines 223–226

> "Oh I always think [the chaperones] makes a difference. That's why I like to get an adult to sit at or near a table because most of the time, not always, they'll get involved. It really helps. It helps the children to always have someone to respond to what they're doing and encourage them. These particular parents were able."
>
> Sally, School 2 Post-lesson Interview, 12 Feb. 04, lines 123–129

During these lessons, chaperones aided the educators by offering the students more personal attention. They sat with the students during the small group activities and worked through the activities with them. These educators felt that in doing so chaperones offered the students a more challenging and personal experience.

Using teachers and chaperones summary.

Classroom teachers and chaperones were present throughout all classes observed. However, not all classes for NC Museum had chaperones or met the required adult to students ratio. Educators informally assigned roles to teachers and chaperones. Teachers were designated as timekeepers and student managers, and chaperones were assigned the role of activity helpers. Table 15 summarizes the findings in this sub-section along with the data that support those findings.

Table 15. Summary of findings and excerpts from *Taking Advantage of Others* section.
(PL=Post-lesson; LD=Lesson Dialogue)

Findings	Evidence Summary	Evidence Referenced
Classroom teachers as timekeepers		
Science lessons were allocated 45 or 50 minutes, which was reduced when classes were late. Verbal and non-verbal cues from the teachers informed the educators on the amount of time they had and whether it was permissible to extend their lessons beyond the allocated time.	• Julia said sometimes teachers gave her hand signals to let her know it was time for the class to leave. Late teachers for Sally's classes informed her at the start of class the time they had to leave.	• Julia, School 6, 4/21/04 *Snap, crackle, pop!* PL Interview (lines 258–261) Sally, School 1, 2/11/04 *Forces in motion* PL Interview
	• Gary said he watched teachers' and chaperones' behaviors (such as watching the clock, talking with each other, leaving and returning into the room) to suggest whether he had to stop or could continue his lesson.	• Gary, School 4 , 5/28/04 *Snap, crackle, pop!* PL Interview (lines 221–228)
	• Janet said she asked the teacher how long she could keep the students.	• Janet, School 2, 5/13/04 *Simple machines* PL Interview (lines 301–303)
	• Gary said that sometimes he looked at the museum's program schedule to determine whether he needed to end the lesson on time or could extend the lesson a few minutes.	• Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 113–118)
Classroom teachers as student managers		
Educators did not rely on teachers to manage their classes, but were attentive to the teachers' management rapport with their students and appreciative of teachers who took the initiative to manage their students. Classroom teachers were used to gather the class' attention, which helped educators use their time efficiently.	• Julia used the teachers' interjection to gather students' attention and continued with her lesson. Dialogue showed Julia announced conclusion of the activity and called students back together. The teacher interjected for students to sit and give their attention to Julia. She said this did not change what she did or how she interacted with the students, but she appreciated the teacher's initiative.	• Julia, School 8, 5/11/04 *Snap, crackle, pop!* LD (lines 243–257) PL Interview (lines 169–174)
	• Gary talked about classroom management differences in museums and schools. He said students could not pick up an educator's management routines in 45 minutes, but sometimes teachers' used their routine to gather students' attention.	• Gary, School 4 , 5/28/04 *Snap, crackle, pop!* PL Interview (lines 298–307)

Table 15 *Continued*. Summary of findings and excerpts from *Taking Advantage of Others* section. (PL=Post-lesson; LD=Lesson Dialogue)

Classroom teachers as student managers (continued)	• Janet talked about the behavior of students in her classes and that the teachers did not have control over their students. She said students were having conversations during her lessons and were a challenge to get under control. She noted that this was a type of lesson that had occasions for talking but also time when the class came back together. • Gary talked about his own methods to manage the class, which he gained from student teaching. He said he did not normally rely on the teachers for classroom management and had his own phrase ("I need all eyes on me please") to gather students' attention. Rather than using management routines, Gary was explicit with his intentions. Sally switched lights on and off, waited for students to quiet, and then addressed them. • Sally talked about classroom rules regardless of setting during her initial interview. She said some rules were necessary in any classroom to prevent chaos and promote learning, and that she let students know she expected them to follow these rules.	• Janet, School 3, 2/24/04 *Adaptation advantages* PL Interview (lines 1–8) • Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 239–250) Sally Researcher field notes • Sally, Initial Interview, 10/24/03 (lines 45–52)
Educators preferred teachers attend to behavior management that endangered students' safety or disrupted the whole class' experience. Teachers had the management rapport and leverage to handle inappropriate student behavior.	I. Gary talked about the need for the teachers to handle students' behaviors that endangered others' safety. He said when students' behaviors risked safety or hindered the lesson, he addressed the students and hinted for the teachers to interject. • Gary responded to the teacher's involvement in resolving the students' conflict at the start of the activity. He said he appreciated the teacher taking the initiative to help the students form groups, although he wanted to give them the opportunity to resolve it themselves.	• Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 258–270) • Gary, School 3, 5/12/04 *Snap, crackle, pop!* PL Interview (lines 233–239)

Table 15 *Continued*. Summary of findings and excerpts from *Taking Advantage of Others* section. (PL=Post-lesson; LD=Lesson Dialogue)

Classroom teachers as student managers (continued)	• Julia admitted the presence of the teachers in her lesson did not affect what she did in her lessons, but the teachers' presence affected the students' behaviors.	• Julia, School 6, 4/21/04 *Snap, crackle, pop!* PL Interview (lines 378–381)
	• Janet continued to teach her lesson without pause or recognition of the teacher's behavior management activities in classes for all three schools. Dialogue for School 3 showed Janet continued her lesson without acknowledgement of teacher's interjection towards students' behaviors. Janet said she did not feel it was her job to discipline the students since she did not have the rapport or leverage to make a difference. Her role was to offer students the information and experiences.	• Janet, School 1, 2/11/4 *Forces in motion* Researcher field notes School 2, 2/13/04 *Simple machines* Class C LD (lines 281–296) School 3, 2/24/04 *Adaptation advantages* PL Interview (lines 10–45)
	• Gary talked about the influence of the teachers on the students' behaviors. He said it lessened his anxiety, especially at the beginning of class if they entered in a state of chaos and confusion. The teachers' attitude helped keep students on track.	• Gary School 2, 4/16/04 *Creepies & crawlies* PL Interview (lines 80–107)
Chaperone as activity helpers Chaperones were used as activity helpers in order to offer students more personal attention. Educators asked chaperones to join students during small group or participate in whole group demonstrations, when possible.	• Janet talked about the presence of the chaperones helping her attend to the students. She said chaperones help and encourage students with activities because she could not attend to every child.	• Janet, School 1, 2/11/04 *Forces in motion* PL Interview (lines 267–273)
	• Julia and Sally talked about how chaperones contributed to their lessons. Julia said chaperones challenged students and extended activities. Sally said chaperones offered students extra personal attention during lessons.	• Julia, School 8, 5/11/04 *Snap, crackle, pop!* PL Interview (lines 223–226) Sally, School 2, 2/12/04 *Simple machines* PL Interview (lines 123–129)

Section 3. Teaching Goals and Philosophies

Nurture Science and Learning

The educators' teaching goals and philosophies offered additional insights on their reasons for making changes in their lessons. Regardless of the reason that prompted a change in their lessons, upholding their goal made the change permissible. When asked about her personal goal for these one-time science lessons, Sally said,

> "I want them to just be interested in the topic. Some of them will take a whole lot of facts, some of them will take not much of what we say and do. If I can just get them interested enough so that they will want to go and find out more than they already know. Or to say, 'man that was really cool and next time something comes up about this subject I'm going to really be ready to find out more,' or that, 'I want to go find out more.' I just want to stir their interest and make them think that this is just so wonderful that they need to find out more somehow."
>
> Sally, Initial Interview, 24 Oct. 03, lines 239–245

While the information students retained or comprehended could vary, Sally wanted students to become interested in the subject matter so that they pursued the content on their own. Janet, Julia, and Gary echoed these sentiments during their initial interviews.

> "I just want people to go home and be like, 'Yeah and we had the best time at the museum. We took this class and it was about simple machines and we learned how to shoot the sponge man into the air using different fulcrum and levers, and all that kind of stuff. And to be able to go home and to relay positive experience to their parents and some information they may have learned. That makes the parents go you know, 'the museum is a good place,' and it makes it seem a little more educational than just going to the museum, 'we just played on the playground all day long.' "
>
> Janet, Initial Interview, 22 Oct. 03, lines 168–175

> "But mainly the program is to just get them pulled in, get them excited and if they already know something about science, to encourage them to go further with it. So yes the goal is multi-faceted once they walk in."
>
> Julia, Initial Interview, 14 Apr. 04, lines 119–125

> "In these classes, I mean the main goal is again to convey knowledge, to widen [students'] understanding of science, and also just to get them interested and excited about it. And hopefully even just have them come back so they can explore the museum on their own or with their family. And [develop an] interest maybe in other museums or just other institutions, that's part of it. And just trying to give every child …a positive experience with learning and with science. And a chance to succeed."
>
> Gary, Initial Interview, 14 Apr. 04, lines 100–105

These educators wanted to provide positive experiences in their lessons to incite interest in science among the students and encourage them to continue learning and perhaps even return to the museum on their own. The educators alluded to these sentiments when they talked about the rationale and justification of their changes in some of the examples excerpted and discussed above. The educators suggested that underlying their changes in the lessons was the need to maintain an overall experience, and that experience was to be positive and nurture interest in science and learning.

Content retention and comprehension was valued, but the educators' comments revealed the sentiment that it was not necessary for this to occur in their singular experience. Janet said,

> "The students will probably always remember that, 'I went to the museum and did this stuff.' They may not remember all the facts and figures or exactly what it was, but I think they will carry with them the idea that they got to go into this classroom and they got to do their own experiments at the science museum, that kind of stuff. But as far as like the actual technical knowledge, they'll probably remember a little bit but it's just things that have to be repeated. Whether they're in this classroom or in another classroom they just have to learn them over time. So it's just another way for different types of learners to maybe get a little bit more knowledge instead of just hearing it out of the teacher's mouth if they actually get to experience it here at the museum."
>
> Janet, Initial Interview, 22 Oct. 03, lines 323–331

Janet expected the positive experience from the lesson and its association to the museum to be retained. The details of the content were connected to the memories, but they needed to be revisited and reiterated over time. Julia's comment complemented Janet's thought. Julia said,

> “I kind of think of it like a chain link that when they come in they don’t quite have all the links together but hopefully by the time that they leave the room and they go back out and over a period of weeks or in that school year, those links will be added onto that chain and by the time they get to say high school or college, they’re ready to tackle more in science.”
> Julia, Initial Interview, 14 Apr. 04, lines 248–251

Julia perceived her lesson as one experience out of many others that the students have had and will have, and these experiences were connected and would made sense over time. Thus while their lessons were singular experiences, the educators did not perceive or strive towards making them isolated incidents in the students’ lives. Irrespective of the teachers’ intents, these educators used their lessons to create positive memories with science and learning so that over time, the students would pursue science and learning, and even return to the museum.

Goals and Philosophies Summary

To summarize, the goals for these short, one-time science lessons were similar among all four educators at the two museums in this study. These educators pointed out the purposes of their lessons were to offer students a positive experience with science and encourage them to pursue science on their own. Content retention and comprehension was appreciated, but not necessary. The educators recognized the singular nature of their lessons, and the need for that information to be reiterated and revisited over time. Table 16 summarizes the data referenced in this section.

Table 16. Summary of findings and excerpts from *Teaching Goals and Philosophies* section

Findings Summary	Evidence Summary	Evidence Referenced
Teaching goals and philosophies		
Educators wanted to provide positive experiences in their lessons to incite interest in science among the students and encourage them to continue learning and perhaps return to the museum on their own.	• Sally talked about her goal for these lessons. She said she wanted students to be interested in the topic and want to go and find out more on their own.	• Sally, Initial Interview, 10/24/03 (lines 239–245)
	• Janet talked about her goal for these lessons. She said she wanted students to return home and talk about what they did and learned at the museum, and that they had a good time. Then parents would have a positive impression of the museum.	• Janet, Initial Interview, 10/22/03 (lines 168–175)
	• Julia talked about her goal for these lessons. She said she wanted to get students excited and encouraged them to learn more about science.	• Julia, Initial Interview, 4/14/04 (lines 119–125)
	• Gary talked about his goal for these lessons. He said he wanted to convey knowledge, widen students' understanding of science, and get them interested and excited about science so that they continued to explore on their own and return to the museum.	• Gary, Initial Interview, 4/14/04 (lines 100–105)
Content retention and comprehension from these lessons were valued, but this did not occur in the singular experience of the lessons.	• Janet talked about what she expected students to remember and retain. She said students may not remember all the facts and technical information from the lessons, but they will remember the experience in the lessons at the museum. The contents of the lessons will need to be revisited and repeated over time.	• Janet, Initial Interview, 10/22/03 (lines 323–331)
	• Julia talked about the role of her lesson on students' learning. She said her lesson was one piece of the students' whole understanding that needed to be revisited over time.	• Julia, Initial Interview, 4/14/04 (lines 248–251)

CHAPTER V. DISCUSSION, IMPLICATIONS, & RECOMMENDATIONS

Introduction

This chapter is comprised of three sections. First, the Discussion section reviews the findings reported and highlights the connections alluded to in the previous chapter. Pulling together the results into five major findings, this section addresses the research questions, and relates them to what has been reported in the literature. Second, the Implications section explores how these findings might apply to school field trips and all those involved. And finally, the Recommendations section proposes actions for practitioners and research questions that emerge from this study.

Discussion

Adapting Instruction to Individual Classes

The first question asked how educators teaching one-time lessons in museums adapted their instruction to the students that they taught. Findings from lessons observed in this study suggested that educators adapted their instruction by manipulating elements in the lessons that were within their control and by taking advantage of others. The educators reported and were observed changing the details within their lessons, such as segments of their lessons and what the educators said. They changed in order to accommodate the classes of students while maintaining consistency in the objectives and procedures so that all students received similar experiences. They made changes in these details based on the roles and goals for the lessons that the educators defined.

These changes also relate to the sub-question of how perceived variability in entering student knowledge affect instruction. The educators modified the details within the lessons to suit their perceptions of students' knowledge and interests, which they determined through classroom assessments and comparisons with previous classes. They gained insight to anticipate students' abilities through repeating the same lesson plan to different grades and classes of students. The second sub-question queried how time limitations affected instruction. Findings from this study indicated time was a familiar challenge that became more arduous when classes were late. However, familiarity with the lessons enabled educators to make needed accommodations seamlessly and without stress. Educators changed details within the lessons and used the presence of classroom teachers and chaperones to maximize their allotted time. Findings related to Question 1 are organized into five statements and discussed further in the remainder of this section.

1. Repeating lessons compensate for one-time nature of lessons.

Learning is a multi-faceted process, unbounded by time and place (Anderson *et al.*, 2003; Rennie & Johnston, 2004). It is a building process that involves connecting new experiences with past thoughts and activities (Driver *et al.*, 1994; Piaget, 1983). Thus, consideration of student knowledge before, during, and after instruction is an important aspect of teaching. Determining student knowledge can be challenging for educators teaching one-time lessons in museums since their time with the students is limited and there are no opportunities for preparation or follow up, but educators admit this is a usual part of their teaching. They compensate for the one-time nature of their lessons by relying on insight and comfort gained from teaching hundreds of previous classes. Educators use student comments and behaviors from past classes to anticipate and plan for capabilities, reactions, and prior knowledge of students in current classes, based on their grade levels and responses even though there were no prior interactions with these students. Repeating the same lesson plan with different grades and groups of students also developed comfort with the lesson and content, and ways in which explanations and directions can be easily understood. Consequently, comfort with a lesson plan and insight into student knowledge and abilities helped educators ascertain student knowledge and respond promptly and efficiently to students they did not know.

Tran (2002) drew similar conclusions, even though the educators in her study were neither teaching the same lesson nor at the same museum. Findings from that study revealed that educators gained comfort in the lesson plan through repetition with different groups of students. They used the repetition to refine their instruction of a lesson and to compensate for their lack of rapport and familiarity with the students. Regular repetition also afforded opportunities to make changes due to problems and personal preferences in the lessons immediately without having to wait an entire school year. This present study supported those conclusions, and added that educators used what they learned from previous lessons to anticipate student knowledge, responses, and behavior in current and future lessons in order to customize their pre-planned lessons to the abilities and interests of the students.

The educators in this study were observant of students' behaviors and comments, which they used to determine students' understanding. This understanding informed the educators on their instruction, their revisions, and their pace. Unlike in schools, the educators did not use tests, projects, presentations, written work, or other such assignments to check students' comprehension of the lessons. Instead they relied on other classroom assessment strategies that were more appropriate to their setting and purpose (Graue, 1993). Classroom assessments predominantly relied on students' comments, questions, facial expressions, and body language. The educators paid attention to how and with what students responded to the contents and activities of their lessons, and made quick judgements based on those responses. The educators did not know the capabilities and interests specific to students in a class, but had an idea of what to expect based on the many other classes they taught at that grade.

The educators acknowledged this strategy was not foolproof. They admitted their assumptions were not always accurate and students' interests, states of mind, and personalities at that moment of the field trip could influence how they responded or behaved in a class that was not in their usual schoolroom with their usual teacher. Janet assumed students in her third *Simple machines* lesson (School 2) were familiar with the concepts due to students' performance in the previous two classes, but conceded that this was an incorrect assumption on her part (Table 10, p. 102). Gary, noticing students in School 4 *Snap, crackle, pop!* were more sluggish than expected, decided not to go into details about atoms (Table 13, p. 139). He pointed out this was perhaps the first time those students sat down after being in the museum for two hours. Despite the occasions for errors, the validity and reliability of the educators' judgements came from the thousands of students to whom they taught the same lesson year after year.

However, sometimes the educators' comfort and insight with the lessons reduced potential student involvement. Janet progressively reduced student involvement from her first to her third class during Demonstration 2 in School 2, and cited her growing familiarity with that segment of the lesson and preempting students offering suggestions not supported in her demonstration as her reasons for doing so. Gary addressed discrepancies in results for the rods and materials activity in School 1 *Snap, crackle, pop!* before students made comments because he learned from previous classes that students accused one another of experimenter errors (Table 10, p. 102). In both situations, the educators' familiarity with the lessons and anticipation of student comments influenced them to reduce the level of student involvement in their lessons. But as Sally pointed out in her situation, she did not feel the reduction took away from the students' overall experience in the lesson. The educators felt that a positive, memorable experience with science to nurture interest and pursuit of science and learning was the primary goal of all the lessons; reducing student involvement in one particular segment did not take away from this.

2. Details within science lessons can vary according to the students.

The educators in this study recognized the value of student knowledge and interest for their lessons from experience with thousands of students each year, and that their lessons needed to change to accommodate the students' needs. Literature on teaching in schools recommends assessment be integrated with instruction so that assessment results guide instruction (Gong *et al.*, 1992; Graue, 1993; National Research Council, 1996; Shepard, 2000). The findings in this study suggest that this was part of science lessons at these museums. The lesson plans were generic, but had to fit the needs of the individual groups of students in order to meet the educators' goals. As Bell and Cowie (2001) characterized, these educators used different sources of evidence (student comments, questions, and body language) within their control to determine student understanding. Since their time and knowledge of the students were limited, they relied heavily on their experiences to hone their instincts and professional knowledge of teaching and content matter. The judgements were quick and based on a surface level assessment of student interest and knowledge, but this reflected the level to which they modified their lessons and could be related to the goals of their lessons.

In response to their impressions of student knowledge and comprehension, the educators made changes to the details within their lessons. Changes occurred in lesson structure and content, which was part of the lesson design. All lessons were comprised of three types of segments (Talk, Demonstration, and Activity) with different ways for students to participate, and each lesson had a different combination of segments. The segments' objectives were consistent with the lesson topic, and their general procedures were maintained regardless of the educators or students. However, the lesson structure was flexible since educators could rearrange, omit, and change the length of each individual segment within a lesson (Table 12, p. 125). Segments were omitted or included based on the educators' judgement of students' abilities and prior knowledge. Segments were lengthened or shortened due to students' interests or comprehension. Least common was rearranging the order of segments because some segments build on previous segments. But for some lesson plans, educators could rearrange the order of the segments to delay a topic of discussion. Consequently, versatility of the segmented lessons depended on the design of the segments to be complementary and adaptable but also interchangeable and self-contained.

The details in lesson contents were also at the educators' discretion (Table 13, p.139). What the educators said and how they said it was flexible to the needs of the students by manipulating the depth and details of their discussion or level of student involvement. Educators went into more detail if students were interested or familiar with the contents of a discussion and thus offered more comments and questions. Educators went into more depth within a segment if students were older or demonstrated they understood the contents. Educators also involved the students in the dialogue, rather than telling them a list of information, if students showed interest, familiarity, or comprehension. The educators ascertained students' interests and comprehension of the lessons from the way students responded (body language such as eagerness to ask and answer questions, willingness to share, or looks of perplexity) and with what they responded (answers, comments, and questions).

Consequently, the educators were sensitive to the similarities among groups of students and fit these similarities into their pre-determined lessons, while at the same time remained mindful of the differences. Differences occurred in regards to the students' knowledge, interest, and comprehension prior to and during the lessons. They gathered information about the students based on verbal and non-verbal responses to the discussions and activities within the lessons. While these educators made changes to their teaching based on student understanding in the lessons observed in this study, these changes were minor and students were not offered opportunities for self-assessment. The minor changes could be due to negligible differences between the classes of students prior to the lessons. Unfortunately data on student interest and understanding were not collected for this study. Despite the potential value of self-assessment to help students grasp what they were learning and their level of achievement (Black & Wiliam, 1998b), this was perhaps not possible since time in the lessons was limited. Nonetheless, these educators acknowledged the need to consider students' abilities and interests, and made changes accordingly. They used assessments that suited students' needs, which emerged from practice rather than training since none of these educators received formal preparation for teaching in museums (Table 4, p.61). Attention to these differences customized the pre-determined lessons to the needs of each class, and suggested that it was possible for instruction to change based on class needs despite the generic nature of these lessons. Changes made were manipulations of elements in the lesson plan, not the lesson plan as a whole.

This also suggested that these educators were perceptive to the students' levels of preparedness. Student responses and behaviors could reveal whether the field trip or subject matter was discussed in school. The literature suggests that preparation about the field trip location and subject matter prior to field trips contributed to student learning (Anderson & Lucas, 1997; Falk *et al.*, 1978; Kubota & Olstad, 1991; Orion & Hofstein, 1994; Rix & McSorley, 1999). While this current study did not examine student learning, findings suggest that educators were attentive to students' preparedness and modified their lessons accordingly. Preparing students prior to field trips could help the students' anxiety levels and participation during the museum lessons, which could influence their behaviors and what they gained from the lessons. Clearly, the educators were adaptable to the students.

More attention should perhaps be paid to post-visit activities and discussions. These science lessons were singular experiences for the students despite the educators' desires otherwise. The educators endeavored to adapt their lessons to the students, but were unable to follow up on their lessons after the students left. If the classroom teacher did not make time to follow up on the lessons or field trips either, then the students were left to make sense of the experiences on their own time and in their own way. Anderson *et al.* (2000) reported that post-visit activities were crucial for students to develop their understanding and incorporate their field trip experience. Thus teachers should allocate time back at school to review the field trip and museum lesson in order to take full advantage of the experiences from these lessons.

3. Educators' roles and goals are the foundation for their choices.

These educators viewed the primary goals of their short, one-time lessons as promoting interest in science and learning so that students, parents, and teachers were encouraged to pursue science, experience learning in a casual and non-judgmental setting, and return to the museum in the future. Though conceptual gains were valued, they recognized the challenge due to the ephemeral nature of their lessons. Instead they aimed towards affective gains and lifelong learning. The fourth grade field trip to the museum was available only in one time period of a person's life, but the museum was accessible well beyond school and childhood. These educators used their lessons to spark interest in the students to pursue learning and return to the museum, and this ultimately formed the foundation of their choices.

Whether the initial thought to modify their lesson was prompted by time, the students, or the educators' own judgements, the final decision was driven by a desire to maintain an overall positive experience for the students. This correlated with the perceived educator role as provider of positive and memorable experiences to nurture that goal. These educators believed they nurtured interest in science and learning through the positive and memorable experiences they provided and their actions, attitudes, and comments during the lessons. The educators' goals and perceived roles coincided partially with sentiments of the educators in Tran (2002) and supported the contention that learning extended beyond the physical walls of the learning environment and the temporal boundaries of the learning experience (Anderson *et al.*, 2003; Anderson *et al.*, 2000; Rennie & Johnston, 2004). Similar to the four educators in this study, the eight educators studied by Tran (2002) reported nurturing interest in science as a primary goal for their lessons. They used the activities in their lessons to promote confidence and interest in doing science and create positive memories for science. Since the educators' teaching perspectives reside in a learning environment accessible to learners well beyond school, they strive towards a goal that extends past school and the single field trip experience.

The thoughts and rationales of the educators in this study suggest they invest in a lifelong learning perspective. Wollins *et al*. (1992) and Anderson *et al.* (2002) report that these lessons are prominent in students' memories, thus offering support to the educators' intentions. Learning is unbounded by time, place, or social context (Anderson *et al.*, 2003) and extends beyond meaning making and conceptual change (Schauble, 1996). Instead these educators take advantage of the attention and curiosity their novel lessons incite (Carson *et al.*, 2001; Koran *et al.*, 1984; Phaf & Wolters, 1993) to develop motivation and interest in science and learning. This investment through affective means is intended to pay off in the future as students return on their own and pursue science for intrinsic reasons.

4. Refine teaching to use time efficiently.

Time was a familiar challenge because 45 or 50 minutes per science lesson were allotted to this type of school program at these museums. The program's format (using the same lesson plan for different groups of students) enabled educators to hone their skills in order to maximize instructional time and make the activities and contents flow seamlessly and without stress, regardless of changes within the lessons. Instruction began once all the students arrived and were seated. Unlike reports on time use in school (Honzay, 1986-87; Karweit, 1985), these educators used most (if not more) of their allocated time for instruction and offered opportunities for students to engage in learning activities during that time. There was no need for taking attendance, collecting homework, or carrying out classroom chores that consumed valuable teaching time in schools. Segments in each lesson flowed from one to the other without dead time.

Students were dismissed once the last segment was completed. While the educators appreciated more time, they felt that there was sufficient time to complete their lessons as long as students were not tardy.

On occasions when there was potential for dead time, the educators addressed them the next time they taught the lesson. For example, Sally said she decided to teach her *Adaptation advantages* lessons (School 3) in the order the lesson was originally written so that the live animal was discussed and shown to the students before the last activity. She admitted experimenting with the order since she was not constrained by time or student knowledge, but did not like this order of events. She alluded to the presence of dead time as her reason for not liking this order. She said,

> "…because there's nothing to do. You're just sitting there waiting. You've either already touched it and you're talking about that. That's not too bad. Or you're sitting there waiting for the person to come so you can touch it and you're not doing anything else. And it's not unreasonable that you would want to talk to your neighbor. I might go back to doing it the other way but I wanted to try it like it was written."
>
> Sally, School 3 Post-lesson Interview, 25 Feb. 04, lines 134–169

Sally noticed that students had to sit and wait their turn to touch and see the animal up close, and thus their desire to talk amongst themselves was not unreasonable. She was bothered by this dead time, and would switch the order so the animal was introduced at the end and students touched it as they exited the room, which eliminated the perceived dead time.

Other factors that used up precious instructional time, such as classroom management, disciplinary activities, instructional techniques, and student attention (Aronson *et al.*, 1999; Metzker, 2003) were addressed through the lessons' novelty to the students but familiarity to the educators. Student attentions were lured through the novelty of the setting, lesson materials, and activities (Carson *et al.*, 2001; Koran *et al.*, 1984; Phaf & Wolters, 1993). Repeating the same lesson plan with different groups of students allowed educators to refine instructional techniques down to the explanations, directions, and transitions specific to that particular lesson. These educators used their own strategies to manage the classes, and were conscious of segments within the lessons that required more attention than others. Furthermore, they took advantage of the teachers' and chaperones' presence to make efficient and effective use of the limited time. Teachers were used as timekeepers and student managers, and chaperones were assigned the role of activity helpers. Meanwhile, the educators manipulated the lessons with the same strategies described above for student knowledge and interests to accommodate time constraints.

5. Designate roles to teachers and chaperones to maximize time.

There was value in preparing teachers to plan and conduct field trips (Chesebrough, 1994; Olson *et al.*, 2001; Smith *et al.*, 1998). The literature suggested teachers conduct activities prior to the field trips to prepare students mentally and emotionally (Anderson & Lucas, 1997; Kubota & Olstad, 1991). Also, planned activities during the field trips occupied and engaged students (Griffin & Symington, 1997), while activities after the field trips helped students process, understand, and incorporate their experiences (Anderson *et al.*, 2003; Anderson *et al.*, 2000). Findings from this study suggested that in addition to planning and conducting field trips, teachers should also be aware of their roles and responsibilities during the field trips. Roles for teachers and chaperones emerged from the educators' reflections of their lessons.

These educators alluded to using teachers as timekeepers, which offered educators some flexibility with time. Educators received verbal and non-verbal cues from teachers regarding how much time they had remaining in their lessons and whether it was permissible to extend the lesson a few minutes beyond the allotted 45 or 50 minutes. Time became an obstacle on occasions when students were late, and the timekeeper role became even more valuable. On these instances, the educators were challenged with shortening the lessons without taking from the overall experience, and knowing the amount of time they had helped them decide on the needed changes irrespective of the students. The teachers who were 15 minutes late (School 1 *Forces in motion*) informed Sally the time they had to leave when they arrived at her classroom. Sally estimated her lessons would be approximately 30 (for Class B) or 40 (for Class A) minutes, and then adjusted her lessons accordingly. The museum's program schedule could also affect the flexibility of time because it was not possible for consecutively scheduled classes to extend far beyond the allotted time without impacting subsequent lessons. In this study, consecutive lessons at NC Museum and MD Museum did not extend more than two minutes beyond the allotted 45 or 50 minutes, while lessons that exceeded the limit more than two minutes did not have another class immediately following. Those extra minutes in either situation are not likely if the teachers insist upon leaving on time. Furthermore, teachers' management rapport with their students affected time.

The task of managing the students varied from group to group, and classroom teachers sometimes aided the task. These educators used their own methods to manage the classes and relied on their knowledge of the lessons to anticipate student reactions to parts of their lessons. Gary commented,

> "I try not to rely on the classroom teacher too much for behavior management and normally I feel that I have generally good control of the class. Like just saying things like you know, 'I need eyes on me right now'."
>
> Gary, School 3 Post-lesson Interview, 12 May 04, lines 239–250

However, they appreciated occasions when the teachers took the initiative to address their classes, which usually occurred when the educators needed to gather the whole class' attention. In response to the teacher's interjections to call students' attention in School 8, Julia remarked,

> "I was actually glad she was [there] because she knows her students better than I do. …it didn't really affect how I interacted with them. It was just a relief because…by the end of this program you're going to lose your voice from talking so much and talking so loud and having to yell to get their attention."
>
> Julia, School 8 Post-lesson Interview, 11 May 04, lines 169–174

The teacher's interjections did not affect what the educators did in the lessons or how they interacted with the students, but saved them from having to call the students together and wait for students' attention.

The educators were perceptive of the teachers' relationships and influence over their classes, and expected them to intercede for individual behavior problems that endangered students' safety or impeded the experiences for everyone else. The educators did not feel they had the management rapport or leverage with the students to be effective. This sentiment was captured in Janet's comment,

> "My job isn't to discipline the children; that should be their teacher…because you know what's it going to matter to the kid if I say you know, 'go sit in the corner. You're going to have [to talk to] your parents,'...I can't call the child's parents. They know I don't have that control over them."
>
> Janet, School 3 Post-lesson Interview, 24 Feb. 04, lines 10–45

There was no time or need to establish this relationship since their time together was limited to 45 or 50 minutes. In this situation for School 3, Janet attributed her struggle in managing the classes to the teachers' lack of control over their students. After commenting that he was confident in his class management skills, Gary commented, "the only time that I would feel that I definitely need support from the teacher is if a student does something that just puts themselves or others at risk" (Gary, School 3 Post-lesson Interview, 12 May 04, lines 258–270). Despite his self-assurance in managing the class as a whole, Gary preferred that the teachers intervene on occasions that required individual attention. While the teachers' presence did not affect the educators or the lessons, the educators acknowledged that the teachers' presence affected the students' behavior. These educators assigned classroom teachers the role of student manager and expected them to interject when students' behavior negatively affected the overall experience for the whole class.

Consequently, these educators are attentive to the classroom climate teachers establish in schools and try to make use of them in their classes at the museum. Classroom climate is a psychological and social atmosphere that develops over time as members in a class get to know one another, work together, and share experiences (Penick & Bonstetter, 1993). It is a dynamic relationship among the students and teacher within their learning environment that is not confined within the physical boundaries of the classroom at school (Moos, 1991). The groups of students participate in these museum science lessons with their learning atmosphere from school already intact since they attend the lessons as classes on a field trip. As a one-time visitor to these classes, the educators have little impact on the climate between the teacher and her students. However, the educators can use the classroom climate to help their classes flow and make efficient use of their limited time. Rather than having to acquaint students with one another or classroom rules, the educators conform to the students. For example, students are allowed to form their own groups, while teachers are free to make changes to these groups as they see fit. Educators manage the classes as best they can, and the ease of this management is a reflection of the rules, order, and organization to which the students are accustomed in their classroom at school. And finally, teachers are relegated behavior management responsibilities when students require more personal attention since educators do not have the relationship or leverage to do so.

In the meantime, chaperones were called upon to take up roles during the educators' lessons. Chaperones helped to offer students personal attention during these lessons. They worked with students during small group activities while the educators wandered from group to group. They also participated in whole class demonstrations when possible. This involvement gave chaperones opportunities to interact with students that were not common in schools, and possibly mimicked family group interactions (Parsons & Muhs, 1994). It was unclear from observations in this study whether chaperones were given instructions on how to interact with the students, but educators acknowledged the value of their participation. These educators reported that the chaperones encouraged and challenged the students in the activities. Chaperones personalized these generic lessons to the specific classes as they helped students make sense of the activities and make connections with specific events in the students' lives.

These designations for the chaperones and teachers arise from use and necessity, but are not formally assigned. Chaperones were encouraged to join the students during small group activities or participate in whole class demonstrations when possible, but this was not required. The chaperones usually joined the groups when asked, but they were not instructed by the educators on how to help the students during the activity. Unless the chaperones received instructions from the classroom teachers prior to the lessons, it was assumed the chaperones know what to do and how to do it. Furthermore, teachers were not informed of their roles. These educators thank the teachers for interjecting or continue their lesson without acknowledging the teachers' management actions, but on no occasions were the teachers asked to manage their class' or individual students' behaviors.

Implications

Findings from this study have implications for teaching professionals, administrators, and researchers in museums and schools.

Make Connections between Schools and Field Trips Explicit

This study suggests that museum educators teach with a lifelong learning perspective and that this is influenced by the nature of the learning environment in which they teach. Their science lessons are brief, singular experiences situated in settings that are supposed to be accessible throughout the students' lifetimes. While initial time with students is limited, opportunities for revisiting are not. Educators value cognitive gains, but recognize they may not be attainable in a one-time lesson, nor are the educators held accountable. Thus the lessons are used as investments and primers for future visits and pursuits of science and learning driven by intrinsically motivated reasons.

Since there are no interactions with students after the lessons, educators leave it up to intangible "hope" that teachers either follow up on the field trip or their lessons intrigue the students enough to want to come back in pursuit of more information, understanding, or experiences. While it was not directly asked, it was the researcher's impressions and experiences that teachers and educators did not usually communicate prior to or after the lessons, thus contributing to the isolation inherent in these lessons. Post-visit activity suggestions to continue the concepts is one common attempt to bridge the gap, but studies suggest few teachers implement activities that synthesize or integrate the field trip experiences when back in the classroom (Anderson & Zhang, 2003; Kisiel, 2003; Storksdieck, 2001).

Anderson and Zhang (2003) and Kisiel (2003) explore teachers' motivations and purposes for planning and implementing field trips to science museums. They report that while curriculum fit is the primary reason that teachers (in Vancouver, Canada and Los Angeles, California, respectively) plan and implement field trips, few help students process and integrate the experiences when they return to the classroom. Storksdieck (2001) examined teachers' and students' reflections of field trip experiences, and found most students did not perceive any post-field trip follow up activities and few teachers reported integrating the field trips into their classroom curriculum. Besides potential challenges due to school agendas and time, perhaps teachers do not know how to interpret and integrate the experiences. With respect to the one-time science lessons in this study, teachers are left to interpret the activities, the intended goals and objectives, and determine student gains for lessons they did not write. This can be particularly daunting for teachers who are already reluctant to teach science or not confident in their science knowledge. Consequently, teachers may be less likely to help students integrate and process the lessons when they return to the classroom.

The lack of appropriate follow-ups by teachers or conceding to intangible hope by educators has potential cognitive and discriminatory consequences. First, the possible gains from these one-time lessons (and even field trip experiences overall) are limited to the abilities and self-motivation of the students. While these are not impossible for students to attain on their own, classroom science education literature suggests this can be challenging and can lead to alternative conceptions. Second, there are also socio-economically and developmentally discriminatory consequences. Teachers' actions (or lack there of) and educators' concessions potentially discriminate against those students who lack the intellectual abilities to make connections on their own or those without the intellectual support structure outside of school, such as tutors, educated and English speaking parents, and access to resources at home. There is potential economic discrimination against those who cannot afford to return to the museum in the near or distant future that can be attributed to cost of admission and transportation and access to and awareness of transportation means. Finally, there is potential discrimination against the social abilities of those who do not have people in their lives to bring them back irrespective of money.

In addition, teachers' lack of follow-up and educators' assumptions raise questions regarding the merit of these science lessons and the funds museums and schools invest in their upkeep and operation. Monetary information for the costs and revenue generated from these one-time lessons was not obtained from the two museums or participating schools in this study. Financial and human resources invested to make them available and usable to teachers suggest schools and museums perceive value in these one-time lessons. However, the return on these investments is unclear. If teachers and educators persist with their current behaviors and perceptions of field trips, then the return is likely not as "profitable" as it could and should be. "Profit" used in this context refers to the intended cognitive and affective gains for students and teachers, not monetary acquisitions. Thus, there is a need to make an explicit connection between these science lessons and the classroom curriculum. Teachers' lack of follow up and educators simply hoping students are intrigued and inspired by their lessons to return in the future is perhaps not enough.

Educator Education as a Task for Teacher Educators

Teaching in museums requires flexibility, breadth and depth of content and pedagogy knowledge, and approachable personalities. The educators' reflections of their teaching from the lessons observed in this study suggest the need to remain flexible with respect to student interests and abilities, available time, and educators' professional abilities and judgement. Changes can occur unexpectedly and the educators need to be ready and able to address them seamlessly and without stress. They should also have a breadth and depth of knowledge pertaining to the content and pedagogical knowledge of the subject matters that they teach. Students can participate in these lessons with a broad range of knowledge and abilities since each lesson targets multiple grade levels, and there are lessons available to pre-k-8th grades. In addition, the educators' personalities ought to be approachable and adaptable. The educators are visitors to a class with a psycho-social learning atmosphere already intact. Thus they need to be personable enough for students to respond to while adaptable to the details that characterize the class.

These needs are addressed in part through the flexible design of these science lessons and the continued repetition of the lesson plans to different groups and ages of students. Educators learn to customize their generic lesson plans to the interests and abilities of the classes in order to meet their goals. However, the customization regards the class as the unit of instruction rather than each student since time with students is limited. The task of adapting to individual students is entrusted to the classroom teachers when they return to school. Breadth and depth of content and pedagogical knowledge, however, is not addressed.

These educators potentially teach science lessons in biology, physics, chemistry, geology, and other disciplines to students from pre-k-8th grades. With less than one hour to do this, they hope to be successful at least in stimulating student interests in science and learning. Of the four educators in this study, two received elementary teaching certifications and a third was currently pursuing it, but only one taught in schools. Two received undergraduate degrees in the biological sciences, while informal conversations with the other two educators suggested that they learned science content from their teaching positions at the museums. As with the eight educators in a previous study (Tran, 2002), these educators learned to teach from practical experience as educators in museums. Assessment and instruction skills emerged from mimicry of veteran educators, practice, and necessity. These skills reflect some contentions proposed in the literature, such as classroom assessment to inform instruction, changing instruction to meet the students' abilities, and engaging students in physical activities.

However, the educators can also benefit from instruction on how to teach. Regarding teaching as a profession and educators in museums as teaching professionals, it may be appropriate to make available science teaching education to address their pedagogical needs. . Science teaching education for educators in science museums is not currently addressed in schools of education, and can be a task for teacher educators. While there are teaching elements that may be unsuitable for instruction in museums, such as summative assessments and establishing classroom climate, there are teaching elements that are applicable, as suggested in this study. Modifications are perhaps necessary to make them relevant to teaching in a museum environment. However, exploration and reflections of these adaptations and accommodations by those intending to teach in museums and schools can be mutually beneficial, and possibly a way for each to understand and be aware of the others roles, interests, and goals.

Field Trip Education for Teachers should be More Than Just Preparing

Emerging from the educators' thoughts and actions is the proposition that roles are not formally defined or designated for teachers and educators so that each knows what is expected of the other. The museum educators define roles of timekeeper and student manager for classroom teachers, but these designations are not made known to teachers or chaperones. Meanwhile, these educators define their roles as providing of memorable experiences and information in order to nurture lifelong interest in science and learning. The educators teach within these parameters, and for the most part, it appears this works.

The student manager and timekeeper roles designated to classroom teachers suggest that educators are attentive to teachers' relationships with their students and, when possible, use these relationships to help them with their lessons. These teacher-student relationships refer to classroom climate; the learning atmospheres between teachers and their classes of students, which persist beyond the walls of their classrooms (Moos, 1991). They are perhaps challenged when on field trips because the settings are different and the potentials for novel stimuli are ubiquitous. The teachers' watchful eyes cannot be everywhere, and thus teachers need to rely on the rapport and relationships established in their classrooms to persist and maintain order at the museums. These established learning atmospheres help the flow of these one-time lessons.

However, there are occasions when teachers do not assume these unspoken roles, as evidenced above when educators struggled with managing the class and the teachers did not interject. It is not clear from this study whether teachers are aware of this role expected of them, but some take the initiative and maintain control of their class. The literature focuses on preparing teachers to plan and execute field trips (Chesebrough, 1994; Olson *et al.*, 2001; Smith *et al.*, 1998) and what they should do with students before, during, and after the field trip experiences (Anderson & Lucas, 1997; Anderson *et al.*, 2000; Kubota & Olstad, 1991; Orion & Hofstein, 1994). It is perhaps assumed that teachers know and maintain their roles and responsibilities during field trips, but this study suggests that this may not always be the case.

Failure to recognize their roles and responsibilities is possibly the reason some teachers do not interject when needed. It can also be the reason some teachers appear to the educators to be disruptive. Disruptive teacher behaviors were not observed in this study, but informal discussions with the educators before and after data collection suggested that teachers sometimes carried on private conversations with chaperones. The researcher's experiences and observations of other science lessons in other museums support these comments. Synthesis of these educators' reflections suggest that perhaps the teachers' disagreeable behaviors is attributed to their lack of awareness of their roles and responsibilities in these science lessons. Teachers are accustomed to leading the class. In these lessons at the museums, they do not lead the lessons, do not have other tasks from their classroom to occupy them, and may not want to overstep the educators' authority.

For the most part, educators in this study admit that they do not rely on the teachers to manage the classes. However, there are occasions when the teachers' interjections are appreciated and needed. It appears that clarifying roles among the teachers and educators can be a way to coordinate everyone's actions towards their intended goals. There may be other roles appropriate for teachers and educators that did not emerge from this study but can further enhance and extend their usefulness for schools and museums.

Recommendations

This study extends the findings from a previous investigation (Tran, 2002) and contributes to the field trip literature from the perspective of museum educators. However, as with most research, this investigation leads to more questions than it answers. The following are thoughts on actions for practitioners and research questions that emerged during the process of collecting, analyzing, and synthesizing this investigation.

Actions for Practitioners

- *Assessment as a valuable tool for teachers*. Although the lesson plans were generic, the educators attempted to customize them to the needs of the students. Classroom teachers can use this to their advantage, regardless of how they intend to use the lessons. As an introduction, students' performance can reveal prior knowledge and understanding of the concepts. As a culmination or supplement to ongoing classroom curriculum, students' comprehension and application of the concepts can be assessed. Educators can aid this endeavor by offering teachers a copy of the lesson plans with the lessons' objectives, activities, and potential assessment rubric. These materials offer tangible objects from the lessons for teachers to use in their curriculum planning, and thus potentially assist teachers in helping students understand and integrate the one-time science lessons after the field trip.
- *Define and designate roles to teachers, chaperones, students, and educators*. Field trip literature and practitioners recognize the value of pre-determined agendas with objectives and activities, as well as the importance for those agendas to be

shared and understood by all participants of the field trip. Likewise, there is potential value in defining and designating roles for all participants of the field trip and making that known to everyone. This is particularly valuable for the teaching professionals so that each knows what is expected of the other. Educators perceive their role as providers of information and experiences, and designate teachers as timekeepers and student managers. It is unclear whether teachers are aware of these designations. Some teachers take the initiative and assume this role instinctively while others do not.

- *Teaching methods and classroom management for educators*.

  These educators teach thousands of students every year. With so little time (especially compared to classroom teachers) to make their point and attempt to achieve their goals, their teaching, assessment, and management strategies need to be versatile, concise, and effective. They refine their methods through repetition of the same lesson plan, but this is limited to the educators' abilities. Just as professional development and continued education is valuable to classroom teachers' teaching abilities, educators also require similar professional guidance specific to their teaching and learning environment. Of potential value to educators in museum are the skills of asking questions to encourage thought and making quick and accurate assessments.

Research Questions

- *How do the teachers' and educators' goals compare?*

  Classroom teachers were not interviewed in this study. Their presence and actions were interpreted through the researcher's field notes and the educators' memories and perceptions. This study suggested educators teach towards interest and motivation for lifelong pursuit of science and learning. How does this goal compare to what classroom teachers have in mind for these science lessons or field trips as a whole? Their goals do not have to be the same, but awareness of one another's intentions and how to address them provide a greater chance of either being achieved. Also, comparing teachers' and educators' goals for these lessons can offer insight into the strengths and weaknesses of these science lessons and provide evidence for museum educators to make informed decisions regarding how they teach and develop these lessons.

- *What do students gain from museum science lessons?*

  Despite the educators' resolve that cognitive gains are valued but not the priority, questions remain about what students gain from these museum science lessons. Museums and schools invest monetary and human resources to develop, maintain, and participate in these lessons, and endeavor to make them useful and appealing to students and teachers. Teachers view them as potentially valuable since they participate in them. But what do students get out of these lessons? What learning takes place? How successful are the educators' attempts toward lifelong learning investments?

- *How do classroom teachers use museum science lessons as assessment tools?*

  This is an exploratory question intended to gather information regarding the way teachers use these science lessons, teachers' perception of the purpose of these lessons, and whether they consider them as possible assessment tools. It inquires anecdotal comments from educators regarding what teachers do with these lessons, and explores the value of these museum science lessons.

- *How are museum science lessons designed to be used as assessment tools? How effective are museum science lessons with clear, measurable objectives when used as assessment tools?*

  This question introduces the significance of having lessons with clear, measurable objectives coupled with authentic objects to which teachers usually do not have access, and thus makes museum science lessons unique and valuable. Correlating the lessons to national standards further strengthens their value. The second question examines the effectiveness of such lesson designs as assessment tools, and explores what teachers, educators and students can potentially gain from this information. They ponder the value of short, one-time lessons at museums and the potential to make them more than singular experiences. If educators take the effort to customize their lessons to the groups of students and teachers are cognizant of this endeavor, can teachers make use of the lesson in such a way that extends the lessons beyond the field trip? How can this be done?

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APPENDICES

Appendix A. Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Teaching science in museums
Principal Investigator: Lynn Uyen Tran   Faculty Sponsor: John E. Penick

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We are asking you to participate in a research study. The purpose of this study is an exploration of the "educator factor" in learning science at informal settings. The study investigates what classroom teachers learn from and how they use one-hour classes offered at informal science settings, and how educators at informal settings can influence this.

INFORMATION
If you agree to participate in this study, you will be asked to:
- Allow the PI to observe and videotape you teach at least three one-hour lessons at your institution (time commitment: duration of lessons);
- Take part in an interview to discuss your teaching goals, beliefs, and background (time commitment: ~45 minutes);
- Engage in informal discussions about the PI's descriptions of your teaching based on observations and interview (time commitment: ~30 minutes);

RISKS
There are no foreseen risks for participating in this study.

BENEFITS
There are no direct benefits to you for participating in this study. However, your participation will greatly contribute to the understanding of learning from science experiences at informal settings.

CONFIDENTIALITY
The information in the study records will be kept strictly confidential. Data will be stored securely in a locked room in the PI's home. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION
There is no compensation for your participation in this study at this time, except for my utmost gratitude.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Lynn Tran, at ophiuroids@yahoo.com, (919) 413-2779, or Dept. Math, Science, & Technology Education, Box 7801, NCSU Campus. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature____ Date _________________
Investigator's signature___________________________________ Date _________________

Appendix B. Initial Interview Protocol

What is your science background?

What is your teaching background?

- How long have you been teaching at the museum?
- What other teaching have you done?
- What kind of preparation/training did you receive in order to teach this and other programs like this?

What is your personal goal for these lessons?

- What are you trying to communicate when you teach these lessons?
- How successful do you think you are at achieving your goal?
- How does your goal compare with the museum's goal?

What effect do you think these programs have on students?

- What effect do you as the educator with whom these students interact have on their learning experience?
- How do you think your teaching approach effect the students and their experience?
- What do you think are appropriate or ideal teaching approaches for these types of lessons?
- How do you want to effect the students?

Appendix C. Post-lesson Interview Protocol

Were the students knowledgeable of the content?
    How can you tell?
    Did this affect your teaching? Elaborate.

Did time affect your teaching?

Did the classroom teacher affect your lesson?

Was there anything in this lesson that had an affect on what you said and did? Please elaborate.

NC MUSEUM ONLY. How did the students in the two classes compare in terms of knowledge?
    How can you tell?
    Did this affect your teaching? Elaborate.

MD MUSEUM ONLY. How did the way you taught this lesson compare to other times you've taught this lesson? Elaborate.)

Appendix D. Interview Unit of Analysis

Unit of analysis for interview data is a complete thought, whether initiated by researcher or educator. There are two examples listed below. Educators were responding to the researcher's questions and their thoughts changed as they talked. Thus two separate interview units were clipped per educators' response. The second unit is in *red italics.*

Gary, School 1 Post-lesson Interview, 14 Apr. 04, lines 156-167
Researcher, "What was the purpose of the discussion?" (referring to discussion immediately following the rods and materials activity)

Gary, "Just give them a sense of different materials that are going to make static electricity. And it's not so much the chart but it's moving on after that, talking about how atoms rub together, saying that all these materials are made of atoms but depending on how they're made up when we rub them together is going to determine whether or not we're going to get a charge. *And depending on the group, sometimes if they're older we do go into more detail but I didn't necessarily get the feeling that they had a strong understanding of atoms from the group because when I mentioned charges only two or three of them seemed to understand. And breaking down the parts of the atoms, I felt it may have been beneficial but I wasn't too sure if that's where I wanted to go with it right then of here's a neutron, an electron. When these electrons rub together, sometimes one comes off and it goes over here. And that's why I kept it a little bit simpler of sometimes when you rub atoms together, they lose different pieces and when that happens, they become charged. Then going into the whole structure of an atom.*"

Julia, School 6 Post-lesson Interview, 21 Apr. 04, lines 11-20
Researcher, "How was the knowledge level for this class?"

Julia, "I would say average to medium, maybe a little less than the average on some things. I think probably they had more trouble following directions and just keeping quiet. So my interpretation would be off a little bit on that. I noticed I did have to keep correcting some of them on how they were doing the experiments and things that I know I said as directions they weren't following through so I think some of it is just the age level and maturity level too in following directions. *There were also a few, just about a few too many of them. I was scheduled for fewer kids and that I think when they broke up into groups probably Jordan got the smaller group and I got the larger so that adds to the confusion sometimes."*

Appendix E. Observation Unit of Analysis

Unit of analysis for observation data is a segment in the lesson. This is an excerpt from Gary School 4, Observation 4 *Snap, crackle, pop!*, on 28 May 2004. The excerpt shows the start for Talk 1 (*in red italics*) and Activity 1 (in blue), and the transition between the two. Bold text marks the start of a unit with time lapsed in minutes and total minutes for that unit in parentheses. There is no minutes lapsed for Talk 1 because this is the start of the lesson.

TALK 1. (3 mins)

Educator, "Is this the whole entire class? Good afternoon and welcome to the Science Center. I hope everyone is really enjoying themselves. It's a brand new science center. You're actually the first visitors we've had. So today is actually our grand opening. I hope you've had fun exploring. Today we're going to do a program called Snap, Crackle and Pop. Any idea what this might be about? Any ideas?"

Student, "Electricity?"

Educator, "Excellent, electricity. It's a certain type of electricity though. Not the electricity that comes out of the wall outlet but another type. You make this type of electricity by rubbing your feet on carpet. What do you think this might be? What do you think?"

Student, "Static electricity."

… (time lapsed)

Educator, "Actually that's static also. If you're close to a television or computer monitor, your hair gets sucked towards it. Also if you wave your hands in front of those, you hear the snaps, crackles and pops. Good, all of that is static electricity. Well also, I don't know if you've ever gotten your clothes out of the dryer and like your socks are stuck to your shirt and everything's all stuck together. That's static electricity. That's what's keeping everything in place, the static. **ACTIVITY 1. -- 3:05 – (14 mins)** Well that's what we're working with here today is static electricity. And we're going to do a few experiments here. What we're going to do is we have three different rods. We have a plastic rod, a glass rod and a rubber rod. We're going to rub three different materials on the rods. Silk, wool and mylar to generate static electricity. Now to do this experiment though, we need to be in groups of three. I'm going to let you pick your own groups and if you can do that now, once you do that if you have a group if you can just spread out just a little bit. And if we end up with a group of two, that's ok. Alright, what I'm going to do…..Does everyone have a group? Or at least have a partner. I'm going to give out the supply boxes. Please don't go through the boxes. We'll go through them just as a group to make sure everyone has the right supplies and we know what we're using."

Student, "We're going to have four."

Teacher, "Why don't you do two and two?'

Appendix F. Domains

Domains are categories organized around relationships that can be expressed semantically (Hatch, 2002, p. 165).

Strict inclusion	X is a kind of Y	A secretary is a kind of non-certified school worker.
Spatial	X is a place in Y	The teachers' lounge is a place in school where students are not allowed.
Cause-effect	X is a result of Y	Larger class sizes are a result of not passing the tax increase.
Rationale	X is a reason for doing Y	Helping children manage their behavior is a reason for prescribing Ritalin.
Locations for action	X is a place for doing Y	The bar at the Holiday Inn is a place for teachers to get together away from school.
Function	X is used for Y	School newsletters are used to communicate with parents.
Means-end	X is a way to do Y	In-school suspension is a way to hold students accountable.
Sequence	X is a step in Y	An interview with the principal is a step in getting a teaching job.
Attribution	X is a characteristic of Y	Curiosity is a characteristic of gifted students.

Appendix G. Analysis Round 1 Outline

Initial Interview

I. Reasons for teaching lessons
  A. Encourage students and parents to return to museum
  B. Promote interest in science and learning for teachers and students
  C. Create positive memories
  D. Help students make connections
  E. Coordinate contents with state standards
II. Ways to teach lessons
  A. Assess student knowledge
  B. Use question and answer
  C. Determine student interest
  D. Model positive attitude and interest
III. Educator questions are used for
  A. Assessing student knowledge
  B. Involving students in lesson
IV. Ways to assess student knowledge
  A. Ask questions
  B. Watch body language
  C. Watch facial expression
  D. Student answers
  E. Student comments
V. Steps in developing comfort
  A. Know content and lesson plan
VI. Ways students learn
  A. Manipulate objects
  B. Use senses
  C. Practical experiences
VII. Reason for educator
  A. Make goals happen

Post-lesson Interview

I. Reasons for teaching lesson
  A. Create concrete memories
  B. Help students understand content
II. Reasons for modifying a lesson
  A. Due to students
    i. Student knowledge
    ii. Student developmental or ability level
    iii. Student behavior & body language
    iv. Accommodate time
  B. Due to educator
    i. Flow of activities
    ii. Comfort with content & lesson plan
III. Ways to modify a lesson
  A. Manipulate elements in lesson

B. Fluctuate pace of lesson
C. Remember content and flow
D. Experience with lesson

IV. Ways to manipulate activities
  A. Purpose of task
  B. Length
  C. Order or sequence
  D. Inclusion/exclusion of activities
  E. Expectations

V. Ways to manipulate discussion
  A. Change vocabulary
  B. Change wording
  C. Order of discussion topic
  D. Detail and depth of content

VI. Uses for classroom teachers
  A. Time keeper
  B. Extension, expansion post-field trip
  C. Student management

VII. Uses for parents and chaperones
  A. Student management, internal to lesson
  B. Expand on activities

VIII. Ways to determine student knowledge
  A. Student comments
  B. Student questions
  C. Student behavior & body language
  D. Student response to educator questions

IX. Ways to use previous lessons
  A. Gain insight into current lesson
  B. Gain comfort (in content & lesson plan) for future lessons

X. Ways teachers manage students
  A. Outside of lesson
    i. Student mind state
    ii. Prior knowledge preparation
    iii. Role modeling
  B. During lesson
    i. Participate in activity
    ii. Appropriate behavior during lesson

Appendix H. Interviews. Analysis Round 2 Outline

I. Reasons for teaching lesson
   A. Create concrete memories
   B. Help students understand content
   C. Promote interest in science and learning
II. Reasons for modifying a lesson
   A. Accommodate time
   B. Due to students (on-the-spot judgments influenced by experience with lesson plan)
      i. Student knowledge
         a. Ways to determine student knowledge
            1. Student comments
            2. Student questions
            3. Student behavior & body language
            4. Student response to educator questions
      ii. Student developmental or ability level
      iii. Student behavior & body language
   C. Due to educator (influenced by familiarity with lesson plan, i.e. repetition)
      i. Flow of activities
      ii. Comfort with content & lesson plan
      iii. Remembering content and directions
III. Ways to modify a lesson
   A. Manipulate
      i. Lesson plan activities – length, order, inclusion/exclusion, and expectations
   B. educator's words – vocabulary, wording, order of discussion topic, detail and depth of content, and length
   C. Fluctuate pace of lesson
   D. Remember content and flow
   E. Experience with lesson
      i. Ways to use previous lessons
         a. Gain insight into current and future lessons
         b. Gain comfort (in content & lesson plan) for future lessons
IV. Uses for classroom teachers
   A. Time keeper
   B. Extension, expansion post-field trip
   C. Student management
      i. External to lesson – student mind state, prior knowledge preparation, role modeling
      ii. Internal to lesson – participation in activity and behavior during lesson
V. Uses for parents and chaperones
   A. Student management, internal to lesson
   B. Expand on activities during lesson

Appendix I. Analysis Round 2 with Observation data

Janet

I. Reasons for teaching lesson
- A. Create concrete memories
- B. Help students understand content
- C. Promote interest in science and learning

II. Reasons for modifying a lesson
- A. Accommodate time [OBS1. *Time is sufficient to teach lesson as designed. Some changes cannot be accommodated because it would take too much time*. OBS2. *Amount of time allotted per activity*.]
- B. Due to students (on-the-spot judgments influenced by experience with lesson plan)
  - i. Student knowledge
    - a. Ways to determine student knowledge
      - 1. Student comments
      - 2. Student questions
      - 3. Student behavior & body language
        - (a) **Talk 1**, go over rules for class behavior → Ss rowdy as they enter & settle into seats
      - 4. Student response to educator questions
      - 5. Compare students to prior classes [OBS2. *Use S comments & behavior of same grade and/or school as indicators of expected S knowledge*.]
  - ii. Student developmental or ability level
  - iii. Student behavior & body language
- C. Due to educator (influenced by familiarity with lesson plan, i.e. repetition)
  - i. Flow of activities
  - ii. Comfort with content & lesson plan [OBS1. *Educator knowledgeable of content in order to explain content at multiple levels.* OBS2. *Educator comfortable with lesson plan thus become more creative with instruction*.]
  - iii. Remembering content and directions [OBS1. *Frequency of teaching lesson contributes to familiarity of lesson & thus memory on content & flow.*]
  - iv. Experience with prior lessons [OBS2. *Control variability in S ideas arising from prior classes that cannot be addressed in lesson*.]

III. Ways to modify a lesson
- A. Manipulate
  - i. lesson plan activities – length, order, inclusion/exclusion, and expectations [OBS1 & 2. *Manipulate length of activity in order to accommodate time*.]
  - ii. educator's words – vocabulary, wording, order of discussion topic, detail and depth of content, and length
    - a. define KE & PE
    - b. **Talk 3**, tell how NASA & scientists rely on these concepts in their research
- B. Fluctuate pace of lesson
- C. Remember content and flow

i. **Demo 2**, during rolling E noticed that corn can rolled to one side & floor was tilted towards direction of ramp, pointed out significance of content distribution & tested tilt by switch direction of ramp.
ii. **Demo 2**, told Ss about corn & floor discovered in previous class
iii. same content discussed, but in different segments

D. Experience with lesson
   i. Ways to use previous lessons
      a. gain insight into current and future lessons (insight = knowing what to expect based on age group, grade, school)
      b. gain comfort (in content & lesson plan) for future lessons (comfort = familiarity w/ content & lesson plan)

IV. Uses for classroom teachers

A. Time keeper
B. Extension, expansion post-field trip
C. Student management
   i. External to lesson – student mind state, prior knowledge preparation, role modeling
   ii. Internal to lesson – participation in activity and behavior during lesson [OBS3. *E's job is not to discipline since have no rapport or can carry out consequences*.]
      a. **(b) Act 1**, S plays around & falls off chair, E walks away from table as T walks towards it, T reprimands S. **Demo 2**, S yelled "shut up!", T pulled S to another table; during voting, S's writing unclear, T calls out for S to clarify.

V. Uses for parents and chaperones

A. Student management, internal to lesson
B. Expand on activities during lesson

Sally

I. Reasons for teaching lesson

A. Create concrete memories
B. Help students understand content
C. Promote interest in science and learning

II. Reasons for modifying a lesson

A. Accommodate time [OBS1. *Time not available to develop discussion despite emergence of concept during activity exploration*. OBS2. *Not enough time to explore & develop S thought, but this does not take away from lesson so okay*.]
   i. **(both, obs 1)** school arrives at museum 15 minutes late. This dominated teaching decisions.
   ii. **(b, obs 1)** T informs E they only have 30 mins for class.
   iii. **(both, obs 2)** lessons ended 5 mins early.
B. Due to students (on-the-spot judgments influenced by experience with lesson plan)
   i. Student knowledge
      a. **(a, obs 2) Demo 2**, Ss suggested inclined plane immediately, p/u on truck wheels to reduce friction → E asked Ss for explanation.

ii. **(b, obs 2) Demo 2**, Ss were not suggesting inclined plane, E led towards plane, E tells Ss how works & truck wheels to reduce friction.
    a. Ways to determine student knowledge
        1. Student comments
        2. Student questions
        3. Student behavior & body language
        4. Student response to educator questions
        5. Compare students to prior classes [OBS1. *Use S responses & comments from same grade and/or school as indicator of expected S knowledge*.]
iii. Student developmental or ability level
iv. Student behavior & body language

C. Due to educator (influenced by familiarity with lesson plan, i.e. repetition)
    i. Flow of activities
    ii. Comfort with content & lesson plan
    iii. Remembering content and directions
        a. **(a, obs 2) Talk 2**, noticed data discrepancy from Act 1 due to spring scale
        b. **(b, obs 2) Act 1**, reminds Ss about spring scale in instructions
        c. **(both, obs 2)** not much difference b/n S groups, E teaching influenced more by what she remembers for details & explanations.

III. Ways to modify a lesson

A. Manipulate
    i. lesson plan activities – length, order, inclusion/exclusion, and expectations [OBS1. *Activity length influenced by time available*.]
        a. **(both, obs 1)** activities shorter than Janet ~ 5 mins, omitted Talk 2.
    ii. **(both compared to Janet, obs 1) Demo 2**, voting before Act 2, rolling after Act 2 → perhaps part of way E teaches this lesson, E asks Ss whether they have changed their vote based on results from Act 2
        a. **(a, obs 2) Talk 3**, omitted
    iii. educator's words – vocabulary, wording, order of discussion topic, detail and depth of content, and length
        a. **(both, obs 1)** introduced & defined vocabulary as content arose (using lesson to provide concrete example to definition of words), but did not go into detail
    iv. **(b, obs 1) Act 2**, PE KE & gravity, leading towards friction but did not pursue until 2nd half of Demo 2.
    v. **(a, obs 1)** PE KE & gravity, no friction

B. Fluctuate pace of lesson

C. Remember content and flow

D. Experience with lesson
    i. Ways to use previous lessons
        a. gain insight into current and future lessons (insight = knowing what to expect based on age group, grade, school)
        b. gain comfort (in content & lesson plan) for future lessons (comfort = familiarity w/ content & lesson plan)
            1. **(obs 1)** E knows lesson well enough to cut out (or shorten) segments that would have most minimal impact on whole experience, time spent on Acts & Demos comparable to Janet who had whole 50 mins. E

mentioned wanted omissions to be subtle so Ss wouldn't realize it's missing & still understand & have a good time.

IV. Uses for classroom teachers

A. Time keeper

i. **(b, obs 1)** T told E at start of lesson that Ss only had 30 mins.

B. Extension, expansion post-field trip

i. **(b, obs 1) Talk 3**, suggested Ss to try on own & T to continue discussion at school, acknowledge no time to talk about Act 2.

C. Student management

i. External to lesson – student mind state, prior knowledge preparation, role modeling

ii. Internal to lesson – participation in activity and behavior during lesson

V. Uses for parents and chaperones

A. Student management, internal to lesson

B. Expand on activities during lesson

Gary

I. Reasons for teaching lesson

A. Create concrete memories

B. Help students understand content

C. Promote interest in science and learning

II. Reasons for modifying a lesson

A. Accommodate time [OBS1. *Class' field trip agenda & punctual arrival influences flexibility of lesson's length*.]

i. **(2)** class arrives on time & no program after → E teaches > 55 mins

B. Due to students (on-the-spot judgments influenced by experience with lesson plan)

i. Student knowledge

a. Ways to determine student knowledge

1. Student comments [OBS1. *E picks up on indicator words and responses to gauge S understanding; these indicators are generated from experience with previous lessons*.]

2. Student questions

(a) **(2) Demo 2c**, Ss propose charge line → E applies their idea; S asks why dry hands → E explains electricity through liquid.

(b) **(3) Demo 2a**, S asks purpose for not letting go of dome → E talks about discharge wand & chances of getting shocked if hand returns to dome; **Talk 4**, Ch asks purpose of stool → E talks about plastic as good insulator to keep e- from grounding; S asks purpose of mirror → E reiterates plastic as insulator to protect E from shock all day;

(c) **(4) Demo 2**, S asks purpose of mirror → E talks about plastic as a bad conductor, thus plastic mirror protects E from shock all day;

3. Student behavior & body language

4. Student response to educator questions

5. Compare students to prior classes [OBS1. *Use S responses & comments from same grade and/or school as indicator of expected S knowledge*.]

ii. Student developmental or ability level
iii. Student behavior & body language
iv. **Teach & respond** → E teaches lesson as planned, remembered, & comfortable, practiced; E responds to S interests & Qs; experience w/ lesson enables E to anticipate interests & Qs so that E has a suitable response

C. Due to educator (influenced by familiarity with lesson plan, i.e. repetition)
  i. Flow of activities
  ii. Comfort with content & lesson plan
  iii. Remembering content and directions

III. Ways to modify a lesson

A. Manipulate
  i. lesson plan activities – length, order, inclusion/exclusion, and expectations
    a. **(compared to Julia) Talk 3** before **Demo 2c**.
  ii. educator's words – vocabulary, wording, order of discussion topic, detail and depth of content, and length
    a. **(both)** talks about plastic as insulator due to Qs about mirror & stool.
    b. **(all compared to Julia) Talk 3**, talk about science behind styrofoam flying & hair standing not during demo but in a separate segment; does not talk about how to avoid lightning strike unless asked in 4.
    c. **(2) Talk 2**, positive & negative charges, atoms lose & gain parts from rubbing & become charged; **Demo 2**, can't see electricity, glow from lightning & VdG due to charged up gases in air
    d. **(3) Talk 2**, positive & negative charges due to protons & electrons; **Demo 2**, can't see electricity, glow from lightning & VdG due to charged up gases in air

B. Fluctuate pace of lesson
C. Remember content and flow
D. Experience with lesson
  i. Ways to use previous lessons
    a. gain insight into current and future lessons (insight = knowing what to expect based on age group, grade, school)
      1. consistency in what E said down to joke, warnings, segues, & content explanations.
    b. gain comfort (in content & lesson plan) for future lessons
      1. Directions for getting into groups for charge line.

IV. Uses for classroom teachers

A. Time keeper
B. Extension, expansion post-field trip
C. Student management
  i. External to lesson – student mind state and prior knowledge preparation
  ii. Internal to lesson – participation in activity, role modeling, and behavior during lesson
    a. **(4) Act**, Ss want to work in group of 4, T suggest 2 of 2, E supports resolution

V. Uses for parents and chaperones

A. Student management, internal to lesson
    i. **(3) Act**, Ss can't decide on groups, Ch directs resolution, E checks in on status & goes with resolution.
B. Expand on activities during lesson

Julia

I. Reasons for teaching lesson
A. Create concrete memories
B. Help students understand content
C. Promote interest in science and learning
D. Help students develop social and cooperative learning skills

II. Reasons for modifying a lesson
A. Accommodate time
    i. **(4) Talk 4**, E leads Talk 4 while Ss line up to leave
B. Due to students (on-the-spot judgments influenced by experience with lesson plan)
    i. Student knowledge
        a. Ways to determine student knowledge
            1. Student comments [OBS2. *E picks up on indicator words and responses to gauge S understanding; these indicators are generated from experience with previous lessons*.]
                (a) **(3) Talk 2**, S notes discrepancy in Act results & thus not convinced plastic is best, E addresses w/ need for experimenter errors & consistency when doing experiments.
            2. Student questions
            3. Student behavior & body language
            4. Student response to educator questions (**8/25/04**. S responses match w/ insight from previous classes → Ss on or off cue from what is expected influences whether E continues as expected or changes drastically; Ss in lessons all responded about the same way to E Qs & tasks so E talk about the same level, added a little more for 5th grade since know Ss know about currents)
            5. Compare students to prior classes [OBS1. *Use S responses & comments from same grade and/or school as indicator of expected S knowledge*.]
    ii. Student developmental or ability level
    iii. Student behavior & body language [OBS4. *S behavior can require management or indicate dislike, lack of interest*.]
C. Due to educator (influenced by familiarity with lesson plan, i.e. repetition)
    i. Flow of activities
    ii. Comfort with content & lesson plan
    iii. Remembering content and directions

III. Ways to modify a lesson
A. Manipulate
    i. lesson plan activities (what is done and how it's done) – length, order, inclusion/exclusion, and expectations
        a. **(4)** omits/alters Talk 4 so Ss go to IMAX

ii. educator's words (what is said and how it's said) – vocabulary, wording, order of discussion topic, detail and depth of content, and length
   a. **(all compared to Gary) Talk 1**, defines static is … & uses example of moving in room; **Demo 2b**,E brings up plastic stool as insulator; **Demos 2**, discuss (for 3) science behind VdG effects during demo so that **Talk 3**, focuses on how to avoid being struck by lightning
   b. **(2) Demo 2**, also talks about ozone created from chem rxn w/ oxygen
   c. **(3) Demo 2**, elaborates on DC/AC → know Ss can handle this since just had electricity class w/ her; **Demo 2a**, discusses like charges repelling as reason for styrofoam jumping & hair standing

B. Fluctuate pace of lesson
C. Remember content and flow
D. Experience with lesson
   i. Ways to use previous lessons
      a. gain insight into current and future lessons (insight = knowing what to expect based on age group, grade, school)
      b. gain comfort (in content & lesson plan) for future lessons (comfort = familiarity w/ content & lesson plan)

IV. Uses for classroom teachers

A. Time keeper
   i. **(3) Talk 3**, T announces it's time to go. E acknowledges that she was waiting for T to cut her off, checked that Ss didn't have another program, they had such good Qs so she kept going until told to stop.
   ii. **(4) Talk 3**, T announces that Ss have IMAX next, E takes cue & leads Talk 4 in line.
B. Extension, expansion post-field trip
C. Student management
   i. External to lesson – student mind state, prior knowledge preparation, role modeling
   ii. Internal to lesson – participation in activity and behavior during lesson
      a. **(2) Demo 2c**, T calls out to Ss to listen
      b. **(4) Act & Talk 3**, T calls out to Ss to quiet down & attention to E

V. Uses for parents and chaperones

A. Student management, internal to lesson
B. Expand on activities during lesson

VI. Uses for experience from previous classes

A. Indicator for student knowledge, behavior, ability
B. Gain insight into current and future lessons
C. Gain comfort in content & lesson plan for future lessons

Appendix J. Analysis Round 2 Refined Outline

Describing nuances in instruction. Answering the first question: How do educators teaching one-hour, one-time lessons in museums adapt their instruction to the students that they teach? (How does perceived variability in entering student knowledge affect instruction? How do time limitations affect instruction?)

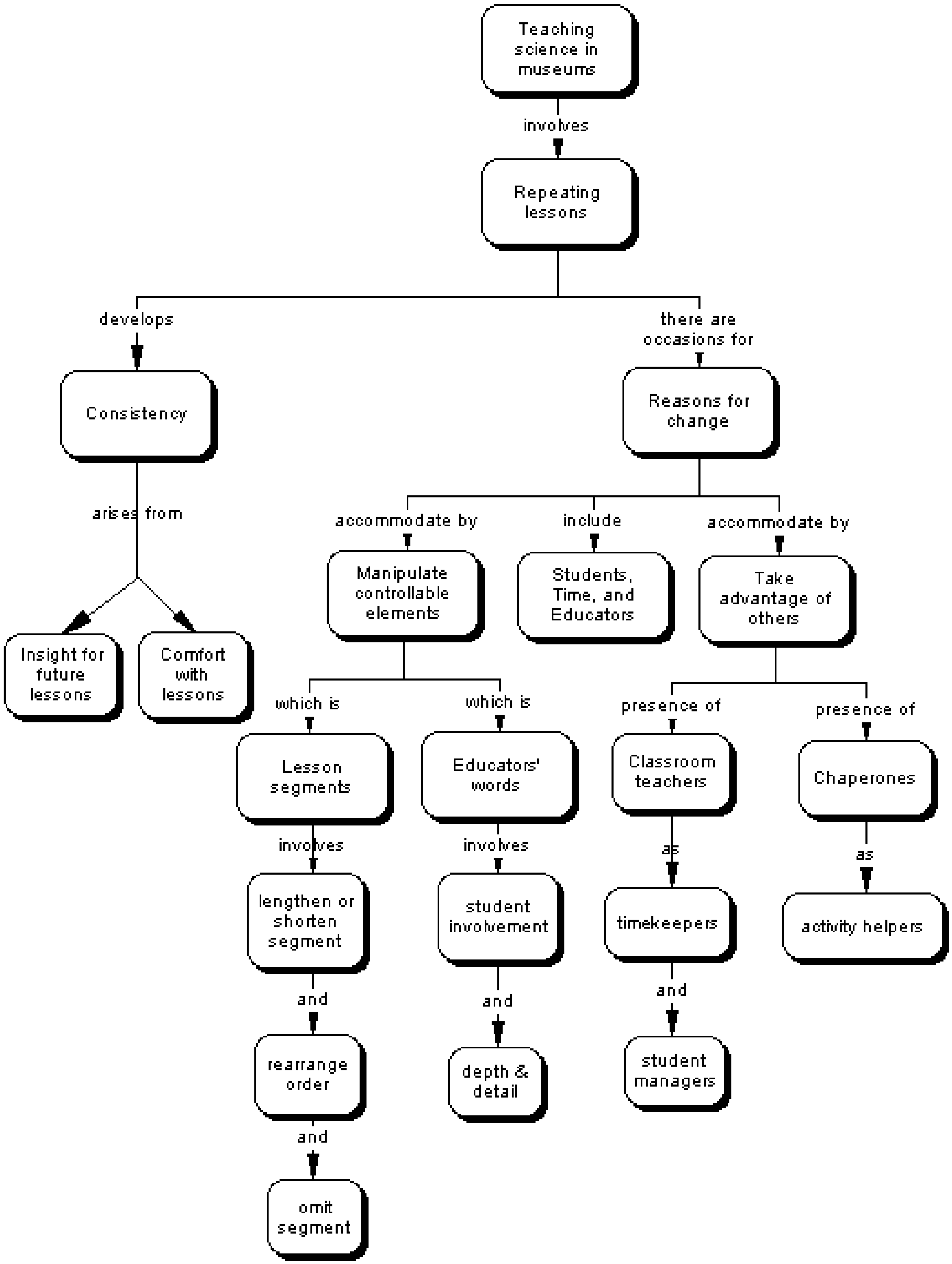
I. Pieces of the lessons.
    A. Lessons are comprised of three types of segments (talk, activity, and demonstration).
    B. Length & order of segments variable, & usually vary according to educator
    C. Accommodate reasons for modifying a lesson
        i. Accommodate time – when time runs out, start dropping off or shortening segments
        ii. Due to students – on-the-spot judgments influenced by experience with lesson plan
            a. What students say
                1. Student comments
                2. Student questions
                3. Student response to educator questions
            b. What students do
                1. Student behavior & body language
        iii. Due to educator – influenced by familiarity with lesson plan, i.e. repetition
            a. Remembering content and directions
            b. Comfort with content & lesson plan

II. Manipulate elements within your control, take advantage of others.
    A. Segmented lessons offer flexibility to accommodate S knowledge & time
    B. What is said and done (segments & words) are changeable to educator & constraints
    C. Manipulate elements within educator's control
        i. Lesson segments
            a. Length
            b. Order
            c. Inclusion or exclusion
        ii. Educator's words
            a. Wording, phrasing
            b. Order of discussion topic
            c. Content detail, depth, or additional info
            d. Delivery method – encouraging Ss to explain, clarify, discover, versus telling Ss
        iii. Remember content and flow, primarily for directions
    D. Take advantage of others
        i. Uses for classroom teachers
            a. During lesson
                1. Time keeper

        2. Student management, behavior & participation
    b. After lesson
        1. Conclude & connect lesson activities to curriculum – usually when low on time & E unable to wrap up activity or lesson
  ii. Uses for parents and chaperones
    a. Student management, internal to lesson
    b. Expand on activities during lesson

III. Repetition develops consistency.
  A. Repeating same lesson plan develops insight & comfort that enables E to respond quickly to Ss
  B. What is said (jokes, segues, directions, explanations) are repeated and refined within educators, not between educators
    i. Perhaps not enough variability in S knowledge
  C. Objectives & procedures of activities & demonstrations remain the same between & within educators
  D. Apply what is learned from previous lessons
    i. Establish expectations of student knowledge – check whether S responses within parameter that is expected for their grade level, especially useful when low on time so as not to go too far above S abilities
    ii. Gain insight into current and future lessons – insight = knowing what to expect based on past experiences with age group, grade, & school
    iii. Gain comfort for future lessons – comfort = familiarity with lesson plan & content based on own research & teaching lesson over and over again.

Appendix K. Findings Diagram



Appendix L. Final Outline

THEMES ACROSS DOMAINS

I. Repetition develops consistency.
   A. Repeating same lesson plan develops consistency
      i. What is said (jokes, segues, directions, explanations) are repeated and refined within educators, not between educators
         a. Perhaps not enough variability in S knowledge
      ii. Objectives & procedures of activities & demonstrations remain the same between & within educators
   B. Repetition develops insight & comfort that enables E to respond quickly to Ss. Apply what is learned from previous lessons
      i. Comfort with lessons – comfort = familiarity with lesson plan & content based on own research & teaching lesson over and over again.
      ii. Insight for current and future lessons – insight = knowing what to expect based on past experiences with age group, grade, & school
II. Reasons for modifying a lesson
   A. Differences between lessons, educators, & topic are subtle.
      i. Objectives & procedures remain the same.
      ii. Details & order of content are slightly different, but major concepts are discussed.
   B. Accommodate time – when time runs out, start dropping off or shortening segments
      i. Time is not always limited. Lessons can change due to extra time perceived.
   C. Due to students – on-the-spot judgments influenced by experience with lesson plan
      i. What students say
         a. Student comments
         b. Student questions
         c. Student response to educator questions
      ii. What students do
         a. Student behavior & body language
   D. Due to educator – influenced by familiarity with lesson plan, i.e. repetition
      i. Remembering content and directions
      ii. Comfort with content & lesson plan
III. Manipulate elements within your control, take advantage of others.
   A. What is said and done (segments & words) are changeable to educator & constraints
      i. Pieces of the lessons. Element built in to lesson design.
         a. Lessons are comprised of three types of segments (talk, activity, and demonstration).
         b. Length & order of segments variable, & usually vary according to educator
         c. Segmented lessons offer flexibility to accommodate S knowledge & time
            1. Length
            2. Order
            3. Inclusion or exclusion

- ii. *Educator's words*. Element arising from educator personality, knowledge, experience.
  - a. Content detail, depth, or additional info
  - b. Delivery method – encouraging Ss to explain, clarify, discover, versus telling Ss

B. Take advantage of others
- i. Uses for classroom teachers
  - a. Time keeper
  - b. Student management, behavior & participation
- ii. Uses for parents and chaperones
  - a. Expand on activities during lesson