

*Enhancing conceptual knowledge and attitudes toward
science for lower socioeconomic status, African American
students through interactive museum visitation
A Master's Thesis*

by
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ABSTRACT

An abstract of the thesis of Toni Nicole Dancu for the Master of Science in Psychology presented January 31, 2005.

Title: Enhancing conceptual knowledge and attitudes toward science for lower socioeconomic status, African American students through interactive museum visitation

This study investigated whether the provision of opportunities and culturally relevant field trip experiences involving informal education could result in increased science curriculum knowledge and interest, which could contribute to reducing the existing achievement gap (the well-documented difference in achievement between majority and minority students). This study measured the effect of a museum visit for a group of low-socioeconomic status (SES), African American, middle school children. Specifically, this study aimed to (a) identify whether a field trip to a local science center could deepen the understanding of school-based learning for children from a primarily low-SES, African American school, (b) determine whether a field trip to a science center could improve children's attitudes (interest, motivation, and enjoyment) toward science, and (c) determine whether participants' understanding and attitudes depended on engagement and/or perceived exhibit relevance.

Main effects from the analyses of variance and t tests suggest that the science center field trip effectively enhanced curriculum knowledge and understanding for the participating low-income, African American middle school students. The field trip

was less successful in improving students' attitudes toward science (in general), however, after visiting the museum, the students' attitudes toward the topic of focus during the field trip (acids and bases) did improve. The majority of the students viewed the exhibits as relevant, and Interaction analyses (ANOVA) suggest that for those who viewed the exhibits as relevant, attitude toward the target topic increased.

ENHANCING CONCEPTUAL KNOWLEDGE AND ATTITUDES
TOWARD SCIENCE FOR LOWER SOCIOECONOMIC STATUS,
AFRICAN AMERICAN STUDENTS THROUGH
INTERACTIVE MUSEUM VISITATION

by

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Preface

Hands-on, informal museums are commonly viewed as pedagogical arenas where learning that occurs in the school environment can be enhanced and interest in curriculum topics increased. The majority of museum studies have been conducted with everyday museum visitors—consisting primarily of children from white, middle-class families. Children from low-socioeconomic status (SES) and minority families may have fewer opportunities for experiences outside formal education. Yet, interactive, hands-on environments may provide experiences that are culturally and contextually relevant for low-SES and minority children. Fewer opportunities for informal education or the need for culturally relevant pedagogy may be contributing to the achievement gap—the difference in level of achievement between minority and low-income students and majority, high-income students. By providing opportunities and culturally relevant experiences, field trips involving informal education could result in increases in curriculum knowledge and interest, which may help to diminish the existing achievement gap.

This study measured the effect of a museum visit for a group of low-SES, African American children. The Oregon Museum of Science and Industry (OMSI) has effectively worked with the local community to increase understanding and interest in science for low-income and minority students by providing after-school science programs such as *Latinos en Ciencia* and the *OMSI Boys and Girls Science Club*.

However, OMSI's after-school programs do not attract many participants between sixth and twelfth grades. School field trips to OMSI may be more attractive for these age groups and still increase understanding and pique interest in science. Specifically, this study aimed to (a) identify whether a field trip to OMSI could deepen the understanding of school-based learning for children from a primarily low-SES, African American school, (b) determine whether a field trip to OMSI could improve children's attitudes (interest, motivation, and enjoyment) toward science, and (c) determine whether participants' understanding and attitudes depended on engagement and/or perceived exhibit relevance.

The findings suggest that the field trip to OMSI effectively enhanced curriculum knowledge and understanding for the participating low-income, African American middle school students. The field trip to OMSI was less successful in improving the students' attitudes toward science (in general), however after visiting the museum, the students' attitudes toward the topic of focus during the field trip (acids and bases) did improve. Results suggest that the majority of the students viewed the exhibits at OMSI as relevant, and for those who saw the exhibits as relevant, attitude toward the target topic increased.

Enhancing conceptual knowledge and attitudes toward science for
lower socioeconomic status, African American students
through interactive museum visitation

Literature Review

Informal Learning in Museums

Why Expect Learning to Occur in a Museum?

Over the past ten to fifteen years literature regarding learning in museums has grown in quantity and has received increased attention from the general population. Informal, hands-on programs are becoming more intentional in educating and advocating important life skills (Quinn, 1999). The educational importance of museums was the focal point of the American Association of Museums (AAM) presidential report in 2000. AAM president, Edward H. Able, Jr., reminisced about the 1990 AAM goal to place education in the mission statements and goals of museums. He celebrated in the proof of a “job well done”—evidenced by a 1998 report by the Institute of Museum and Library Services (IMLS) that found 88% of museums in America provide educational programs for K–12 and the current relationship forged between the AAM and the U.S. Department of Education (USDE) (Able, 2000, p. 75). A well-known expert in the field of informal education, John Falk (1999) recognizes that museums are increasingly becoming significant educational entities. It can be said

with confidence that museums in the 21st century are expected to play an active role in edifying the public.

Why Do We Need to Evaluate Informal Learning Outcomes?

It is important for exhibits to be evaluated for two main reasons: (a) if interactive museums hold educational value they can contribute to public knowledge in core subjects, such as science and technology; and (b) if museums can provide proof of their educational value, they can increase funding from sources invested in public education, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF). Funding agencies often require evaluations to ensure that the monetary support provided is advancing the goals stated within a grant application. Those goals are frequently related to cognitive or affective dimensions of learning.

The increased focus on educational outcomes has resulted in the need to evaluate informal learning centers. The educational value of museums has been frequently questioned within the larger educational community. The Carnegie Council on Adolescent Development (1992) suggested youth programs specify and evaluate intended outcomes and goals using reliable measures. Although informal institutions may clearly impact cognitive and affective learning (i.e., attitudinal changes), providing evidence of learning has proven difficult. This difficulty arises from the great range of learning possibilities, the need for time (or possibly more than one visit) for people to consolidate ideas learned, and the inability to detect subsequent information sought after curiosity is sparked by the museum (Falk, 1999).

What Has Past Research Found in Regard to Museums and Cognitive Learning?

Learning in museum settings has been defined in a variety of ways. Museum studies most commonly refer to informal learning as a kind of conceptual change or an increase in understanding or knowledge due to the museum visit. Researchers in this area also identify gains in scientific skills—observing with the senses, measuring, comparing, and classifying—as an indirect form of learning (Barclay, Benelli, & Schoon, 1999; Wellington, 1990). Finally, affective dimensions of learning—attitudinal change, such as increases in interest, motivation, or enjoyment in a topic—are often reported in museum studies. Each of these types of learning is described in more detail below.

Conceptual change.

The majority of research conducted in informal museum settings has shown conceptual change or increases in visitor understanding after a museum visit (e.g., Anderson & Lucas, 1997; Balling & Falk, 1980; Eason & Linn, 1976; Eratuuli & Sneider, 1990; Falk & Storksdieck, 2002; Gennaro, 1981; Giese, Davis-Dorsey, & Gutierrez, 1993; Gilbert & Priest, 1997; Tulley & Lucas, 1991; Tunnicliffe & Laterveer-de Beer, 2002; Wright, 1980). Dierking, Luke, and Buchner (2003) discovered through a variety of methods that exhibits at the Louisville Science Center and the California Science Center, were capable of expanding visitors' understanding and perception in science and technology topics. In a study conducted by Falk (1983), sixty-three 12- and 13-year-old children from average to above average SES levels

and medium to low intelligence levels (based on standardized intelligence tests used by British schools) were taken to the human biology exhibit in a museum in London. Children exhibited substantial gains on multiple choice and true/false content knowledge tests. Falk (1983) also discovered that these cognitive gains could be predicted (83% accuracy) through unobtrusive measures such as a function of time on task and behavior during the visit.

Another example of conceptual increases in learning after a museum visit can be found in a pilot study conducted by Giese, Davis-Dorsey, and Gutierrez, Jr. (1993) during a collaborative activity between fourth grade classrooms and a history museum. A pre/post-multiple-choice test and a creative writing assignment were employed to assess learning. According to these measures, students showed significant increases in understanding and knowledge after the museum visit (Giese et al., 1993). Changes in understanding after an informal learning experience have been observed months after the experiences have occurred (e.g., Balling & Falk, 1980; Dierking, Luke, & Buchner, 2003; Falk, 1983a; Falk & Balling, 1982; Falk, Moussouri, & Coulson, 1998).

Similar cognitive changes have been identified through research conducted in a variety of informal learning contexts other than museums, such as after school programs and science camps (Jones, 1997; Paris, Yambor, & Wai-Ling Pacard, 1998; Rahm, 2002; Stover & Saunders, 2000). Summer camp facilitators for a science center sponsored camp used pretests to identify common misconceptions in 14 pupils (Stover & Saunders, 2000). Discussions and demonstrations were then tailored to the pre-

misconceptions. After the camp, significant increases in scores on posttests (compared to pretest scores) were found (Stover & Saunders, 2000). Scott Paris and his colleagues (1998) assessed the effects of a six-week program on 184 third, fourth, and fifth graders. Using a battery of pre- and post-measures the authors found significant increases in knowledge and problem solving abilities after completing the program (Paris et al., 1998). Such gains in knowledge from pretest to posttest are commonly found after an interactive, informal learning experience (e.g., Balling & Falk, 1980; Farmer & Wott, 1995; Gennaro, 1981; Giese et al., 1993; Paris et al., 1998; Rix & McSorley, 1999; Stover & Saunders, 2000; Tunnicliffe & Laterveer-de Beer, 2002).

Indirect gains in knowledge.

Some informal learning studies reveal more complex results, such as interactions between prior knowledge, or level of novelty, and learning. In a study regarding gains in knowledge and interest, Falk and Adelman (2003) compared results across levels of prior knowledge and interest. Through the use of open- and closed-ended interview questions, the authors discovered that complex results were found when more detailed comparisons were made. Specifically, gains in knowledge were found for visitors entering with limited knowledge (as opposed to moderate or extensive) and moderate interest (as opposed to minimal or extensive). Gains in interest were found for visitors entering with minimal to moderate interest. These findings are important because the likelihood of increasing both knowledge and interest is high for the majority of visitors who typically enter free-choice learning

environments with low to moderate knowledge and moderate to extensive interest (Falk & Adelman, 2003). The current study took into account children's current science grades to try to assess the effects of prior knowledge.

Equally complex studies have focused on the interaction of environmental novelty and learning. The novelty of an environment has proven to be more distracting for younger children (third grade and lower) while stimulating and encouraging for older school children (fifth grade and up) (Balling & Falk, 1980; Falk & Balling, 1982). Balling and Falk recommend moderation in terms of novelty for children of all ages on field trips; in the case of each extreme, novel and boring, children's off-task behaviors increased and were detrimental to learning. Moderate levels of novelty can increase a child's experience and learning potential. The present study took into account children's prior science museum visits in order to assess the effects of novelty on learning and employed a pre-visit orientation to reduce the effects.

Other studies have identified certain characteristics of the exhibit as important factors that affect learning. Although the list is quite long (for examples see Borin & Dritsas, 1997; Falk & Storksdieck, 2002), two of the factors, Exhibit Engagement and Exhibit Relevance, are of central importance to the current study. Falk and Storksdieck (2002) conducted a multi-factor investigation on ten variables and their effect on learning outcomes. The authors identified Exhibit Characteristics as one of the most influential variables. Exhibit Characteristics was measured as a composite of Engagement Level while at the exhibit and Time Spent at the exhibit. Engagement

Level was comprised of actions and emotions. Skinner and Belmont (1993) posit that engaged children exhibit positive emotions while exercising high levels of effort and concentration in the accomplishment of learning. Falk and Storksdieck (2002) discovered that visitors' Engagement Level (and Time Spent) during the museum visit significantly impacted learning. Engagement Level has also been identified as a major variable affecting learning in the classroom (Greenwood & Terry, 1994; Skinner, Wellborn, & Connell, 1990). Children who are more engaged in a topic, either in school or in an informal setting, are more likely to gain a greater understanding of that topic. The current study assessed the relationship between children's engagement level and learning.

The second exhibit characteristic of central importance to the present study is Exhibit Relevance. Borun and Dritsas (1997) conducted a series of observations along with a literature review and identified several exhibit characteristics associated with increased learning. Relevance was one of seven major factors that elicited learning behaviors. An exhibit is considered relevant if it provides cognitive links to visitors' previous ideas, knowledge, or experiences (Borin & Dritsas, 1997). In other words, Exhibit Relevance requires that the visitor be able to connect the exhibit content with what the visitor knows a priori or to something familiar. Hein (2001) claims that the amount of personal connection between the visitor and the exhibit material is directly related to what is learned. The present study explored the concept of exhibit relevance

through the qualitative responses of the participating students and the relationship of those responses to cognitive and affective learning outcomes.

Another area of museum research has focused on indirect learning measures, such as skills and processes, which lead to future learning. Wellington (1990) asserts science centers contribute mostly to knowledge “that” something happens or “that” something is possible. However, Wellington also promotes the idea that science centers indirectly contribute to knowledge about “how” and “why” by introducing new topics that will later be more readily understood. This view is further demonstrated by a small, in-depth study of 26 UK children’s experiences with three exhibits conducted by Rix and McSorley (1999). Using Wellington’s categories of knowledge “that,” knowledge “how,” and knowledge “why” to classify children’s answers to open-ended questions about three exhibits, the researchers confirmed that children more often learn “that” an exhibit does something rather than “how” or “why” an exhibit does something.

Although knowledge “that” is not part of immediate conceptual change, the use of scientific processes in changing variables within an exhibit can be argued to enhance a visitor’s future learning. Supplementing the questionnaires with observation and video analysis, Rix and McSorley (1999) studied the children’s use of scientific processes and skills throughout the visit: varying factors to observe change, focused exploration, use of scientific vocabulary to explain phenomenon, and some *systematic* manipulation during exhibit exploration. Such scientific processes have been observed in visitors on

many occasions (Ault & Herrick, 1991; Bell & Rabkin, 2002; Eratuuli & Sneider, 1990; Rix & McSorley, 1999).

Affective learning/Attitudinal change.

In addition to cognitive growth through informal learning, Wellington (1990) and Bitgood (1989) advocate that interactive, hands-on science can improve psychomotor functioning and affective learning. Although psychomotor learning was beyond the scope of this thesis, affective learning was explored. Moreover, many of the museum studies that have not found favorable results in cognitive learning outcomes (Ault & Herrick, 1991; Henriksen & Jorde, 2001), especially over and above outcomes due to classroom lessons (Flexer & Borun, 1984), have found favorable results in affective/attitudinal domains.

Affective learning includes changes in attitude, motivation, interest, and enjoyment due to an experience. Improving science affect is an important function of interactive science museums because positive affect can: (a) lead to increased interest in school-based topics and (b) encourage youth to pursue careers in the field of science. According to Slate and Jones (1998), positive attitudes toward science (including motivation and importance) are necessary if improvements to science education are to be realized. Motivation cultivated in informal settings could extend into future motivation and behavior in science related experiences (Meredith, Fortner, & Mullins, 1997).

Many believe that gains in factual knowledge are difficult to identify or even to expect from class field trips to science centers (Dierking et al., 2003; Russell, 1990). Those who think factual knowledge will not be found in such research, usually believe affective gains are likely to be found and are just as important (Russell, 1990). Some research supports these beliefs. In a study conducted with 416 fifth and sixth graders, comparing class lessons and museum visits, the authors found that a class lesson, alone or in combination with an exhibit visit, yields the highest levels of cognitive learning (Flexer & Borun, 1984). However, a museum visit, alone or in combination with a lesson, was found to yield the highest affective scores, such as interest, enjoyment, and motivation for future learning (Flexer & Borun, 1984; Paris et al., 1998).

Finson and Enochs (1987) examined the effects of a science-technology museum visit on attitude toward science-technology-society. Improvements in attitude were found in students whose teachers planned for the visit when compared to children who did not attend the museum (Finson & Enochs, 1987). Paris and his colleagues discovered that the effects of hands-on learning on attitude/affect declined as children grew older (Paris et al., 1998); however, these results are inconclusive. For example, Finson and Enochs (1987) found increases in attitude scores were highest for sixth graders, second highest for eighth graders, yet lowest for seventh graders. A final example of affective learning is provided by the previously mentioned study by Rix and McSorley (1999). The largest differences found after the museum visit were in the

realm of attitudinal change. Pre- and post-qualitative questionnaires about attitudes toward science concluded that children's attitudes toward science had greatly improved (Rix & McSorley, 1999). The researchers do suggest that to obtain lasting improvements in science attitudes, teachers should take advantage of these moments and continue to cultivate this interest.

Why Do We Need Museums in Addition to Schools?

The learning that occurs in an informal environment can help to solidify previously learned information, open the door for future understanding, and lend relevance and context to a concept taught in the school setting. Hands-on environments are also enjoyable; they can increase interest and entice visitors to want to learn more about a subject. Questioning and hands-on playfulness promote scientific thought, further curiosity, and build a foundation for later learning (Barclay et al., 1999). For new knowledge to be formed, people must be repeatedly exposed to concepts (Resnick & Chi, 1988). People must have opportunities that encourage them to explore topics again and, possibly, more deeply. This kind of encouragement can be found in informal education settings such as museums.

It is important to extend children's school-acquired knowledge in an environment that does not simulate school activities (Quinn, 1999). One reason for extending knowledge in different contexts is that the exercise or application of a concept across diverse contexts has been shown to strengthen the acquisition of knowledge and increase the concept's generalization (e.g., Gibson, 1969). The features that characterize free-

choice learning in settings like hands-on museums are: informal, voluntary, non-sequential, fragmentary, collaborative, curiosity driven, individual, multi-sensory, and satisfactory (Griffin, 1998; Templeton, 1988). Inquiry and investigation in such informal settings encourage and develop independent learners (Hawkey, 2002). The learning that occurs in an informal setting is more contextually relevant and more intrinsically motivated than that which occurs in a formal school setting. Formal and informal educational enterprises may both be necessary, and it is expected that together they can enhance the experience that either arena can provide alone.

Given the above considerations, a study of museum learning should include measures of knowledge acquisition, conceptual change, and affective learning. Additionally, a study of museum learning should address factors that impact cognitive and affective learning in a museum setting: level of engagement while at the exhibits, previous visits, prior knowledge, and perceptions of exhibit relevance. The current study aims to address each of these aspects.

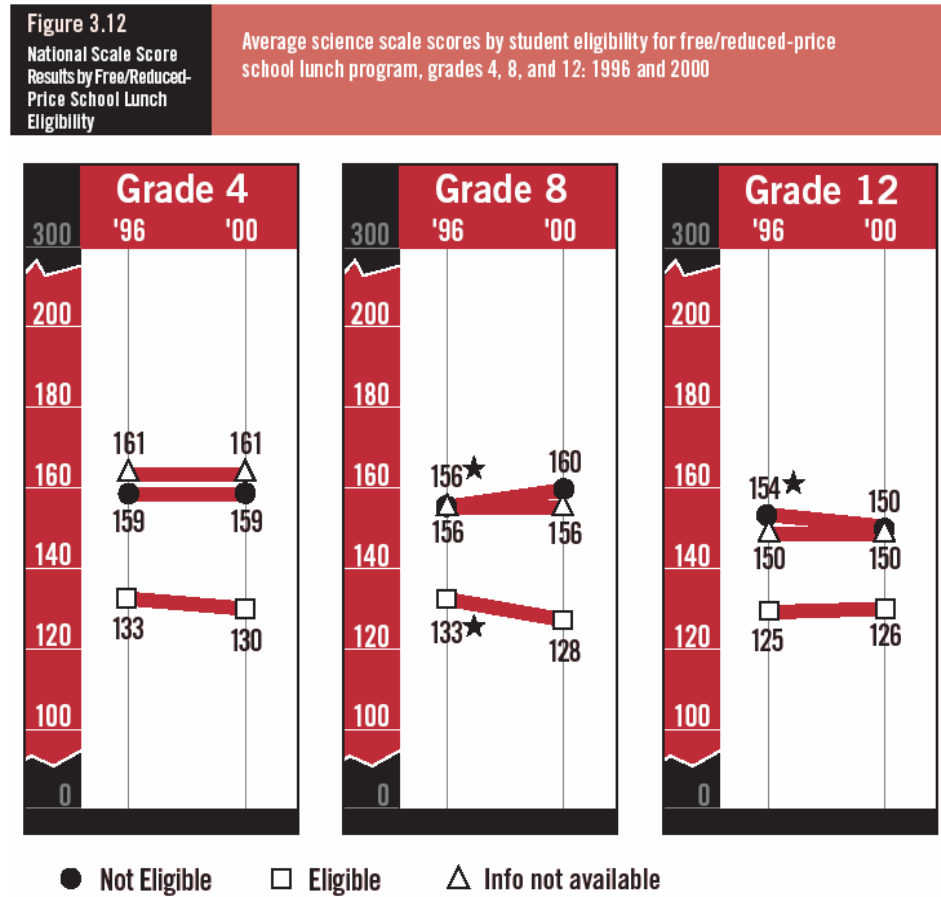
African American Achievement in Science:

*A Discrepancy Between Socioeconomic Status and Access to Pedagogical
Experiences, or Culturally Different Ways of Learning and Knowing?*

What is the “Achievement Gap?”

A well-documented achievement gap exists between children and adults from low-socioeconomic, non-white populations and the more privileged majority. Individuals from low-socioeconomic and minority populations continually display lower academic achievement as evidenced by grades, test scores, school completion, and education levels (Slate & Jones, 1998; The National Task Force on Women, 1989; Van Laar & Sidanius, 2001). See Figures 1 and 2 for the most recent National Assessment of Educational Progress (2003) data on low-SES (determined by eligibility for a school lunch program) and African American students, respectively. Eradicating this achievement gap has been a high priority in the education system the past century (The National Task Force on Women, 1989; Van Laar & Sidanius, 2001).

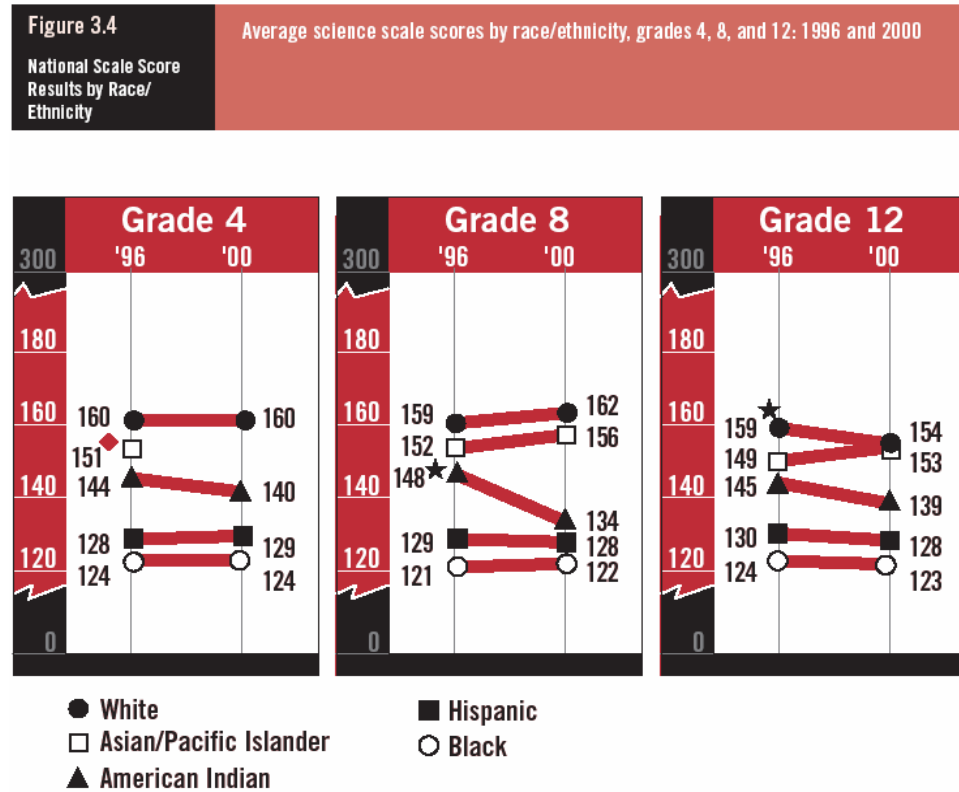
Figure 1 (adapted from O'Sullivan, Lauko, Grigg, Qian, & Zhang, 2003)



★ Significantly different from 2000.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 1996 and 2000 Science Assessments.

Figure 2 (adapted from O'Sullivan et al., 2003)



★ Significantly different from 2000.

◆ Special analyses raised concerns about the accuracy and precision of national grade 4 Asian/Pacific Islander results in 2000. As a result, they are omitted from the body of this report. See appendix A for a more detailed discussion.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 1996 and 2000 Science Assessments.

Research regarding the achievement gap usually focuses on two main contributing factors: (a) socioeconomic status, which is usually attributed to resource availability, and (b) minority/majority group differences, which are often related to culturally relevant ways of learning and knowing. The effects of these factors on the achievement gap are often difficult to disentangle because minority populations, especially African Americans and Hispanics, are over-represented in lower socioeconomic populations (Biddle, 2001; Kozol, 1991). First, differences in

achievement in lower socioeconomic groups and how these differences contribute to lower levels of achievement are discussed. These differences will then be related to minority differences in achievement. Next, culturally relevant ways of learning and knowing and how these differences impact African American achievement will be discussed. The current levels of African American achievement in science will be reviewed. Finally, the aforementioned factors contributing to the achievement gap will be considered in relation to museum use.

Socioeconomic Status (SES) and the Achievement Gap

The socioeconomic status of children and their broader social environment strongly determine life outcomes, such as education and achievement (Fischer et al., 1996). This inequity is not occurring in the United States alone. In an international effort to understand inequalities in education, thirteen countries, including the United States, were examined. Each of these countries had experienced educational reforms, however, these reforms were not related to increases in educational opportunity for students from the lower socioeconomic strata (Shavit & Blossfeld, 1993). Large percentages of children are living in poverty throughout industrialized Western nations; in the United States as many as 20% of students attending school live in poverty (Barton, 1998). Therefore, the problem of low social status, and how low status is related to educational achievement, is especially important in the United States.

Data from a nationally representative sample of 14,868 students taking math and science in 10th grade were analyzed to discern the factors affecting the achievement gap (data were collected by the National Center for Educational Statistics in 1995). Researchers found that, indeed, students from higher SES tended to show substantially higher achievement levels than students from lower SES families (Elliott, 1998). Naturally, the next step is to understand how low status groups achieve less academically.

A large body of achievement gap research focuses on how school district funding affects achievement. “The United States also differs from other advanced nations in that it collects most of the funds needed for public education through taxes in local school districts, and this means that support for public education in America varies sharply between rich suburbs and less affluent city ghettos or poor, rural communities” (Biddle, 2001, p.19). This difference in school funding per school year in America ranges from schools receiving \$15,000 per student to schools receiving less than \$3,000 per student (Biddle, 2001; Kozol, 1991). In essence, poor children attend poor schools, and rich children attend rich schools.

It is easy to understand this disparity without truly understanding the implications of such inequalities. When researchers say that the poorest children attend the poorest schools, they mean the schools with the most overcrowding, least space, least resources, and, often, fewest well-trained teachers. Kozol (1991) described sub-standard schools where children had to stand in classrooms until others inevitably

dropped out, four unrelated classes were taught in the same room at the same time, libraries did not own reference books, and obvious dilapidation existed both inside and outside. Children attending such poorly funded schools see and understand the differences between their schools and “rich” schools. The quotes of teens in Kozol’s (1991) book, *Savage Inequalities*, illuminate the inequity and implications of this imbalance from the eyes of the teens experiencing them first hand:

You can look around you at their school, although it’s impolite to do that, and you take a deep breath at the sight of all those beautiful surroundings. Then you come back home and see that these are things you do not have. You think of the difference. Not at first. It takes a while to settle in.

People from the outside may think that we don’t know what it is like for other students, but we visit other schools and we have eyes and we have brains. You cannot hide the differences. You see it and compare.

...I do not have that freedom [that rich people enjoy] and I can’t go to their schools (p. 104).

Although originally contested (see Hanushek, 1989), most recent research supports the claim that unequal funding and access are significantly related to unequal achievement (Elliott, 1998; Greenwald, Hedges, & Laine, 1996; Hedges, Laine, & Greenwald, 1994; Hedges & Nowell, 1999; Payne & Biddle, 1999; Van Laar & Sidanius, 2001). Specifically, spending less per student does affect academic achievement (Elliott, 1998; Payne & Biddle, 1999). The relationship between unequal funding and access to level of achievement is supported by a recent re-meta-analysis of Hanushek’s (1989) research that had refuted this relationship. Using the same data

that Hanushek used, but employing more sophisticated meta-analytic techniques (combined significance tests and combined estimation methods, cf. vote count methods), Hedges, Laine, and Greenwald (1994) found that higher Per Pupil Expenditure (PPE) *was* significantly (positively) related to student academic achievement.

A review of seven nationally representative studies of twelfth graders from 1965–1992 was conducted to determine whether the achievement gap could be attributed to differences in social class (Hedges & Nowell, 1999). Using the linear equating method to compare indices across surveys, the authors found that social class accounted for approximately one-third of the differences across science achievement test scores (similar results were obtained for other curricular subjects) (Hedges & Nowell, 1999). A good portion of the relationship between social class and science achievement can be explained by resources being allocated to teachers' salaries, teacher training in emphasizing inquiry skills, and providing adequate science equipment (Elliott, 1998). As one author concludes, not only does money matter, how the money is spent also matters (Elliott, 1998).

School funding and socioeconomic status are substantive predictors of mathematic achievement as well (Tate, 1997). If one includes curriculum level as a predictor (better schools are presenting higher levels of curriculum), the three predictors explain 33% of the variability in mathematics achievement across the nation (Payne & Biddle, 1999; Tate, 1997). Interestingly, race-ethnicity was not a predictor

of mathematics achievement when the other three variables were included in the regression equation (Payne & Biddle, 1999; Tate, 1997). However, race was highly correlated with child poverty and lower levels of curriculum (Payne & Biddle, 1999).

Because blacks are disproportionately represented in the lower socioeconomic strata of society, achievement in science and other areas is more likely a function of class rather than race (Hill, Pettus, & Hedin, 1990). Biddle (2001) suggests that race, ethnicity, and social class interact with poverty to affect education in complex ways. The overrepresentation of minorities in lower socioeconomic neighborhoods is one way researchers approach the minority/majority achievement gap. One can contend, then, that a main reason for the gap in science or math achievement is less Per Pupil Expenditure—that is, fewer resources and less access to pedagogical tools. Another explanation for the achievement gap lies in culturally different ways of learning and knowing.

Cultural Variations in Learning and Knowing and the Achievement Gap

Aside from the argument that minority achievement levels are more likely a function of the high proportion of minorities in low-SES situations, another explanation is gaining support among educators and researchers. Minority students are raised in different cultures than majority students, and, therefore, learn, understand, and communicate in very different ways. Researchers with this point of view believe that “...if science is open to multiple ways of knowing, doing, and communicating, then those students whose lives are not mirrored in traditional school science will find

connections between themselves and science more easily” (Barton, 1998, p. 528). This view expresses a need for culturally relevant pedagogy.

Culturally differentiated ways of learning and knowing are embedded in culturally variable world views (Nelson-Barber & Trumbull Estrin, 1995). Such differences include: (a) learning patterns and approaches to problem solving, (b) ways of communicating knowledge, and (c) values of what is important or appropriate to know (Nelson-Barber & Trumbull Estrin, 1995). Ogbu (1995) articulated this argument well: culture is an adaptive way of life for a group of people, which produces cultural ideas, values, emotions, perceptions, skills, and behavioral patterns.

Ogbu (1995) acknowledged that different cultures often exist within a given population and these cultures differ in their adaptations in life. These differences may be due to alternative physical or social environments (low-socioeconomic neighborhoods) or due to alternative historical experiences that have shaped how cultural members perceive and react to their environment and others. The culture within the school, which prescribes specific learning styles, may differ greatly from a child’s own culturally acquired learning styles (Ogbu, 1995). Disparity between the school culture and the child’s culture may lead to falsely assessing a child’s intellectual abilities (Ogbu, 1995). The discrepancy between school culture and a child’s home culture often leads to unsuccessful learning experiences for these

children, while a goodness of fit between the school culture and the child's culture leads to a more successful learning experience.

A person's culture also defines what is important to learn, how to learn, what to remember, and how to interpret or perceive information (Nelson-Barber & Trumbull Estrin, 1995). Children are enculturated to values that underlie the understanding of science. In the school system, children are enculturated to science discourse that may or may not mesh with their previous values and understanding of science (Nelson-Barber & Trumbull Estrin, 1995). Integrating these values and patterns of discourse is part of learning which all students face; however, certain cultures may more easily integrate while others face more challenges in this integration process (Nelson-Barber & Trumbull Estrin, 1995). Usually children from the dominant culture fall into the former category, while children from the non-dominant culture often fall into the latter (Nelson-Barber & Trumbull Estrin, 1995).

Culture influences the way a population communicates. The United States is a pluralistic society with many different cultures or subcultures, each with their own distinct communication norms. Cross-cultural communication can often challenge those norms and lead to communication bias (Ogbu, 1995). Sources of culturally-based communication and language-based bias include: *situational bias*, *communicative style bias*, and *cognitive style bias* (Cole & Griffin, 1987; Taylor & Latham Lee, 1987). Taylor and Latham Lee (1987) defined each in turn. *Situational bias* refers to the cultural differences regarding who may speak to whom, how language is produced and

interpreted, and expectations/behaviors within various social situations. *Communicative style bias* refers to the divergent values, rules of interaction, and event perceptions that influence how one relays information. An example of communicative style for African Americans is the cultural resistance to stating the obvious (as in the obvious answer to an obvious question on a test) (Ward, 1971). *Cognitive style bias* refers to how individuals perceive, process, and organize information. There are various cognitive styles, which may be elicited through sociocultural factors, economic factors, or child rearing practices. Cognitive style may influence linguistic style. Taylor and Latham Lee (1987) related these and other biases to test-taking issues (see also Clawson, Firment, & Trower, 1981), while other researchers have related these biases to the judgment of students' abilities (Nelson-Barber & Trumbull Estrin, 1995). These differences highlight the need for culturally responsive pedagogy. Seiler (2001) argued that national standards and schools tend to ignore sociocultural, political, and economic contexts of minority and low-SES students. Addressing the interests, abilities, and aims of the students in pedagogy will allow learning to take place, learning that will address the achievement gap (Seiler, 2001).

Differences in achievement scores between low-SES, African Americans and middle- to high-SES, white Americans exist. These differences may be largely due to resources or cultural variations in learning, understanding, interacting, perceiving, and communicating. It is feasible that, regardless of the underlying reason for these

differences, one can identify the discrepancy in achievement and identify ways to diminish the gap that address both resources and culturally relevant pedagogy.

Where Do African Americans Currently Stand in Relation to Science Achievement?

According to the National Center for Educational Statistics, a six-year gap in science was detected in 1994, meaning that African American seniors in high school were performing at a sixth-grade level in science (Thernstrom & Thernstrom, 1997). A similar achievement gap for black students in science was observed for children at the ages of nine and thirteen (Thernstrom & Thernstrom, 1997). According to White (1992), the science achievement gap exists across all age groups. The previously mentioned review conducted by Hedges and Nowell (1999) discovered that black Americans were over-represented in the lower 5% of achievement test scores and, at a greater magnitude, underrepresented in the upper 5% of test scores.

African Americans comprise 12% of the population, 9% of the total work force, and 7% of total workforce in science and engineering (Bureau of Labor Statistics, 2003; Division of Science Resources Statistics, 2004; National Science Board, 2002). Fields such as science and industry are beginning to look toward minorities to fill their positions. “In a very real sense, the ability of the United States to retain and improve its position as a world economic power depends heavily on the Nation’s ability to recruit, train, and retain talented scientists and engineers” (White, 1992, p. xi). The National Task force on Women, Minorities, and the Handicapped in Science and Technology (1989) was formed to try to increase parity in both science and technology education and workforce.

Some research suggests that the achievement gap is diminishing (Tate, 1997); other research suggests the gap leveled off at some point in the 1970s (Hedges & Nowell, 1999); and still other research suggests the gap has widened since the 1970s (Thernstrom & Thernstrom, 1997). Regardless, the fact is that the achievement gap still exists. It is possible to use our knowledge about unequal resources and the need for culturally relevant educational tools to actively eradicate the gap.

What Special Role Might Museums Fill in Science Learning for Low-income African American Middle School Students?

As mentioned, reducing the achievement gap has long been a priority of the education system (The National Task Force on Women, 1989; Van Laar & Sidanius, 2001). An eradication plan should provide access to a greater variety of educational contexts, such as museums. Van Laar and Sidanius (2001) suggested that the limited wealth of low status children also limits access to enriching experiences such as visits to museums, cultural events, and trips to far away places and exotic cultures. Beane and Pope (2002) suggested that museum visits may be especially important for underserved youth:

Although all youths can benefit from these programs, the probability of a positive impact on the observable affective and cognitive development is even higher for adolescents who, because of their cultural or economic backgrounds, have previously lacked regular

access to the science museum, its objects, exhibits, programs, and people (p. 327).

Addressing these inequalities could be a way to minimize the achievement gap.

Museums could increase funding and access by targeting funding agencies to promote increased numbers of field trips for children who attend low-status schools.

Because many classrooms have decontextualized learning in areas related to science (Nelson-Barber & Trumbull Estrin, 1995; Ogbu, 1995), field trips can aid in reestablishing the context, and perhaps the relevance, of the subject matter.

Recontextualization will help improve science education for minorities; museums are one way to supplement school curriculum through recontextualizing the information (Cole & Griffin, 1987). Hands-on contextual learning and experiential activities may help children to learn in ways that are relevant, comfortable, and understandable to them.

In order to increase a visitor's willingness to explore, investigate, question, and challenge, an exhibit must be personally or culturally relevant to the visitor. The amount of personal connection between the learner and what is taught is directly related to what is learned (Hein, 2001). Recognizing the importance of learners' backgrounds is necessary in creating culturally relevant exhibits. A museum exhibit can achieve relevance through graphics, text, or activity. If any or all of these factors are personally or culturally relevant to the learner, cognitive and/or affective gains are more likely to occur.

Research also indicates that African American students may learn better in contexts that involve movement (Allen & Boykin, 1991; Boykin & Allen, 1988; Boykin & Cunningham, 2001). Allen and Boykin (1991) discovered that low-socioeconomic status African American students performed significantly better than low-socioeconomic status European Americans on recall tasks when exposed to information in a high movement situation accompanied by music. Conversely, low-socioeconomic status European Americans performed better than low-socioeconomic status African American students on recall tasks when exposed to information in a low movement, sans music, rote situation. In a similar study, Boykin & Cunningham (2001) discovered that these effects are stronger for encoding processes than inference processes, although African Americans revealed increased ability for both processes when taught in a high movement context. Low movement, rote situations are similar to those found in school contexts, while high movement contexts are similar to those found in informal educational environments. According to the findings of Boykin and his colleagues (Allen & Boykin, 1991; Boykin & Allen, 1988; Boykin & Cunningham, 2001), cultural experiences may prime children from different backgrounds to experience compatibility within different learning contexts.

Unlike school learning, which depends on verbal or written symbols for communication, learning in a museum relies more on direct hands-on interaction with objects and depends on nonverbal pedagogy (Ramey-Gassert, 1997), which can be more relevant to lower socioeconomic and minority children (Ogbu, 1995). If an

exhibit is personally or culturally relevant, the likelihood of reaching the learner is increased. It is also plausible that the active context of a hands-on museum will be compatible with African American cultural experiences and allow for increased understanding and recall ability (Boykin & Cunningham, 2001).

What Has Past Research Found in Regard to Low-income or Minority Children and Informal Learning?

The informal learning community has realized the importance of extending resources to minority and lower SES neighborhoods. Leisure research indicates that participation in cultural activities, such as museums, is significantly less likely for non-white, as well as lower class, Americans (Dimaggio & Ostrower, 1990; Falk, 1995; Stamps & Stamps, 1985). The Commission on Museums for a New Century reported in 1984 that cultural pluralism in museum exhibits, employees, and visitors should be a focus for museum practice (Able, 1989). As previously mentioned, a major problem in diversifying the visitor population is unequal access to programs for children from differing SES backgrounds (ASTC, 2001; Quinn, 1999). Most museums have made efforts to attract and fund programs for underrepresented populations, and most have been successful in diversifying their visitor population.

Although many interactive museum programs have targeted lower SES and minority youth (cf. YouthALIVE!), very little research has been published on the effectiveness of these programs. For example, the YouthALIVE! program was developed to enhance opportunities for adolescents from minority and low-income

communities (Beane & Pope, 2002). YouthALIVE! programs exist in over 70 museums. As of 1999, 71% of all participants were from low-income communities and over 46% of the program participants were African American (ASTC, 2001). Yet, even the YouthALIVE! program director acknowledges that little rigorous research exists on such programs (Beane & Pope, 2002). Only a few of the previously mentioned museum studies specified a fairly diverse subject pool (Balling & Falk, 1980; Falk, 1983b; Falk & Storksdieck, 2002; Paris et al., 1998; Stover & Saunders, 2000), while many did not identify the socioeconomic or ethnic makeup of participants (Eason & Linn, 1976; Eratuuli & Sneider, 1990; Falk, 1983b; Falk & Balling, 1982; Farmer & Wott, 1995; Finson & Enochs, 1987; Flexer & Borun, 1984; Gilbert & Priest, 1997; Henriksen & Jorde, 2001; Kubota & Olstad, 1991; Paris, Troop, Henderlong, & Sulfaro, 1994; Prentice, Guerin, & McGugan, 1998; Rix & McSorley, 1999; Stronk, 1983; Tulley & Lucas, 1991; Tunnicliffe & Laterveer-de Beer, 2002; Wright, 1980). A review of the literature revealed two main studies that focused on minority or low-SES populations and informal education.

The first study evaluated the effectiveness of the City Farmers program in teaching inner-city, African American teens about teamwork, gardening, garden science, community, and work (Rahm, 2002). Through videotaped observation the researcher was able to identify three types of questions posed during the project: (a) information questions, (b) knowledge integration questions, and (c) inquiry questions

(Rahm, 2002). The author found that these questions normally led to emergent learning for the participants.

The second study was conducted shortly after revamping the Young Scholars Program at Ohio State University to emphasize hands-on activities (Jones, 1997). This program worked with underserved, African American youth from urban residences. Through qualitative research methods, Jones identified the importance of framing information in relevant ways for this population. The researcher found that hands-on activities increased understanding and interest about agriculture and science by making the material more contextually relevant for the target population (Jones, 1997).

As shown earlier, museums can be a valuable resource for increasing learning and interest in core school curriculum topics, such as science and technology. Supplementing school-based curriculum with interactive museum visits can enhance children's learning (Resnick & Chi, 1988). Increases in understanding and interest can help minority and low-SES students attain higher levels of achievement, therefore reducing the aforementioned achievement gap. The current low levels of achievement are related to later college attendance and achievement in the job market. Fields such as science are actively trying to diversify their employee pool (White, 1992). If interactive museums can help to increase achievement and improve attitudes toward (especially career interest) science for minority and low-income children, they may effectively aid in the diversification of such organizations.

Developmental Theory and Museum Learning

When conducting research that spans the fields of psychology, formal education, and informal education, one must consider theories that can illuminate the understanding of each field and the implications of the results in each field. As previously mentioned, America is a pluralistic society in which many subcultures are represented. Because this research will be conducted with youth from a low-socioeconomic, primarily African American culture, it is important that the theories behind the research be culturally sensitive, such as constructivism, or culturally explicit, such as sociocultural theory. Constructivist theory has been mentioned in psychology literature (Hatano, 1993), formal education literature (Nelson-Barber & Trumbull Estrin, 1995), and museum literature (Anderson, Lucas, & Ginns, 2003; Hein, 1991, 1999, 2001). Sociocultural learning theory has also been addressed within psychology (Cole, John-Steiner, Scribner, & Souberman, 1978; Hatano, 1993), formal education (Cobb, Wood, & Yackel, 1993; Moll & Whitmore, 1993; Nelson-Barber & Trumbull Estrin, 1995), and informal education (Dierking et al., 2003; Jensen, 1994; Ogbu, 1995). The two theories often coincide, creating what one author deems constructivist Vygotskianism (Hatano, 1993). Due to the relevance of context in this research, apprenticeship learning or situated cognition theory is also necessary in understanding the research results. Each will be explored, in turn, and related to museum learning.

Constructivism

Recent theories in museum studies and education are often grounded in personal construction of meaning and understanding made possible by individual experiences and knowledge prior to the museum visit or class lecture. These theories can be summarized by constructivism, which is a function of two beliefs: the learner must be active, physically and mentally, in their construction of knowledge, and the knowledge constructed must be relevant (personally, culturally, and socially) to the learner. Constructivism is an ideal theory for museum learning because the theory encourages an interactive environment, substantiates the importance of gaining mental processes for understanding, establishes play as a learning experience, and is inherently sensitive to cultural and individual diversity (Hein, 2001). However, it is important to note that both Falk and Hein warn that a *single* museum visit may not be sufficient for visitors to construct new attitudes, meaning, or understanding regarding a topic (Falk, 1999; Price & Hein, 1991).

Constructivist theory is not new in psychology. Many constructivist views may be traced back to Piaget's notion that children actively construct knowledge (Miller, 1993). Constructivist theorists view the individual as active in the process of learning (Nelson-Barber & Trumbull Estrin, 1995; Novak, 1993). A child's (or adult's) role in learning is often viewed as reciprocal (Hein, 2001; Moll & Whitmore, 1993)—the child influences their environment as their environment influences them. This

reciprocal interaction between the knower and the known can also be seen in Piagetian theory (Miller, 1993).

Once it is understood that Piagetian theory may underlie constructivist theory, it is important to recognize that constructivism is separate and sheds new light on learning. The constructivist theory of learning acknowledges that individuals' current conceptions are products of diverse personal experiences, observations of objects, culture, language, and pedagogy (Anderson et al., 2003). Constructivism posits that a person's ideas, prejudices, memories, opinions, and worldviews play a role in their (socially-mediated) construction of knowledge or meaning making (Hein, 1999).

Ideally, constructivism is the capacity for human beings to use prior understanding in the construction and communication of meaning (Novak, 1993). When viewing learning through a constructivist lens, a child's experiences and influences interact to create a new sense of meaning. Because children's experiences influence their current understanding, these experiences and interactions will forever pervade each new experience, perception, interpretation, and subsequent understanding of concepts. An exhibit's relevance to the learner depends on the learner's background (i.e., perception, worldview, previous knowledge, and skills) (Hein, 1995). If a learner experiences a personal or cultural connection to an exhibit, then cognitive or affective gains are more likely to occur.

Learning, according to constructivism, can be gradual or occur as a rapid restructuring of conceptual knowledge (Anderson et al., 2003; Nelson-Barber &

Trumbull Estrin, 1995). These processes are similar to Piaget's assimilation, accommodation, and equilibration processes. When learners experience different variations or interpretations of a concept, their own personal meaning eventually (gradually as in assimilation) combines with field knowledge to create their own, more complete, understanding of the field (Hein, 2001). As in Piaget's accommodation process, constructing one's own personal meaning eventually requires one to replace previous concepts. Piaget believed that concept development occurred out of the necessity to resolve conflicting ideas, which are provoked through questions and resolved through a process deemed equilibration (von Glasersfeld, 1996). These conflicting ideas oftentimes result during peer interaction and are resolved between peers. A museum field trip, employing small student groups, may facilitate such equilibrating concept development. Accommodation is not guaranteed in any learning situation (Hein, 2001), therefore, it is important to provide repeated exposure and varied experiences to allow children to gradually subsume field knowledge in their own personal meaning of a concept. For the purpose of the current study, it was thought that the museum visit could either be the necessary repeated exposure and varied experience, therefore enhancing learning opportunities, or the *single* visit could be an inherent limitation, which could make it difficult to see any significant increases in understanding or attitudes toward science.

Vygotsky, Contextualism, and Socioculturalism

Contextualism and constructivism share many underlying theoretical views. As in constructivism, contextualism maintains the child actively constructs knowledge, and the child's previous knowledge, language, perceptions, and interactions all influence the child's subsequent learning and meaning making. The most notable difference between the two theories is that constructivists view the child as influencing the environment and vice versa, while contextualists believe that these effects cannot be separated. Contextualists view the child-in-activity-in-context as the unit of study, meaning that the child is shaped by his or her social-cultural-historical context (Cole et al., 1978; Miller, 1993; Rogoff, 1990). These contexts are inseparable—the focus of contextual research is on the process of child in culture in context in history as a unit. This distinction, however, is not often made in the research literature, and the distinguishing lines in defining the unit of study are often crossed by both constructivists and contextualists.

Vygotsky is considered a contextual theorist. Vygotsky's most cited theoretical concept is the zone of proximal development, often referred to as the "zone." Vygotsky acknowledged that a child could reach a certain degree of understanding or ability alone (Cole et al., 1978). Vygotsky also recognized that when an adult or more skilled child scaffolds—prompts, encourages, and assists—a child, that same child can reach their full potential in understanding or ability (Cole et al., 1978). Vygotsky believed that a child's full potential already existed within the child but was not within

the child's immediate grasp without scaffolding (Cole et al., 1978). The difference between the child's actual ability and the level of competency possible when scaffolding is present is the zone of proximal development (Cole et al., 1978).

Functions which are not matured, but in the process of maturing, are the functions that are effectively encouraged by the zone (Cole et al., 1978; Miller, 1993).

In most literature, scaffolding is provided by an adult or more experienced child, however, many believe Vygotsky's scaffolding referred to "...any situation in which some activity is leading children beyond their current level of functioning" (Miller, 1993, p. 384). Therefore, in the context of this research, it was thought that the exhibit activities would also scaffold the child's level of understanding. Hands-on experiences within an interactive museum can help children to reach potential understanding of a topic that may otherwise need more time (days, months, years) to mature. Ideally, a school lecture will introduce a child to a set of concepts. An exhibit must find the appropriate level at which to engage the learner. Following a child's introductory understanding, a well-designed exhibit that allows the child to question, investigate, and manipulate the properties at a higher level should scaffold the child and allow the child to reach a greater level of understanding.

Vygotsky viewed learning as the process, not the product—learning stimulates internal developmental processes which operate in a social environment containing more skilled others (Cole et al., 1978). Eventually these processes are automated and internalized and the child has advanced developmentally (Cole et al., 1978). Given the

developmental process Vygotsky associated with learning, it was thought that identifying what was learned after a single visit, without giving the child time to consolidate and automate the information, could prove difficult (Cole et al., 1978; Falk, 1999). The majority of school curriculum is aimed at children's actual developmental level, but Vygotsky argued that it is necessary to teach in the zone, thus allowing children to reach a new, higher stage of the developmental process (Cole et al., 1978). Hands-on processes learned in a science museum can stimulate learning at a higher level, learning within the zone of proximal development. "Science centers are envisioned to entice learners to go beyond their present knowledge and to construct a newer, larger vista of scientific thinking" (Ramey-Gassert, 1997, p. 436). Vygotsky also believed in the importance of cultural and social influences on cognitive development.

Vygotsky's sociocultural theory postulates that the culture in which one lives permeates all aspects of that person's life. Some cultural influences are listed (Miller, 1993) followed by parenthetical examples: beliefs (religion), knowledge (poisonous vegetation), values (collectivism), interactions (engagement), customs (holidays), language (verbal and nonverbal), skills (how to hunt), structures (transportation systems), and objects (technology). Culture is considered a medium through which experiences are perceived, interpreted, understood, and enacted (Miller, 1993).

A child's gain in knowledge and conceptual understanding is mediated by their cultural influences (Miller, 1993). A child's culture will provide them with

psychological tools, which will influence both thought and behavior in the learning process (Miller, 1993). For instance, language is thought to be the most powerful psychological tool provided by a culture, shaping a child's thought, attention, perception, behavior, speech, and goals (Cole et al., 1978; Kozulin, 1986; Miller, 1993). All of the psychological tools provided by one's culture influence a learner's perception of relevance of a topic or exhibit. Exhibit relevance can influence how a learner perceives, attends to, interacts with, and discusses an exhibit. The tools emphasized within a culture are related to the cultural needs and values, and therefore differ between cultures (Miller, 1993). This is important in understanding how children raised in a subculture, such as those in the pluralistic United States, are expected to respond and interact within a culture that emphasizes different tools (language, communication, values, and skills). Contextualist and sociocultural research is collected across countries, social classes, and ethnic groups (Kozulin, 1998; Miller, 1993).

In Vygotsky's sociocultural theory, all intellectual functioning exists primarily between two individuals (adult-child or more skilled child-child) (Miller, 1993). This intermental activity (intersubjectivity) eventually turns inward, whereupon the child begins to use what they have learned socially and culturally in an intramental, personal manner (Miller, 1993; Rogoff, 1990). This theory suggests that all thought is conceived through social interaction that is culturally mediated and therefore will always be seen through this sociocultural lens. "Different types of settings offer

different types of interpsychological activities” (Miller, 1993, p. 386). What a child experiences at home influences school experiences, both of which will influence museum experiences, which will reciprocally influence future experiences in the school and at home. All of these contextual experiences will be internalized in the child’s active interpretation of his or her world (Miller, 1993).

As previously mentioned, sociocultural research has focused on intercultural cognitive differences between social class and minority/majority cultures. Researchers have developed a deeper understanding of social class and minority cultural differences in the U.S. education system. Some researchers (cf. Vygotsky) believe that, “Intercultural cognitive differences are attributed to the variance in systems of psychological tools and in the methods of their acquisition practiced in other cultures” (Kozulin, 1998, p. 102). Others (cf. Cole) posit that minority differences do not lie in the acquisition of cognitive processes but in the culturally required manifestation of these processes, which differ depending on context. Kozulin believes that different cultures and subcultures approach learning material, mediating language, and problem solving in manners that lack parity. Majority students, Kozulin argues, grow up thinking, talking, and interacting in a manner conducive to school learning. Minority children often do not have the same exposure to cognitive practices that are conducive to school-based learning (Kozulin, 1998). Thus, children trying to work within two cultural systems often find themselves torn between what may seem a competition between their home culture and the dominant school culture. Typically, both cultural

systems suffer (Cobern, 1993; Rogoff, 1990). If an educational venue such as a museum can approach a topic in a manner that is culturally relevant to minority children, then that educational venue can help enhance interest and understanding of that topic. Apprenticeship learning, or situated cognition, is a theory often embedded in sociocultural theory, which is commonly used when addressing cognitive learning. Additionally, many researchers follow a combined constructivist-contextualist approach to understanding learning.

Apprenticeship Learning/Situated Cognition

A related theory is apprenticeship learning or situated cognition, which are terms used interchangeably by researchers and theorists. The main focus of this theory is learning in doing (Lave, 1990), in other words—learning experiences are contextually embedded. “Cognitive apprenticeship is the development of concepts through continual authentic activity” (Brown, Collins, & Duguid, 1989, p. 39). Through varied experiences, a concept will continually gain new meaning and understanding, because each repeated occurrence adds a new context through which the person’s understanding of the concept will be re-shaped, re-assessed, and further comprehended (Brown et al., 1989).

Many argue that the defining difference between formal and informal learning is that formal learning is decontextualized and abstracted, while informal learning is context-embedded and fairly concrete or applied (Brown et al., 1989; Lave, 1990). Situated learning theorists hold that the process of learning relies on practice, and is

socially and culturally constituted (Lave, 1990). Apprenticeship learning is presented as a valuable tool to “think with” when creating curriculum, not a practice that can be carried out verbatim in contemporary Western schools (Lave, 1990, p. 311). Why is apprenticeship learning exemplary? One example concerns enhanced motivation that results from learning in contextually meaningful situations. Lave (1990) contests that 85% of apprentices become masters, and that when the apprentices do resign the reasons are usually extraneous.

Ownership of the problem is an integral part of apprenticeship learning (Lave, 1990). The master does not present a hypothetical problem and ask the apprentice to solve it; rather the apprentice naturally encounters each problem and is motivated to solve each in the given situation (Lave, 1990). Apprentices are motivated to solve problems because the problems, once they arise, are their own. In other words, the problems have been made personally relevant. In apprenticeship learning, the learner is presented with numerous and varied opportunities to independently practice and solve relevant problems (Lave, 1990). After a period of observation, apprentices experiment until they can create a close approximation and then they practice (Lave, 1990). The current research project allowed children at the museum to experiment with presumably relevant problems, however, the single visit limited the children’s ability to practice and experiment numerous times.

Contrary to apprenticeship learning (and hands-on learning), in a typical educational environment, children do not rely on themselves to creatively identify a

solution or discover a procedure (Lave, 1990). Science and math are often explained as “what experts know”—devoid of scientific inquiry processes (Lave, 1990).

Education should allow children to assign meaning to concepts and critically analyze relationships between concepts; this enables learning in relation to one’s own life and gives value to the subject at hand. Museums can enable learning in relation to one’s own life and give value to the topic by providing exhibits that are designed to elicit culturally and personally relevant connections. Learning which is embedded within activity employs both physical and social contexts and helps to deepen understanding, the activities give meaning and purpose to formal education (Brown et al., 1989; see also Falk & Dierking, 1992; Lave, 1990). Museums can supplement formal education by providing a variety of interactive experiences, where children can actively participate, identify their own questions, and manipulate portions of the exhibit to solve those questions. Once children view themselves as active in the appropriation of knowledge, they are more likely to pursue new information, thus entering a world of self-directed, sustainable knowledge (Lave, 1990).

A Constructivist Vygotskianism? Combining Constructivism and Contextual Socioculturalism.

Due to the similarities in conceptual views amongst constructivists and contextualists, it is not surprising that the two theoretical viewpoints often cross boundaries. Some researchers are even advocating a “constructivist Vygotskian

conception” (Hatano, 1993, p. 156). Hatano (1993) outlines four core assumptions necessary to achieve this conception:

- 1) Learners are active throughout life, they actively explore and interact with objects and with others.
- 2) Learners seek to understand and are able to gain new knowledge through relevant prior knowledge.
- 3) Learning occurs in both horizontal and vertical social interactions.
- 4) Knowledge construction is enhanced through multiple resources; bits of orthogonal information are eventually juxtaposed to create further conceptual understanding.

Children’s personal experiences that lead to either confirming or disconfirming information serve to enhance their ability to shape information into conceptual understanding (Hatano, 1993). The type of research Hatano deems constructivist Vygotskianism is exemplified by the work of Moll and Whitmore (1993) and Cobb, Wood, and Yackel (1993).

Moll and Whitmore (1993) conducted a classroom case study aimed at teaching practices that incorporated cultural and social transaction in teaching and learning. The authors believe that semiotic and social interactions mediate the construction of meaning (Moll & Whitmore, 1993). The active child appropriates these mediation techniques through cultural and social interactions, these mediation techniques in turn influence the child’s meaning making in future learning experiences

(Moll & Whitmore, 1993). Moll and Whitmore discovered that employing authentic and relevant tasks and materials facilitated these meaningful interactions in the classroom and was highly conducive to learning.

In a research study conducted with “constructivist Vygotskian” practices in second grade mathematics classrooms, Cobb, et al. (1993) explicitly viewed learning as actively constructed in the face of experientially based problems. The researchers and teachers focused on the importance of communication and social interactions in children making meaning of mathematics and also avoided predetermined “correct” reasoning and approaches to obtain answers (Cobb et al., 1993). Therefore, the children were free to reason amongst themselves and determine differential approaches to the mathematic questions. The teacher and students together ascertained mathematical justifications and explanations. They then reformulated these explanations in ways that were compatible with both the students and socially acknowledged mathematical practices (Cobb et al., 1993). Quantitative results indicated that participating students’ scores did not differ from non-participating students’ scores on computational measures and were significantly higher on the concepts and application portion of a state test (Cobb et al., 1993).

The above examples of constructivist Vygotskianism focus on the child as the unit of analysis. However, the researchers incorporated contextually relevant learning environments via Vygotsky’s sociocultural perspective. It is easy to see how the combination of these two theoretical approaches can be used in the study of museum

learning. As one researcher said, "...as museum visitors interact with museum collections, they construct personal and social meanings which are unique to their individual characteristics and cultural backgrounds" (Jensen, 1994, p. 301).

Apprenticeship learning, or situated cognition, also approaches learning through a sociocultural perspective, however, the focus on gaining knowledge from doing and learning in the field is more radical than the other approaches mentioned above.

Theories such as constructivism, contextualism and socioculturalism, and apprenticeship learning all highlight why interactive museums should provide an excellent atmosphere conducive to learning. These theories do not, however, explain how a museum visit could encourage conceptual change. Therefore, a simple explanation of conceptual change theory is necessary to elucidate how an interactive museum is an exemplary setting for conceptual change to occur.

Theory of Conceptual Change

Mentally represented structures can be defined as concepts, beliefs, and theory (Carey, 1991). People hold representations of each, building from single concepts into beliefs and possibly, later, into theories about domains of experiences or knowledge. Conceptual change can occur during knowledge acquisition in several ways: core and peripheral concepts can be switched around (what one thinks is the defining characteristic of a concept can become a property of a more fundamental characteristic), concepts can become integrated into larger categories or delineated within categories, and concepts can be organized within separate defining theories

(Carey, 1991). Personal constructivists refer to this process as the deconstruction of misconceptions and reconstruction of valid conceptions (Cobern, 1993). The deconstruction and reconstruction necessary for conceptual change is a gradual transformative process that requires time (Posner, Strike, Hewson, & Gertzog, 1982). Conceptual change in science education occurs when one personally realizes that science conceptions are more intelligible and reasonable than one's own previously held conceptions (Cobern, 1993). The latter two views are similar to Piaget's assimilation, accommodation, and equilibration mentioned above, in fact this terminology is used by some conceptual change theorists (see Posner et al., 1982).

In an interactive museum setting, concepts previously held by students and introduced within the classroom are expected to be experienced in context. Children, through questioning, manipulation, and discussion, should therefore have the opportunity for personal conceptual change. For example, children may switch their understandings of core and peripheral concepts, integrate concepts, delineate concepts, or add new concepts to pre-existing understandings due to their further, hands-on exploration of a phenomenon. It was uncertain whether the single opportunity to visit a science museum proposed for this study would be sufficient for conceptual change to take place. However, if conceptual change did occur, it was thought that it would be easily identified through concept mapping, the qualitative method described in detail below.

Purpose of the Present Study

The purpose of the present study was to evaluate the impact of an interactive museum visit to OMSI for African American children from a low-socioeconomic neighborhood on enhancing school learning and improving attitudes toward science.

Several factors were taken into account:

- Level of Engagement while interacting with the exhibits.
- Number of Previous Visits to a science museum (such as OMSI) in the past two years (novelty).
- Student's Prior Knowledge (current science grade).
- Child's perception of Peers' Attitudes toward science.
- Child's perception of Home Support.
- Child's perception of exhibit Relevance.

Data were collected from three classes at Inner City Middle School.* Participants from ethnic backgrounds other than African American or from middle- to high-SES homes were not included in the data analyses. A mixed-methods design was employed, seeking convergence of qualitative and quantitative methods for assessing cognitive learning and allowing for a more in-depth understanding of attitudinal measures.

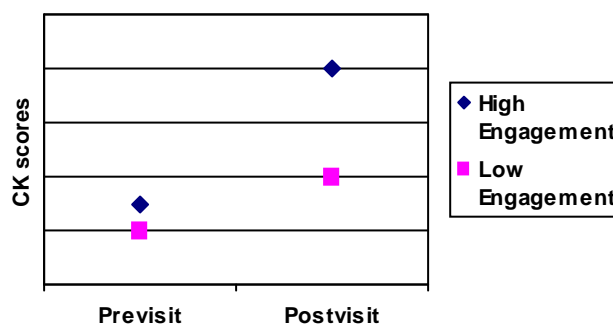
* Name has been changed to protect the anonymity of the participating school and students.

Hypotheses

Hypothesis 1. Content Knowledge Scores were expected to increase significantly from Pre- to Post-Museum Visit when averaging over possible modifying variables. The following interactions were examined:

- A. A significant interaction was expected between Pre/Post-Museum Visit and the level of Engagement while at the exhibits on Content Knowledge Scores. Specifically, children who exhibited High Engagement at the museum exhibits were expected to demonstrate higher gains on Content Knowledge Scores, while children who exhibited Low Engagement were expected to demonstrate little or no gains in Content Knowledge Scores (see Figure 3).

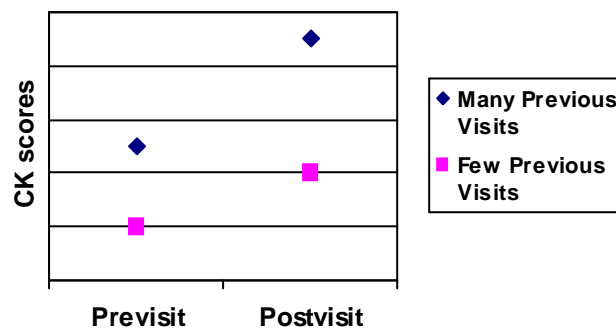
Figure 3 Expected Interaction between Pre/Post-Museum Visit and Engagement on Content Knowledge Scores



- B. A significant interaction was expected between Pre/Post-Museum Visit and Previous Visits to a science center on Content Knowledge

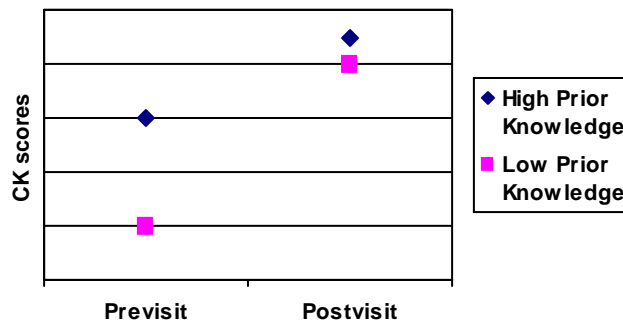
Scores. Specifically, children who had experienced more than one Previous Visit to a science center were expected to experience higher gains in Content Knowledge Scores (see Figure 4).

Figure 4 Expected Interaction between Pre/Post-Museum Visit and Previous Visits on Content Knowledge Scores



- C. A significant interaction was expected between Pre/Post-Museum Visit and children's Prior Knowledge on Content Knowledge Scores. Specifically, children with Low to moderate Prior Knowledge were expected to show larger gains in Content Knowledge Scores (see Figure 5).

Figure 5 Expected Interaction between Pre/Post-Museum Visit and Prior Knowledge on Content Knowledge Scores

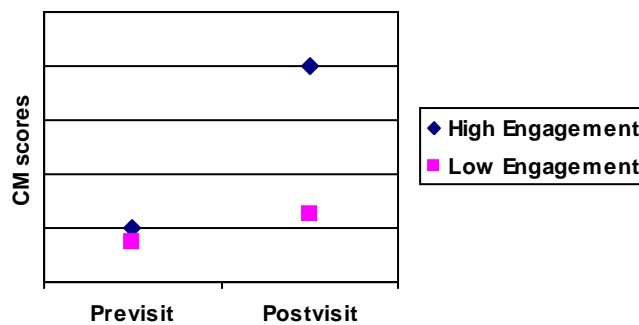


D. An exploratory analysis was conducted to discover whether an interaction occurred between Pre/Post-Museum Visit and children's level of Home Support on Content Knowledge Scores, however, no specific hypotheses were made.

Hypothesis 2. It was hypothesized that Concept Map Scores would increase significantly from Pre- to Post-Museum Visit when averaging over possible modifying variables. Changes to concept maps include: (a) number of propositions (labeled connections between two concepts); (b) number of examples provided; and (c) number of cross-links, which are indicative of knowledge integration. The aforementioned map changes were added together to create an overall Concept Map Score for each individual. The following interactions were examined:

- A. A significant interaction was expected between Pre/Post-Museum Visit and level of Engagement while at the exhibits on Concept Map Scores. Specifically, children who exhibited High Engagement at the museum exhibits were expected to demonstrate greater gains in Concept Map Scores, while children who exhibited Low Engagement were expected to demonstrate little to no conceptual gains (see Figure 6).

Figure 6 Expected Interaction between Pre/Post-Museum Visit and Engagement on Concept Map Scores



- B, C, and D. The interactions between Pre/Post-Museum Visit and Previous Visits, Prior Knowledge, and Home Support on Concept Map Scores (hypotheses B, C, and D, respectively) were all expected to be non-significant because concept maps are open-ended, thus allowing for all individuals (regardless of Previous Visits, Prior Knowledge, or Home Support) to make personal

changes to their concept maps (see Figures 7, 8, and 9, respectively).

Figure 7 Expected Interaction between Pre/Post-Museum Visit and Previous Visits on Concept Map Scores

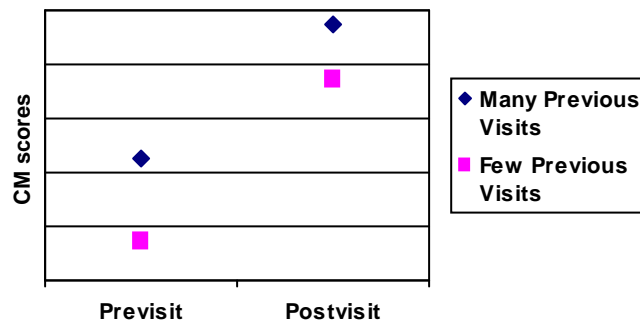


Figure 8 Expected Interaction between Pre/Post-Museum Visit and Prior Knowledge on Concept Map Scores

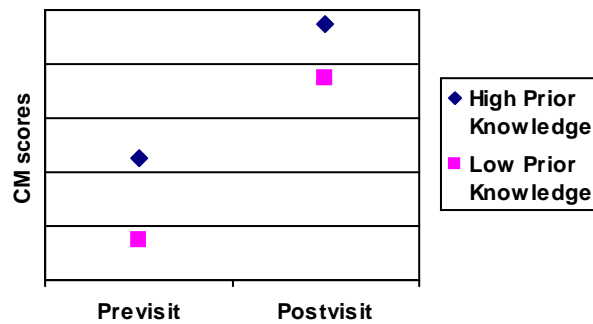
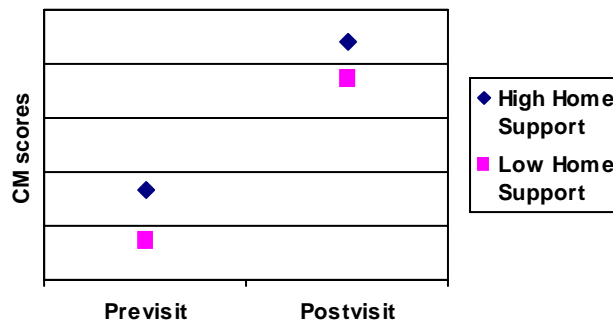


Figure 9 Expected Interaction between Pre/Post-Museum Visit
and Home Support on Concept Map Scores



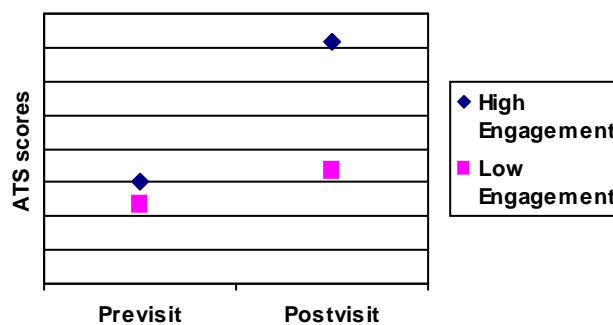
Concept maps may be able to reveal whether the museum visit has made the topic more relevant to the students. For example, if children view the topic as more relevant then they may include themselves, or people they know, in their post-museum visit concept maps. Consequently, personal references in concept maps were tallied and examined.

Hypothesis 3. Differences were not thought to be strong enough to espouse specific hypotheses regarding changes in students' Attitude Toward Science Scores from Pre- to Post-Museum Visit. However, interactions were expected to yield strong results:

- A. A significant interaction was expected between Pre/Post-Museum Visit and level of Engagement while at the exhibits on Attitude Toward Science Scores. Specifically, children who exhibited High Engagement were expected to experience the highest gains in

Attitudes Toward Science Scores, while children who exhibited Low Engagement were expected to show the least gains in Attitude Toward Science Scores (see Figure 10).

Figure 10 Expected Interaction between Pre/Post-Museum Visit and Engagement on Attitude Toward Science Scores



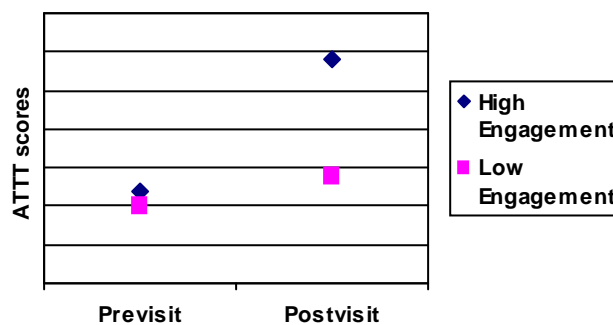
- B. An exploratory analysis was performed to discover whether an interaction occurred between Pre/Post-Museum Visit and children's Previous Visits to a science center on Attitude Toward Science Scores, however, no specific hypotheses were made.
- C. An exploratory analysis was also conducted to discover whether an interaction occurred between Pre/Post-Museum Visit and children's perception of Peers' Attitudes toward science on Attitude Toward Science Scores, however, no specific hypotheses were made.

Hypothesis 4. It was predicted that Attitude Toward Target Topic (acids and bases) Scores would improve significantly from Pre- to Post-Museum Visit

when averaging over possible modifying variables. The following interactions were examined:

- A. A significant interaction was expected between Pre/Post-Museum Visit and level of Engagement while at the exhibits on Attitude Toward Target Topic Scores. Specifically, children who exhibited High Engagement were expected to experience the highest gains in Attitudes Toward Target Topic Scores, while children who exhibited Low Engagement were expected to show the least gains in Attitudes Toward Target Topic Scores (see Figure 11).

Figure 11 Expected Interaction between Pre/Post-Museum Visit and Engagement on Attitude Toward Target Topic Scores



- B. An exploratory analysis was conducted to discover whether an interaction occurred between Pre/Post-Museum Visit and children's Previous Visits to a science center on Attitude Toward Target Topic Scores, however, no specific hypotheses were made.

C. An exploratory analysis was also performed to discover whether an interaction occurred between Pre/Post-Museum Visit and children's perception of Peers' Attitudes toward science on Attitude Toward Target Topic Scores, however, no specific hypotheses were made. The researcher also evaluated children's qualitative answers to questions regarding favored exhibits and exhibit relevance.

Hypothesis 5. Children who claimed higher levels of exhibit Relevance in their qualitative answers or included themselves or people they know in their concept maps about acids and bases were expected to show higher gains in Pre- to Post-Museum Visit on Content Knowledge Scores (A), Concept Mapping Scores (B), Attitudes Toward Science Scores (C), and Attitude Toward Target Topic Scores (D) (see Figures 12, 13, 14, and 15, respectively).

Figure 12 Expected Interaction between Pre/Post-Museum Visit and Relevance on Content Knowledge Scores

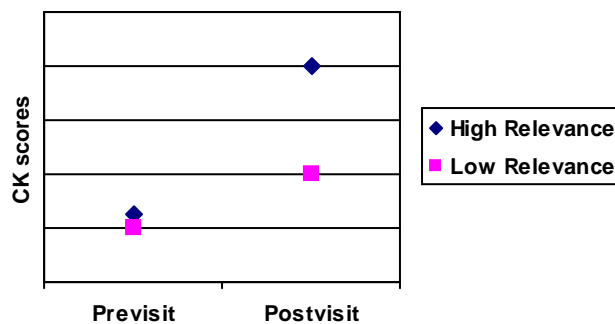


Figure 13 Expected Interaction between Pre/Post-Museum Visit and Relevance on Concept Maps Scores

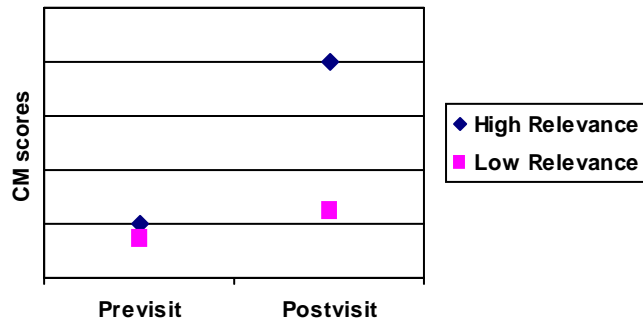


Figure 14 Expected Interaction between Pre/Post-Museum Visit and Relevance on Attitude Toward Science Scores

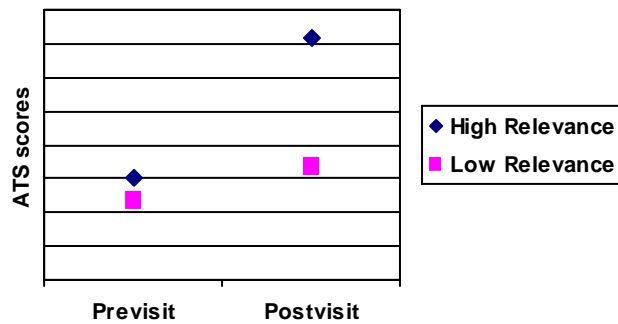
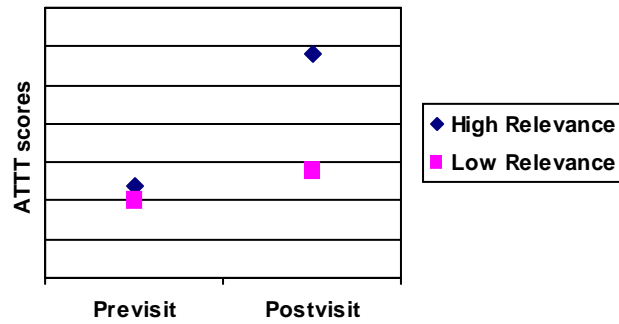


Figure 15 Expected Interaction between Pre/Post-Museum Visit and Relevance on Attitude Toward Target Topic Scores



Method

Participants

Participants were recruited from three seventh grade classes at Inner City Middle School (ICMS).^{*} Inner City Middle School students are predominately African American, the majority of which are from low-income families. There are no indicators that ICMS is vastly different from the surrounding schools with similar populations. For example, 73% of children attending ICMS participate in the Federal Child Nutrition (FCN) program (a measure of SES) and 67% are African American (Oregon Department of Education, 2002a; Portland Public Schools, 2003). The Oregon Department of Education Statewide Assessment Results in Science (2002b) data show that only 42% of ICMS students met the standards. Comparative schools include Urban Middle School^{*} with 74% of students participating in the FCN program, 40.5% African American students, and only 30% of students who met the standards in 2002 and City Heights Middle School,^{*} which has 81% of its students participating in the FCN program and 44% African American students, and, in 2002, only 21% of City Heights' students met standards (Oregon Department of Education, 2002a, 2002b; Portland Public Schools, 2003). Therefore, ICMS has been chosen to represent this population in the Portland area. Participants were offered a free classroom field trip to the Oregon Museum of Science and Industry (OMSI)—provided by OMSI. A middle school population was chosen for this study for several reasons: (a) middle school

^{*} Names have been changed to protect the anonymity of the schools and student bodies referenced.

children have not had high exposure to a large proportion of the science and industry information covered by OMSI; (b) new topics covered in the classroom could be aligned with the science and industry topics covered by OMSI; and (c) a middle school sample included the age group for which attendance to the after-school programs provided by OMSI typically begins to decline (for instance, OMSI Boys and Girls Science Club records from 2002–2003 indicate that 203 children from the 6–11-year-old age group participated, while only 17 children from the 12–17-year-old age group participated).

The three classrooms consisted of 64 students who were invited to attend the field trip and participate in the study. Two students did not turn in their informed consent/permission slip forms. One student attended the field trip but did not assent to participate in the data collection. Three students were absent on the day of the field trip. Students who were not African American or did not participate in the free/reduced lunch program were included in the field trip and data collection, but the data provided by those 16 students were not included in the analyses. Therefore, the available data set contained the responses of 42 students. Furthermore, 15 students were unable to provide all of the necessary data (typically because those students were absent during one or more days of data collection). In the end, there were 27 complete data cases. The average age for both the available data set and the complete data set participants was thirteen. Of the 27 participants, 14 were male and 13 were female.

Letter of Consent

The letter of consent was sent home with students as part of the field trip participation form. The letter explained to adults that their child's science teacher at Inner City and OMSI were working together with a Portland State University (PSU) graduate student to evaluate the effectiveness of school field trips to OMSI in deepening the understanding of concepts covered in the classroom and increasing interest in science. Adults were informed that participation in the field trip was not contingent on their child's participation in the study; however, their child's participation would help to determine whether such field trips continue. See Appendix A.

Informed Assent

Assent was gained from each child individually. The informed assent dialogue was read out loud to the entire class and then each child went into the hallway to hear the dialogue once again, talk one-on-one with the researcher, and give their assent or dissent to participate in the study. The informed assent dialogue was designed to give students an idea about what a study is, what participation in the study would entail, and the voluntary nature of participation. See Appendix B for the full dialogue.

Experimental Design

The study employed a within-subjects design. All children completed pretests, attended the museum, and completed posttests. The within subjects design was expected to increase power (over the control group design) by combining all classes

(i.e., for a matched sample t test) rather than comparing classes and dividing the power in half. Each possible threat to validity in a within subjects design was considered:

- History is considered a threat when something that happens on a grander scale affects participants' knowledge between pre- and posttests (Cook & Campbell, 1979). Generally, history was not thought to be a threat to the present study because it is very unlikely that an event occurred in the short amount of time between testing periods that affected the specified age group. However, the research was conducted under a particular set of circumstances (i.e., after concept map training, researcher visits to the classroom, and even the bus ride), which may have affected the research in ways that are impossible to statistically disentangle.
- Maturation is considered a threat when the changes in pre- and posttests can be attributed to normal changes that occur with time (Cook & Campbell, 1979). Maturation was not thought to be a threat to the present study because very little time elapsed between testing periods.
- Instrumentation is considered a threat when learning or cueing due to the pretest affects scores on the posttest (Cook & Campbell, 1979). As with history effects, instrumentation effects may have affected the research in ways that are impossible to statistically disentangle.

The aforementioned threats to validity were taken into consideration while conducting the research and precautions were taken to try to reduce the likelihood that validity would be compromised. These threats to validity are revisited in the discussion section below.

Price and Hein (1991) illuminate the need for varied methods when conducting research in informal settings, stating that program influences are extremely complex, and the many outcomes considered effective vary within each program. The researcher acknowledges the complexity of informal learning and therefore employed a mixed-methods approach to hopefully expand the understanding of informal learning gained through this research. Qualitative and quantitative data were collected concurrently in an effort to triangulate findings. Triangulation entails the collection of two different types of data to obtain independent estimates, which can confirm findings (Bamberger, 2003). Specifically, the weaknesses of content knowledge testing were offset by the strengths of concept mapping, and two separate attitude questionnaires were used to help reach deeper understanding (Cresswell, 2003).

Several statistical analyses were conducted. Analyses were performed on four dependent variables and seven independent variables (for variable descriptions see Figure 16 at the end of the *Instruments* section below). Four main effects and eighteen interactions were hypothesized and examined. Given the small sample size, separate repeated measures ANOVAs were conducted for each hypothesized interaction thus allowing for greater cell sizes and meaningful data analysis and interpretation.

Instruments

Dependent Measures

Content Knowledge Testing.

Paper-and-pencil multiple choice and true/false content knowledge tests were administered. Comparable questions were developed for pre/post-content knowledge tests. See Appendices C and E for instruments. Possible scores for content knowledge tests ranged from 0 to 10 (refer to Appendices D and F for the scoring key). Actual scores on the pre-visit content knowledge test ranged from 1 to 7, while actual scores on the post-visit content knowledge test ranged from 1 to 10.

It is important to note that some previous visitor studies have found content knowledge tests to poorly assess a child's learning from a museum experience, since each child incorporates a different set of concepts while at the museum (Bitgood, 1989; Hein, 1998; Meredith et al., 1997; Price & Hein, 1991). Concepts deemed important by schools or researchers may be related to parts of the exhibit a child does not spend time with or try to fully understand. Conversely, a child may notice part of an exhibit that challenges a preconceived notion held by the child and therefore change his/her concept map (described below) accordingly. Many changes in a child's understanding may not be predetermined by researchers and, consequently, may go unrecognized with content knowledge tests. Therefore, concept mapping was also used to determine conceptual changes that occurred after the museum visit.

Concept Mapping.

Concept mapping was used to assess conceptual change/learning after the museum visit. Concept mapping recognizes interrelationships between concepts and propositions that are left unacknowledged through paper-and-pencil tests (Novak, 1993). Concept mapping is similar to brainstorming, in that subjects begin with a general term, e.g., chemistry, and draw lines from this term to self-added concepts to create a map of concepts they consider related to the original term. “If new experiences provide a basis for meaningful learning, new concepts are added to an individual’s concept map or new relationships become evident between previous concepts” (Novak, 1993, p. 180). Post-concept maps can be compared to prior maps and evaluated for changes within the individual’s personal map. Concept mapping was a useful tool for this study because it allowed each youth to incorporate different concepts from their visit, while still allowing the researcher to compare the results.

Children were given a brief lesson on concept mapping (Appendix G), and the researcher completed an unrelated concept map on the board with each classroom. Children created their first concept maps directly after the lesson, while the researcher provided suggestions and encouragement. The teacher, along with the researcher, then used concept mapping in the classroom on two additional occasions to allow children an opportunity to become comfortable with the method. Once the teacher finished lecturing on the target topic, all children completed a pre-visit concept map on acids and bases. After the class visit to OMSI, each child completed a post-visit concept

map on the same topic. Maps were evaluated to identify whether there were changes in concept map scores from pre- to post-Museum Visit (see the detailed scoring section below).

There are a variety of methods used for administering and scoring concept maps (for a review see Ruiz-Primo & Shavelson, 1996). Concept maps can be arranged hierarchically or in an interrelational network, depending on the teacher's or researcher's preferred organizational approach. In their review, Ruiz-Primo and Shavelson (1996) suggest scoring can focus on a single aspect, all aspects, or any combination of the following: propositions (number, accuracy, cross-links), hierarchy levels, and examples. Novak and Gowin's (1984) scoring method, or a variation on their approach, is the most commonly used (Ruiz-Primo & Shavelson, 1996), and the relational method proposed by McClure has been shown to offer the highest validity and reliability (McClure, Sonak, & Suen, 1999). Falk, Moussouri, and Coulson describe Personal Meaning Mapping (a variation of concept mapping) as a tool for measuring changes in learning via the extent, breadth, depth, and mastery of understanding (1998). For Falk and his colleagues, it is not the "correct" answers that are compared, but each person's change in understanding across four semi-independent dimensions:

- Extent: change in quantity and appropriateness of vocabulary used.
- Breadth: change in the quantity of appropriate concept use.
- Depth: change in complexity and detail of conceptual understanding.

- Mastery: change in overall ease in articulating their understanding (an objective judgment made by the researcher) (Falk et al., 1998).

The above information was carefully considered before determining the method by which to score the concept maps.

In the context of this study concept maps were scored using a modification of the scoring method proposed by Novak and Gowin (1984), while heeding the assertion by Falk and his colleagues that the focus should be on changes in personal understanding rather than on correct answers (1998). Maps were not assessed for hierarchical structure because students were offered a choice between hierarchical and interrelation network organization of concept maps. A proposition is the combination of two concepts and a labeled line. One point was awarded for each proposition and for each example, both of which reflect the extent of knowledge regarding the central topic. Children were awarded 10 points for each cross-link (inner connections between the self-added concepts), which reflect higher-order knowledge integration. Proposition, example, and cross-link scores were added together to obtain cumulative concept map scores (Novak & Gowin, 1984) and pre/post-concept map scores were evaluated to identify whether conceptual understanding was enhanced or learning occurred after the museum visit.

Inter-rater agreement between two raters for Concept Mapping Scores was assessed on 25% of the maps. Scores were considered to be in agreement if they were within one point of each other. Inter-rater agreement was 89%. All maps were then

co-rated by the two raters to allow for any discrepancies to be discussed. Possible concept map scores could range from 0 to infinity. Actual concept map scores covered broad ranges: the lowest pre-visit map score was 3, while the highest pre-visit map score was 159¹; the lowest post-visit map score was 6, while the highest post-visit map score was 142.

Content Knowledge Scores and Concept Map Scores were assessed for inter-correlations between the two measures. The Spearman correlation between Content Knowledge Scores and Concept Mapping Scores was .01 pretest and .05 posttest. The low inter-correlations indicate that the two separate outcome measures of knowledge and understanding were non-redundant and warranted.

Attitude Toward Science Questionnaire.

This research adopted two attitude toward science questionnaires, one that was a combination of two previously employed measures, both originally designed to use with low-income, African American samples, and one that was originally developed for use in a combined school/interactive museum setting with a fairly diverse subject pool. The two questionnaires were then combined to create a single Attitude Toward Science questionnaire. See Appendix H.

- The first survey was constructed using some questions from (a) a research study that looked at attitudes toward science by gender, grade level (third through fifth), and race (Slate & Jones, 1998), and (b) an evaluation of

¹ The maximum scores reported here were outliers and removed prior to data analysis; the maximum scores used in the concept mapping analyses were 93 both pre- and post-Museum Visit.

standards-based teaching techniques for urban, African American middle school students in science (Kahle, Meece, & Scantlebury, 1999). The first survey consists of five questions, scored on a four-point scale ranging from “strongly agree” to “strongly disagree.” This survey was used in its entirety. The second survey consists of four items, scored on a five-point scale ranging from “strongly agree” to “strongly disagree.” Three of the four items were added to the end of the first survey and the scale was adjusted to resemble that of the first survey (it was administered on a four-point scale). In the context of this study, the coefficient alpha² for this measure was .84 pre-visit and .78 post-visit.

- The second survey was originally developed for use in the evaluation of an informal, extracurricular science program (Paris et al., 1998). The attitude interest scale consists of 16 items, which were collapsed into 11 items. The five items were removed either due to redundancy or due to unrelated content. The items are scored on a five-point scale, ranging from “it’s boring” to “it’s awesome.” While piloting this measure with an eighth grade classroom at the same school, the youth helped to reword the item responses in a manner that was more clear and relevant to them. The final survey scale ranged from “it’s weak” to “it’s tight.” In the current study, the coefficient alpha for this measure was .74 pre-visit and .77 post-visit.

² Coefficient alphas for all scales were conducted using the available data set (n = 27-42).

The possible range for the entire scale was 19 to 87. In the context of this research, the entire scale pre-visit range was between 36 and 73, and the post-visit range was between 42 and 75; the coefficient alpha for the combined questionnaire was .85 for both pre- and post-visit.

Attitude Toward Target Topic Questionnaire.

The Attitude Toward Target Topic survey was also adapted from the previously mentioned evaluation of an informal, extracurricular science program (Paris et al., 1998). The original instrument, the curriculum interest scale, consisted of 16 items. This measure was adapted to relate to the topic chosen for this research study, acids and bases. Several of the items were collapsed into single items in order to shorten the scale and the wording was altered post-pilot testing (cf. the Attitude Toward Science scale described above). The final survey consisted of eight questions scored on a five-point scale ranging from “it’s weak” to “it’s tight.” See Appendix I. Possible scores on the questionnaire ranged from 8 to 40. Actual pre-visit scores ranged from 19 to 39 and post-visit scores ranged from 20 to 40. The coefficient alpha for the current study was .81 pre-visit and .76 post-visit.

Independent Measures

Level of Engagement.

A chaperone recorded each child’s level of Engagement while at the three target exhibits. A separate engagement level rating was collected for 25% of the students in order to obtain inter-rater agreement. Therefore, each student was rated by

a single chaperone, and, for 25% of the students, a second rating was collected in order to determine inter-rater agreement. In all, seven chaperones and two agreement raters recorded level of engagement. Chaperones rated between three and four students per field trip. Chaperones and agreement raters were given a brief observation sheet that provided rating space by exhibit and children in their group, ratings ranged from 1 = low engagement, 2 = moderate–low engagement, 3 = moderate–high engagement, and 4 = high engagement. See Appendix J for the chaperone training dialogue and Appendix K for the chaperone observation sheet. Children’s engagement levels at the three exhibits were then averaged to form a single average Engagement level variable. Engagement level was then computed into a two-level variable using a median split³ (4 = High Engagement and anything less than 4 = Low Engagement). Inter-rater agreement between chaperones and agreement raters was low, 64%, when comparing ratings on initial four-level engagement ratings. However, when comparing ratings after Engagement level was computed into a two-level variable (i.e., High and Low Engagement), inter-rater agreement rose to 82%. Finally, chaperones and agreement raters were asked to record any comments regarding children’s level of engagement that they felt were noteworthy and would help with the interpretation of the data.

³ All median splits (Engagement, Previous Visits, Peer Attitude, and Home Support) were calculated using the available data set—thus gaining a more representative split than if the calculations were performed on the smaller, complete data set (see Figure 16 for the number of students from the complete data set that fell above the available data set medians).

Participant Information Form.

The researcher prepared a self-report instrument to obtain background information on each participant. See Appendix L. Background information included:

- Number of previous visits to a science museum (such as OMSI) in the past two years. Previous Visits was computed into a two-level variable using a median split (> 1 = Many visits and ≤ 1 = Few visits),
- Child's perception of peers' attitudes toward science. This was assessed via a short measure consisting of five items previously used in research with low-SES, African American middle-school students (Kahle et al., 1999). The five items are scored on a five-point scale ranging from "more than once a week" to "less than once a month." In the context of this study, scores ranged from 5 to 21 and the coefficient alpha was .77. Peer Attitude was computed into a two-level variable using a median split (≥ 9 = High Peer Attitude and < 9 = Low Peer Attitude).
- Home support for science (or any other subject) learning, which was measured using a home support scale originally developed for use with low-income, African American youth (Kahle et al., 1999). The home support scale consists of four questions, scored on a five-point scale ranging from "more than once a week" to "less than once a month." In the current study, scores ranged from 4 to 20 and the coefficient alpha was .87. Home Support was also computed

into a two-level variable using a median split (≥ 10 = High Home Support and < 10 = Low Home Support).

Prior Knowledge.

Prior knowledge was measured using students' current science grade. This variable was divided into two levels—high (A, B) and low (C, D, F)—(see Figure 16). The teacher provided information regarding students' current science grades. It is important to acknowledge the overlap in definitions between Prior Knowledge and Relevance (i.e., prior experience is a component of both definitions). However, in the context of this study, the two variables should not be conflated because each was measured in a manner distinct from the other—Prior Knowledge was measured as the students' current science grade, while Relevance was measured as something the students had at home, had seen or done before, or that was meaningful to them (see below).

Qualitative Preference and Relevance Questionnaire.

Several open-ended qualitative questions were developed in order to assess preference and Relevance of each exhibit to the children. The wording of each question was discussed with the students' teacher, and revisions were made in accordance with the teacher's feedback. Questions regarding specific exhibits followed a digital picture of that exhibit. This questionnaire was administered post-visit only. See Appendix M.

Figure 16 Summary of Research Design Variables

Dependent variables				Independent variables			
Variable name	Collection time	Possible range	Actual range Pre/Post	Variable name	Collection time	Levels	N
Content Knowledge Score	Pre/Post	1–10	1–7/ 1–10	Class Period	Pre	5 th 6 th 7 th	10 9 8
Concept Mapping Score	Pre/Post	0–∞	3–159* / 6–142	Engagement	During	High Low	18 9
Attitude Toward Science Score	Pre/Post	19–87	36–73/ 42–75	Previous Visits	Pre	Many Few	18 9
Attitude Toward Target Topic Score	Pre/Post	8–40	19–39/ 20–40	Prior Knowledge	Pre	High (A, B) Low (C, D, F)	9 18
				Home Support	Pre	High Low	11 16
				Peer Attitude	Pre	High Low	10 17
				Relevance	Post	Some None	21 6

* The maximum concept mapping scores reported here were outliers and removed prior to data analysis; the maximum scores used in the concept mapping analyses were 93 both pre- and post-Museum Visit.

Procedure

Several science teachers at Inner City Middle School were invited to participate with their classes. The administration and teachers were given a brief summary of the research project, benefits to their classes, and expenditures expected of them (number of meetings, lecture coordination, trip to OMSI to choose exhibit(s), classroom time for measures, and two hours for each field trip). To allow each child to enter with a basic knowledge of the material explained by the exhibit, classroom lectures were coordinated with the exhibit themes. Given the time required of participating teachers, only one seventh grade teacher was able to participate, along with her three seventh grade classes. The researcher and teacher chose the exhibit hall that coincided with the classroom-coordinated lectures during the period of the study (the Chemistry Lab). The OMSI exhibits were used to reinforce the knowledge obtained in the classroom. It is understood in the field of museum studies that information is of greater interest and more easily comprehended if visitors have some prior experience with the content covered by the exhibit.

The researcher met with the students in the beginning stages of the project in order to become acquainted and to allow children to get used to her presence. After concept mapping was explained and practiced, the researcher explained the project and sent children home with the informed consent and field trip participation form. After gaining informed consent, each child was told about the study and given an opportunity to assent to participation. The Attitude Toward Science measure and the

Personal Information form were administered two weeks prior to the museum visit. The classroom science teacher covered the chosen topic during the week prior to the museum visit. The following Tuesday, the researcher administered the pre-Museum Visit conceptual measures (Concept Mapping and Content Knowledge test) and the Attitude Toward Target Topic questionnaire followed by the field trip orientation. Orientation included a digital slideshow of OMSI (inside and out) and specific shots of the target exhibits (exhibits are described in detail below). While each target exhibit slide was shown, children were asked to write down what they predicted would happen. The purpose of prediction was to encourage children's own interests and questioning while at each exhibit. During orientation, each student was given a map of OMSI. The following day, Wednesday, children attended a field trip to OMSI (described in detail below). Chaperones observed participants and recorded their level of engagement while at the target exhibits. The next day, the researcher administered the battery of post-visit measures. Finally, on Friday, those who were absent the previous day filled out their post-visit measures and the researcher threw a small party to thank the students for their participation (i.e., chips, cupcakes, juice). Refer to Appendix N for an overview of procedures.

Field trips

In designing the field trip, many concerns were addressed. Due to the array of research that has been conducted regarding field trips to informal learning centers, especially to museums, the precautions taken in planning this field trip are discussed.

To reduce novelty and orient students, children were given a pre-visit orientation (Balling & Falk, 1980; Falk & Balling, 1982). The effects of pre-visit orientation have been empirically proven across all socioeconomic status groups and even in other countries, such as India (Falk, 1983a). Children were informed about the amount of time they would spend in the related hall (i.e., Chemistry Lab), the amount of free time they would have in the museum, and the allotted time in the gift shop. Children were also informed about what they would have for lunch and where they would eat lunch.

The museum visit was integrated with classroom topics. The list of suggestions by Price and Hein (1991) were closely followed by the researcher in planning the museum visit:

- Divide students into small working groups and encourage teamwork (the youth were divided into teacher-assigned groups of three or four students accompanied by an adult).
- Include teachers in visit preparation (the teacher chose the target exhibit hall and aided in choosing the target exhibits).
- Consist of three or more visits (unfortunately, funding did not allow for more than one visit, this is a limitation to this study).
- Last about two hours (participating classes' museum visits lasted approximately an hour and a half total).
- Be well planned—leaving time to answer questions and promote conversations.

- Offer a variety of activities (exploration time, demonstration time, rest time).
- Not employ worksheets while at the museum.
- Begin with exploration/hands-on/observation time and follow with concept and vocabulary instruction (that is, beginning with instruction and following with exploration does not work as well).

Exhibits

Three exhibits were chosen for this study. The exhibits are housed in the Chemistry Lab at OMSI. Each of the three exhibits covered the target topic, acids and bases. The information covered by each exhibit was directly related to the information covered in the acids and bases chapter of the children's textbook. The first exhibit, *Forwards and Backwards*, allowed children to experiment with the reversibility of acids and bases. The second exhibit, *Natural Indicators*, encouraged children to experiment with a variety of everyday plants that can be used to test the pH of a solution. The third exhibit, *Reaction, Yes or No?*, allowed children to observe three effects due to a chemical reaction (phenol red was used as an indicator in this experiment)—heat, color change, and production of gas. Refer to figures of exhibits in Appendix M.

Data Reduction

Missing Data.

Given the applied setting for data collection, missing data were expected. The variables containing the most missing data were Pre- and Post-Concept Map Scores,

each missing 19% (8/42) of the cases. The variables containing the least missing data were Pre- and Post-Attitude Toward Target Topic Scores and Post-Content Knowledge Scores, all of which were missing 10% (4/42) of the cases. Two methods were used to determine how to handle missing data: a complete cases data set was created and analyzed ($n = 27$); and a mean imputed data set was created and analyzed ($n = 42$). The results of these two data sets suggested no substantive differences from the available data set ($n = 27$ – 42 per analysis). Therefore, analyses from the complete cases data set ($n = 27$) are reported to ensure that results reflect the actual data while maintaining a consistent sample size throughout the results section.

Median Splits.

Median splits allowed the researcher to condense multi-level variables into two-level variables (a practical approach when analyzing small data sets). As previously mentioned, Engagement, Previous Visits, Prior Knowledge, and Home Support were each divided into dichotomous high/low variables based on the respective medians (50% of respondents above the median score). It is important to note that the median splits from the available data set ($n=27$ – 42) were employed in all analyses (including those from the complete data set reported below). It was determined that while reporting the smaller complete data set, the median splits from the available data set should be used to ensure that the results reflect all available data.

Outliers.

Very few outliers were present in the data as identified by stem-and-leaf plots. The outliers that were present were extremely high Pre- and Post-Concept Mapping Scores from the same individual. Two strategies were employed to determine whether the outliers were skewing the results of the analyses. First, outliers were removed and all analyses were conducted. Second, the top and bottom 2.5% of the data was removed from each variable and all analyses were conducted. Both strategies led to substantive differences in the concept mapping analyses. When further examining the outlying case, the Pre-Concept Map Score was 66 points higher than the next highest Score and the Post-Concept Map Score was 49 points higher than the next highest Score. Given the extreme scores for this single individual, this case was not included in the concept mapping analyses. Therefore, the sample size for the concept mapping statistics is 26 (as opposed to 27).

Results

Initial Class Period Comparisons

As mentioned earlier, students came from three different classes, 5th, 6th, and 7th periods, covering the same material, taught by the same teacher. The three classes were compared on Pre-Content Knowledge Scores and Pre-Attitude Toward Science Scores to determine whether they were significantly different, thus allowing for subsequent analyses to be run with class periods combined. The alpha level was set at .05 for *all* statistical analyses. In the tables that follow, significant findings are indicated by asterisks (* $p < .05$, ** $p < .01$, *** $p < .001$). Class period comparisons were made via univariate analyses of variance (ANOVA). Classes did not differ significantly on Pre-Content Knowledge Scores, $F(2, 24) = .06$, $p = .94$, $\eta^2 = .005$ (see Table 1 for means and standard deviations). Classes did not differ significantly on the Pre-visit Attitude Toward Science Scores, $F(2, 24) = 1.99$, $p = .16$, $\eta^2 = .14$ (see Table 2 for means and standard deviations). Because no differences were found between class periods on the knowledge or attitude measures, class periods were aggregated for all subsequent analyses.

Table 1

Class Period Scores on Pre-visit Content Knowledge

Class Period	Mean	SD
5 th period (n = 10)	3.70	1.14
6 th period (n = 9)	3.56	1.42
7 th period (n = 8)	3.81	2.07
Total (n = 27)	3.69	1.49

*p < .05 **p < .01 ***p < .001

Table 2

Class Period Scores on Pre-visit Attitude Toward Science

Class Period	Mean	SD
5 th period (n = 10)	54.90	8.32
6 th period (n = 9)	51.44	9.76
7 th period (n = 8)	60.00	8.45
Total (n = 27)	55.26	9.19

*p < .05 **p < .01 ***p < .001

Content Knowledge

The first dependent variable measured students' content knowledge.

Hypothesis 1 was that students' Content Knowledge Scores would increase significantly from Pre- to Post-Museum Visit. Changes in scores from pretest to posttest were assessed using a matched-samples *t* test. The difference scores can be viewed as the degree of improvement or decrement between the Pre- and Post-Museum Visit Content Knowledge Scores. The results indicate that the mean Pre-visit Content Knowledge Scores ($M = 3.69$, $SD = 1.49$) were significantly lower than the mean Post-visit Content Knowledge Scores ($M = 5.76$, $SD = 1.87$), $t(26) = -4.91$, $p < .001$. The standardized effect size index, d , was .94, indicating a large effect. It appears that the museum experience increased students' science content knowledge.

The more detailed hypotheses examined whether there were meaningful interactions between student's changes in Pre/Post-Content Knowledge Scores and their level of Engagement, Previous Visits, Prior Knowledge, or Home Support. A mixed-factorial analysis of variance on Pre/Post-Content Knowledge Scores was conducted separately for each factor—Engagement, Previous Visits, Prior Knowledge, and Home Support (for means and standard deviations, see Tables 3, 4, 5, and 6, respectively). For each mixed two-way ANOVA, the within-subjects factor was museum visit; the two levels were Pre- and Post-Museum Visit, and the dependent variable was Content Knowledge Score.

Engagement Level

Hypothesis 1A was that a significant interaction would occur between Pre/Post-Museum Visit and level of Engagement while at the exhibits. Specifically, children who were more highly engaged at the exhibits were expected to show higher gains in Content Knowledge Scores from Pre- to Post-Museum Visit. As mentioned previously, the between-subjects variable, Engagement, had two levels—High and Low. Inconsistent with hypothesis 1A, the interaction between Pre/Post-Museum Visit and Engagement level was not significant, $F(1, 25) = .02, p = .90, \text{partial-}\eta^2 < .01$ (see Table 3). It is important to note here that chaperones recorded comments regarding each student's level of engagement while at each exhibit. The most common notes referenced teamwork, questioning, and answering questions. This information helps to understand the actions of the students while engaged at the exhibits and interpret the content knowledge results (see the discussion section).

Previous Visits

Hypothesis 1B was that a significant interaction would occur between Pre/Post-Museum Visit and Previous Visits to a science center. Specifically, it was expected that children who had previously visited a science center would experience higher gains in Content Knowledge Scores. The between-subjects variable, Previous Visits, was divided into two levels—Many visits and Few visits. Contrary to hypothesis 1B, the interaction between Pre/Post-Museum Visit and Previous Visits on

Content Knowledge Scores was also non-significant, $F(1, 25) = .50, p = .49$, partial- $\eta^2 < .02$ (see Table 4).

Prior Knowledge

Hypothesis 1C was that a significant interaction would occur between Pre/Post-Museum Visit and student's Prior Knowledge, in that those who entered with lower levels of Prior Knowledge would make the most gains in Content Knowledge Scores from Pre- to Post-Museum Visit. The between-subjects factor, Prior Knowledge, was divided into High (science grade of A, B) and Low (science grade of C, D, or F). Contrary to hypothesis 1C, the interaction between Pre/Post-Museum Visit and Prior Knowledge was also non-significant, $F(1, 25) = 2.21, p = .16$, partial- $\eta^2 = .08$ (see Table 5).

Home Support

Hypothesis 1D was exploratory and no specific prediction was made regarding the interaction between children's Pre/Post-Museum Visit and their level of Home Support on Content Knowledge Scores. The between-subjects variable, Home Support, was divided into two levels—High and Low. A repeated measures factorial ANOVA was conducted. Results regarding the exploratory hypothesis 1D indicated that the interaction between Pre/Post-Museum Visit and Home Support was not significant, $F(1, 25) < .01, p = .97$, partial- $\eta^2 < .001$ (see Table 6).

Table 3

Mean Content Knowledge Scores as a Function of Pre/Post and Engagement

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Engagement	(SD)	(SD)	(not significant)
Low	3.39	5.39	
(n = 9)	(1.19)	(2.15)	
High	3.83	5.94	
(n = 18)	(1.64)	(1.76)	
Total	3.69	5.76***	
(n = 27)	(1.49)	(1.87)	

*p < .05 **p < .01 ***p < .001

Table 4

Mean Content Knowledge Scores as a Function of Pre/Post and Previous Visits

	<u>Pre-visit</u>	<u>Post-visit</u>	
Previous visits	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Few (n = 9)	3.22 (1.25)	5.72 (1.79)	
Many (n = 18)	3.92 (1.58)	5.78 (1.96)	
Total (n = 27)	3.69 (1.49)	5.76 ^{***} (1.87)	

*p < .05 **p < .01 ***p < .001

Table 5

Mean Content Knowledge Scores as a Function of Pre/Post and Prior Knowledge

	<u>Pre-visit</u>	<u>Post-visit</u>	
Prior knowledge	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Low (n = 18)	3.69 (1.73)	5.33 (1.95)	
High (n = 9)	3.67 (.94)	6.61 (1.45)	
Total (n = 27)	3.69 (1.49)	5.76*** (1.87)	

*p < .05 **p < .01 ***p < .05

Table 6

Mean Content Knowledge Scores as a Function of Pre/Post and Home Support

	<u>Pre-visit</u>	<u>Post-visit</u>	
Home support	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Low	3.50	5.56	
(n = 16)	(1.24)	(1.85)	
High	3.95	6.05	
(n = 11)	(1.84)	(1.96)	
Total	3.69	5.76***	
(n = 27)	(1.49)	(1.87)	

* $p < .05$ ** $p < .01$ *** $p < .001$

Concept Mapping

The second dependent variable measured quality of concept maps. Hypothesis 2 was that students' Concept Map Scores would increase significantly from Pre- to Post-Museum Visit. Changes in scores from pretest to posttest were assessed using a matched-samples t test. The difference scores can be viewed as the degree of improvement or decrement between the Pre- and Post-Museum Visit Concept Map Scores. The results were consistent with hypothesis 2, the mean Pre-visit Concept Map Scores ($M = 33.92$, $SD = 22.98$) were significantly lower than the mean Post-visit Concept Map Scores ($M = 42.92$, $SD = 26.24$), $t(25) = -2.17$, $p < .05$. The standardized

effect size index, d , was .42, indicating a moderate effect. This supports the idea that museum visits of even a brief duration can have a meaningful impact on students' conceptual organizations.⁴

The more complex hypotheses examined whether there were meaningful interactions between Pre/Post-Museum Visit and students' level of Engagement, Previous Visits, Prior Knowledge, and Home Support. A mixed-factorial analysis of variance was conducted separately for each factor—Engagement, Previous Visits, Prior Knowledge, and Home Support. The means and standard deviations for Pre/Post-Museum Visit Concept Map Scores according to Engagement, Previous Visits, Prior Knowledge, and Home Support are presented in Tables 7, 8, 9, and 10, respectively. For each ANOVA, the within-subjects factor was museum visit; the two levels were Pre- and Post-Museum Visit. The dependant variable for each ANOVA was Concept Map Score.

Engagement

Hypothesis 2A was that an interaction should occur between Pre/Post-Museum Visit and level of Engagement while at the exhibits; children who were highly engaged were expected to demonstrate greater gains in Concept Map Scores than children who exhibited lower levels of engagement. The between-subjects variable, Engagement, had two levels—High and Low. Contrary to hypothesis 2A, the

⁴ A non-parametric Wilcoxon test of the difference between ranks yielded similar results, $z = -1.91$, $p = .057$.

interaction between Pre/Post-Museum Visit and level of Engagement on Concept Map Scores was non-significant, $F(1, 24) = .79, p = .47$, partial- $\eta^2 = .02$ (see Table 7).

Previous Visits

Hypothesis 2B stated that the interaction between Pre/Post-Museum Visit and Previous Visits would be non-significant. The between-subjects variable, Previous Visits, had two levels—Many visits and Few visits. Contrary to hypothesis 2B, the interaction between Pre/Post-Museum Visit and Previous Visits on Concept Map Scores was significant, $F(1, 24) = 11.00, p < .01$, partial- $\eta^2 = .31$. Analyses of simple effects were conducted using two paired-samples *t* tests. Results indicate that children who had visited a science center more than once in the past two years (Many Previous Visits) show significant gains in Concept Map Scores from Pre- to Post-Museum Visit, $t(16) = 3.70, p < .01, d = .90$, while for children who had not attended a science museum more than once in the past two years (Few Previous Visits), Concept Map Scores actually decreased from Pre- to Post-Museum Visit, although not to a significant degree, $t(8) = -1.48, p = .18, d = .49$ (see Table 8).

Prior Knowledge

Hypothesis 2C stated that the interaction between Pre/Post-Museum Visit and Prior Knowledge would be non-significant. The between-subjects variable, Prior Knowledge, had two levels—High and Low. Consistent with hypothesis 2C, the interaction between Pre/Post-Museum Visit and Prior Knowledge on Concept Map Scores was non-significant, $F(1, 24) = .95, p = .29$, partial- $\eta^2 < .05$ (see Table 9).

Home Support

Finally, hypothesis 2D stated that the interaction between Pre/Post-Museum Visit and Home Support would be non-significant. The between-subjects variable, Home Support, had two levels—High and Low. Consistent with hypothesis 2D, the interaction between Pre/Post-Museum Visit and Home Support on Concept Map Scores was also non-significant, $F(1, 24) = .02, p = .90, \text{partial-}\eta^2 < .01$ (see Table 10).

It was thought that concept maps might indicate whether students perceived the target topic (acids and bases) as more relevant to their lives after interacting with the exhibits. For example, if a child did not include him/herself or his/her family in the concept map prior to the museum visit but chose to add him/herself or his/her family to the post-visit concept map, then the results would provide evidence that exhibit developers had created an exhibit that was personally or culturally relevant to the children. However, very few students included personal references in their pre- and post-visit concept maps, 19% (5/26) and 11% (3/26), respectively.

Table 7

Mean Concept Mapping Scores as a Function of Pre/Post and Engagement

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Engagement	(SD)	(SD)	(not significant)
Low	31.44	44.67	
(n = 9)	(23.83)	(25.88)	
High	35.24	42.00	
(n = 17)	(23.15)	(27.17)	
Total	33.92	42.92*	
(n = 26)	(22.98)	(26.24)	

*p < .05 **p < .01 ***p < .001

Table 8

Mean Concept Mapping Scores as a Function of Pre/Post and Previous Visits

Previous visits	<u>Pre-visit</u>		<u>Post-visit</u>	Plot of actual interaction (significant ^{**})
	Mean	Mean	Mean	
	(SD)	(SD)	(SD)	
Few	37.22	30.22		
(n = 9)	(25.66)	(22.77)		
Many	32.18	49.65 ^{**}		
(n = 17)	(22.06)	(26.03)		
Total	33.92	42.92		
(n = 26)	(22.98)	(26.24)		

*p < .05 **p < .01 ***p < .001

Table 9

Mean Concept Mapping Scores as a Function of Pre/Post and Prior Knowledge

	<u>Pre-visit</u>	<u>Post-visit</u>	
Prior knowledge	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Low (n = 17)	27.00 (21.55)	39.24 (27.25)	
High (n = 9)	47.00 (20.66)	49.89 (24.16)	
Total (n = 26)	33.92 (22.98)	42.92 (26.24)	

*p < .05 **p < .01 ***p < .001

Table 10

Mean Concept Mapping Scores as a Function of Pre/Post and Home Support

	<u>Pre-visit</u>	<u>Post-visit</u>	
Home	Mean	Mean	Plot of actual interaction
support	(SD)	(SD)	(not significant)
Low	38.31	46.88	
(n = 16)	(22.15)	(26.88)	
High	26.90	46.18	
(n = 10)	(23.67)	(25.22)	
Total	33.92	42.92*	
(n = 26)	(22.98)	(26.24)	

*p < .05 **p < .01 ***p < .001

Attitude Toward Science

No specific prediction was made regarding changes in Pre/Post-Museum Visit Attitude Toward Science Scores (hypothesis 3). Changes in scores from pretest to posttest were assessed using a matched-samples t test. The difference scores can be viewed as the degree of improvement or decrement between the Pre- and Post-Museum Visit Attitude Toward Science Scores. The results indicate that the mean Pre-visit Attitude Toward Science Scores ($M = 55.26$, $SD = 9.19$) were not significantly different than the mean Post-visit Attitude Toward Science Scores ($M = 57.30$,

$SD = 8.45$), $t(26) = 1.73$, $p = .10$. The standardized effect size index, d , was .33, indicating a small, yet noteworthy, effect.

The more detailed hypotheses examined whether there were meaningful interactions between Pre/Post-Museum Visit and student's level of Engagement, Previous Visits, or perceptions of Peer Attitudes toward science. A two-way mixed-factorial analysis of variance was performed separately for each factor—Engagement, Previous Visits, and Peer Attitudes (for means and standard deviations, see Tables 11, 12, and 13, respectively). For each repeated measures analysis of variance, the within-subjects factor was museum visit; the two levels were Pre- and Post-Museum Visit. The dependent variable was Attitude Toward Science Score.

Engagement

Hypothesis 3A was that an interaction would occur between Pre/Post-Museum Visit and level of Engagement while at the exhibits; children who were more highly engaged were expected to show greater gains in Attitude Toward Science Scores from Pre- to Post-Museum Visit. The between-subjects variable, Engagement, had two levels—High and Low. Inconsistent with hypothesis 3A, the interaction between Pre/Post-Museum Visit and level of Engagement on Attitude Toward Science Scores was non-significant, $F(1, 25) < .01$, $p = .93$, $\text{partial-}\eta^2 < .001$ (see Table 11).

Previous Visits

Hypothesis 3B was exploratory and no specific prediction was made regarding the interaction between Pre/Post-Museum Visit and children's Previous Visits to a

science center. The between-subjects variable, Previous Visits, was divided into two levels—Many visits and Few visits. A two-way repeated measures factorial analysis of variance was performed. Results from the analysis regarding the exploratory hypothesis 3B indicated that the interaction between Pre/Post-Museum Visit and Previous Visits on Attitude Toward Science Scores was not significant, $F(1, 24) = .01$, $p = .91$, partial- $\eta^2 < .001$ (see Table 12).

Peer Attitude

Hypothesis 3C was exploratory and no specific prediction was made regarding the interaction between Pre/Post-Museum Visit and perceptions of Peer Attitudes toward science. The between-subjects variable, Peer Attitude, was also divided into two levels, High and Low, and a two-way factorial analysis of variance was performed. Results of the analysis used to explore hypothesis 3C indicated that the interaction between Pre/Post-Museum Visit and Peer Attitude on Attitude Toward Science Scores was not significant, $F(1, 25) = .75$, $p = .40$, partial- $\eta^2 = .03$ (see Table 13).

Table 11

Mean Attitude Toward Science Scores as a Function of Pre/Post and Engagement

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Engagement	(SD)	(SD)	(not significant)
Low	58.11	60.00	
(n = 9)	(9.78)	(10.10)	
High	53.83	55.94	
(n = 18)	(8.82)	(7.44)	
Total	55.26	57.30	
(n = 27)	(9.20)	(8.45)	

*p < .05 **p < .01 ***p < .001

Table 12

Mean Attitude Toward Science Scores as a Function of Pre/Post and Previous Visits

	<u>Pre-visit</u>	<u>Post-visit</u>	
Previous visits	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Low (n = 9)	54.33 (7.16)	56.56 (8.09)	
High (n = 18)	55.72 (10.22)	57.67 (8.83)	
Total (n = 27)	55.26 (9.19)	57.30 (8.45)	

*p < .05 **p < .01 ***p < .001

Table 13

Mean Attitude Toward Science Scores as a Function of Pre/Post and Peer Attitudes

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Peer attitudes	(SD)	(SD)	(not significant)
Low	53.76	56.59	
(n = 17)	(9.19)	(9.31)	
High	57.80	58.50	
(n = 10)	(9.09)	(7.03)	
Total	55.26	57.30	
(n = 27)	(9.19)	(8.45)	

* $p < .05$ ** $p < .01$ *** $p < .001$

Attitude Toward Target Topic

Hypothesis 4 was that there would be significant gains in Attitude Toward Target Topic Scores from Pre- to Post-Museum Visit. Changes in Attitude Toward Target Topic (acids and bases) Scores from pretest to posttest were assessed using a matched-samples t test. The difference scores can be viewed as the degree of improvement or decrement between the Pre- and Post-Museum Visit Attitude Toward Target Topic Scores. Consistent with hypothesis 4, the mean Pre-visit Attitude Toward Target Topic Scores ($M = 27.96$, $SD = 4.64$) were significantly lower than the mean

Post-visit Attitude Toward Target Topic Scores ($M = 30.33$, $SD = 4.18$), $t(26) = -3.19$, $p < .01$. The standardized effect size index, d , was .61, indicating a moderate effect.

The more complex hypotheses examined whether there were meaningful interactions between Pre/Post-Museum Visit and student's level of Engagement, Previous Visits, or perceptions of Peer Attitudes toward science. A two-way mixed-factorial analysis of variance was performed separately for each factor—Engagement, Previous Visits, and Peer Attitudes (for means and standard deviations, see Tables 14, 15, and 16, respectively). For each repeated measures analysis of variance, the within-subjects factor was museum visit; the two levels were Pre- and Post-Museum Visit. The dependent variable was Attitude Toward Target Topic Scores.

Engagement

Hypothesis 4A was that a significant interaction would occur between Pre/Post-Museum Visit and level of Engagement while at the exhibits. Specifically, students who were highly engaged were expected to show higher gains in Attitude Toward Target Topic Scores. The between-subjects variable, Engagement, had two levels—High and Low. Contrary to hypothesis 4A, the interaction between Pre/Post-Museum Visit and level of Engagement on Attitude Toward Target Topic Scores was not significant, $F(1, 25) = .20$, $p = .66$, $\text{partial-}\eta^2 < .01$ (see Table 14).

Previous Visits

Hypothesis 4B was exploratory and no specific prediction was made regarding the interaction between Pre/Post-Museum Visit and children's Previous Visits. The

between-subjects variable, Previous Visits, was divided into two levels—Many visits and Few visits. A two-way repeated measures factorial analysis of variance was conducted. Results from the analysis to assess exploratory hypothesis 4B indicated that the interaction between Pre/Post-Museum Visit and Previous Visits on Attitude Toward Target Topic Scores was not significant, $F(1, 25) = .06, p = .81$, $\text{partial-}\eta^2 < .01$ (see Table 15).

Peer Attitudes

Hypothesis 4C was exploratory and no specific prediction was made regarding the interaction between Pre/Post-Museum Visit and children's perceptions of Peer Attitudes toward science. The between-subjects variable, Peer Attitude, was also divided into two levels, High and Low, and a two-way factorial analysis of variance was conducted. Results from the exploratory analysis regarding hypothesis 4C indicated that the interaction between Pre/Post-Museum Visit and Peer Attitude on Attitude Toward Target Topic Scores was not significant, $F(1, 25) = .23, p = .64$, $\text{partial-}\eta^2 < .01$ (see Table 16).

Table 14

Mean Attitude Toward Target Topic Scores as a Function of Pre/Post and Engagement

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Engagement	(SD)	(SD)	(not significant)
Low	29.22	31.11	<p>Legend: ◆ High Engagement, ■ Low Engagement</p> <p>Y-axis: ATTT scores (0 to 35)</p> <p>X-axis: Previsit, Postvisit</p>
(n = 9)	(5.54)	(4.86)	
High	27.33	29.94	
(n = 18)	(4.16)	(3.89)	
Total	27.96	30.33**	
(n = 27)	(4.64)	(4.18)	

*p < .05 **p < .01 ***p < .001

Table 15

Mean Attitude Toward Target Topic Scores as a Function of Pre/Post and Previous Visits

	<u>Pre-visit</u>	<u>Post-visit</u>	
Previous visits	Mean (SD)	Mean (SD)	Plot of actual interaction (not significant)
Low (n = 9)	28.11 (5.49)	30.22 (5.56)	
High (n = 18)	27.89 (4.34)	30.39 (3.48)	
Total (n = 27)	27.96 (4.64)	30.33** (4.18)	

*p < .05 **p < .01 ***p < .001

Table 16

Mean Attitude Toward Target Topic Scores as a Function of Pre/Post and Peer Attitudes

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Peer attitudes	(SD)	(SD)	(not significant)
Low	27.71	30.35	
(n = 17)	(4.91)	(4.15)	
High	28.40	30.30	
(n = 10)	(4.38)	(4.45)	
Total	27.96	30.33**	
(n = 27)	(4.64)	(4.18)	

*p < .05 **p < .01 ***p < .001

Qualitative Preference and Relevance

The qualitative questions were used to assess which exhibits the children preferred and whether or not the children viewed the exhibits as relevant. Because the students provided so many rich and varied answers, responses to all available qualitative questionnaires were examined. Of the 42 students who participated in the study and were eligible for data analyses, 4 students were absent on the day the qualitative data were collected; therefore, the total sample size reported is 38. Several questions were not answered by some of the students, the forthcoming questions were each missing four responses; therefore, 10% of the total sample in all subsequent

percentages is accounted for by missing data. The missing data may be a product of the request for students to provide large amounts of information at one time (fatigue) or reflect the few students per class who typically prefer to write as little as possible.

The students generally favored *Reaction, Yes or No?*; 57% even claimed *Reaction, Yes or No?* as their favorite exhibit. *Forwards and Backwards* was the second favorite and *Natural Indicators* the third (14% and 5% claimed these exhibits as their favorite, respectively). Additionally, 7% of the students claimed all three exhibits as their favorite, 5% claimed other exhibits throughout OMSI as their favorite, and 2.5% did not report a favorite. The most common theme underlying the favored status of *Reaction, Yes or No?* was action. One student's response is exemplary of this theme, "I thought it was cool how the chemical bubbled and the balloon was blow[n] up."

When asked whether the Chemistry Lab exhibits were relevant (if it was personally meaningful or if it reminded them of anything at home) only 21% did not find any of the exhibits relevant to them, while 79% of the students found at least one exhibit relevant. Specifically, 24% listed one exhibit as relevant, 29% listed two of the exhibits as relevant to them, and 17% identified all three exhibits as relevant. Of the students who responded, 38% felt *Forwards and Backwards* was relevant, 33% felt *Natural Indicators* was relevant, and more than 59% felt *Reaction, Yes or No?* was relevant.

Several themes were identified throughout the qualitative responses. The top ten themes (theme names are indicated with capital letters), with number of times mentioned in parentheses, are as follows: Past experience (50), Household Materials (39), Experience Alterations (26), Food (21), Balloon (16), add Different materials (15), At Home (12), Extra of the same materials (11), Instruction (10), and Blow things Up or light them on fire (8). Qualitative responses can be divided into two categories: (a) those pertaining to whether the exhibits were relevant and (b) those pertaining to how the youth would change the exhibits to make them more relevant. Below are detailed examples of the common themes for each question followed by exemplary answers provided by the students.

The first set of questions inquired whether each exhibit reminded the respondents of anything they had at home or anything they had done or seen before. When this question was asked in regard to *Forwards and Backwards*, 93% of the children who found the exhibit relevant claimed to have had Past Experience with the experiment or the materials involved in the experiment. Other references to why the youth felt *Forwards and Backwards* was relevant were because it contained Household Materials (37%), more specifically the exhibit reminded them of Kool-Aid (31%), or Food (18%). Examples include, “Magic Kool-Aid I have at home” and “Yes because when dying the egg on Easter.” When the aforementioned question was posed in regard to *Natural Indicators*, the most common response was Household Materials (64%). Other reasons for the exhibit’s relevance include, the presence of Food items

(42%), Past Experience with the experiment or the materials (28%), and the presence of Color (28%). Examples include, “It reminded me about cabbage and it is green and different color roses” and “I drink lemonade a lot and I didn’t know it was an acid.”

When the same question was asked in regard to *Reaction, Yes or No?*, children most often indicated the presence of Household Materials (64%) as the source of the exhibit’s relevance. Other responses included Past Experience with the experiment or the materials in the experiment (60%) and specific references to the Balloon or Food-related items such as vinegar and baking soda (48% and 32%, respectively). Examples include, “It kind of reminded me of a vacuum cleaner when it blows up,” “I’ve blow up a balloon with many different things,” and “It reminded me about helium.”

The next set of questions inquired how the children would change each exhibit to make it more personal, meaningful, or even more fun for them. With regard to *Forwards and Backwards*, 38% of the students gave suggestions. Of those that responded, 62% suggested Experience Alterations—adding Different components (50%) or Extra of the same components (18%)—and 31% suggested increasing the Sensory Experience. Examples of responses pertaining to *Forwards and Backwards* include, “Use bigger amounts of coloring,” “Get more bases and acids or indicators to make gases,” and “Make things edible. Blow things up.” Only 20% of the students gave suggestions regarding *Natural Indicators*, 50% of those who responded suggested Experience Alterations—such as adding Different components (37%). Examples of suggestions for *Natural Indicators* include, “I would use more materials

that we have at home like candy and pickles like whole materials not liquid,” and “By doing something else like making them bubble up because of reaction.” With regard to *Reaction, Yes or No?*, 33% of the children offered suggestions. The most common suggestions included Experience Alterations (78)—specifically, adding Extra of the same ingredients to create a stronger reaction (42%) or adding Different ingredients (28%). Additionally, 21% of those who responded Requested more Relevance and 21% suggested Blowing things Up or lighting the balloon on fire. Examples of answers regarding *Reaction, Yes or No?* include, “I would actually put more in there to try to make the balloon blow all the way,” “Yes, give tips on how to make the balloon bigger,” and “I would have a red balloon with my name on it.”

Responses to the relevance questions were expected to aid in the interpretation of the quantitative results. The exploratory hypothesis was that children who responded positively to the questions regarding whether the exhibits reminded them of something at home, or something they had done or seen before, would also be the children who showed significant gains in understanding and interest from pre- to post-Museum Visit. To test exploratory hypothesis 5, a mixed-factorial analysis of variance was performed separately for each dependant variable—Content Knowledge Scores (5A), Concept Mapping Scores (5B), Attitude Toward Science Scores (5C), and Attitude Toward Target Topic Scores (5D) (for means and standard deviations, see Tables 17, 18, 19, and 20, respectively). The within subjects variable for each analysis was museum visit, with two levels, Pre- and Post-Museum Visit. Each of the factorial-

analyses of variance were conducted with the between-subjects factor, Relevance, which was a two-level variable—perceived at least one exhibit as relevant (Some) or did not perceive any of the exhibits as relevant (None). The interactions between Relevance and Pre/Post-Museum Visit on the two knowledge measures were both non-significant: Relevance and Pre/Post-Museum Visit on Content Knowledge Scores (hypothesis 5A), $F(1, 25) = 2.62, p = .12, \text{partial-}\eta^2 = .10$; Relevance and Pre/Post-Museum Visit on Concept Mapping Scores (hypothesis 5B), $F(1, 24) = .01, p = .92, \text{partial-}\eta^2 < .001$. The interaction between Relevance and Pre/Post-Museum Visit on Attitude Toward Science Scores (hypothesis 5C) was also non-significant, $F(1, 25) = 1.74, p = .20, \text{partial-}\eta^2 = .07$. A significant interaction was found between Relevance and Pre/Post-Museum Visit on Attitude Toward Target Topic Scores (hypothesis 5D), $F(1, 25) = 5.61, p = .03, \text{partial-}\eta^2 = .18$.

Table 17

Mean Content Knowledge Scores as a Function of Pre/Post and Relevance

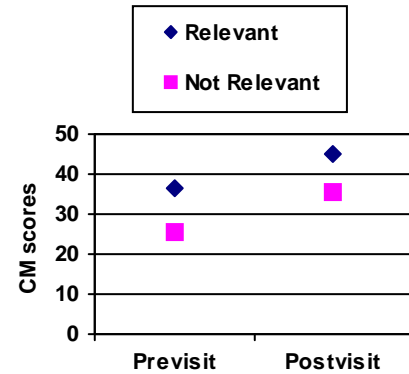
	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Relevance	(SD)	(SD)	(not significant)
Not Relevant	3.92	4.75	
(n = 6)	(1.43)	(1.70)	
Relevant	3.62	6.05	
(n = 21)	(1.54)	(1.86)	
Total	3.69	5.76**	
(n = 27)	(1.49)	(1.87)	

*p < .05 **p < .01 ***p < .001

Table 18

Mean Concept Mapping Scores as a Function of Pre/Post and Relevance

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Relevance	(SD)	(SD)	(not significant)
Not			
Relevant	25.67	35.50	
(n = 6)	(8.89)	(25.25)	
Relevant	36.40	45.15	
(n = 20)	(25.42)	(26.75)	
Total	33.92	42.92	
(n = 26)	(22.98)	(26.24)	



*p < .05 **p < .01 ***p < .001

Table 19

Mean Attitude Toward Science Scores as a Function of Pre/Post and Relevance

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Relevance	(SD)	(SD)	(not significant)
Not			
Relevant	55.67	54.83	
(n = 6)	(10.54)	(8.68)	
Relevant	55.14	58.00	
(n = 21)	(9.06)	(8.46)	
Total	55.26	57.30	
(n = 27)	(9.19)	(8.45)	

*p < .05 **p < .01 ***p < .001

Table 20

Mean Attitude Toward Target Topic Scores as a Function of Pre/Post and Relevance

	<u>Pre-visit</u>	<u>Post-visit</u>	
	Mean	Mean	Plot of actual interaction
Relevance	(SD)	(SD)	(significant *)
Not Relevant	28.17	27.50	
(n = 6)	(4.12)	(4.51)	
Relevant	27.91	31.14	
(n = 21)	(4.88)	(3.81)	
Total	27.96	30.33	
(n = 27)	(4.64)	(4.18)	

*p < .05 **p < .01 ***p < .001

Figure 17 Summary of Knowledge and Understanding Results

	Main effects and interactions	Statistical test	Significance	Effect size	Direction	Hypothesis support
Content knowledge	Overall	t test	Significant ***	$d = .94$	Higher after visit	Supports 1
	Interaction with engagement	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .001$	N/A	Does not support 1A
	Interaction with previous visits	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .02$	N/A	Does not support 1B
	Interaction with prior knowledge	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .08$	N/A	Does not support 1C
	Interaction with home support	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .001$	N/A	Exploratory 1D
	Interaction with relevance	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .10$	N/A	Does not support 5A
Concept mapping	Overall	t test	Significant *	$d = .42$	Higher after visit	Supports 2
	Interaction with engagement	Repeated measures ANOVA	Not Significant	partial- $\eta^2 = .02$	N/A	Does not support 2A
	Interaction with previous visits	Repeated measures ANOVA	Significant **	partial- $\eta^2 = .31$	Increases for S's with many visits	Does not support 2B
	Interaction with prior knowledge	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .05$	N/A	Supports 2C
	Interaction with home support	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .01$	N/A	Supports 2D
	Interaction with relevance	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .001$	N/A	Does not support 5B

* $p < .05$ ** $p < .01$ *** $p < .001$

Figure 18 Summary of Attitudinal Results

	Main effects and interactions	Statistical test	Significance	Effect size	Direction	Hypothesis support
Attitude toward science	Overall	t test	Not significant	$d = .33$	N/A	Exploratory 3
	Interaction with engagement	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .001$	N/A	Does not support 3A
	Interaction with previous visits	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .001$	N/A	Exploratory 3B
	Interaction with peer attitude	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .03$	N/A	Exploratory 3C
	Interaction with relevance	Repeated measures ANOVA	Not significant	partial- $\eta^2 = .07$	N/A	Does not support 5C
Attitude toward target topic	Overall	t test	Significant **	$d = .61$	Higher after visit	Supports 4
	Interaction with engagement	Repeated measures ANOVA	Not significant	Partial- $\eta^2 < .01$	N/A	Does not support 4A
	Interaction with previous visits	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .01$	N/A	Exploratory 4B
	Interaction with peer attitudes	Repeated measures ANOVA	Not significant	partial- $\eta^2 < .01$	N/A	Exploratory 4C
	Interaction with relevance	Repeated measures ANOVA	Significant *	Partial- $\eta^2 = .18$	Gains in attitudes for those who viewed the exhibits as relevant	Supports 5D

* $p < .05$ ** $p < .01$ *** $p < .001$

Discussion

Gains in Knowledge and Understanding

The data analyses revealed that Inner-City Middle School students showed significant gains in both Content Knowledge Scores (hypothesis 1) and Concept Map Scores (hypothesis 2) from Pre- to Post-Museum Visit. The mixed method results suggest that both quantitative and qualitative data are converging on, and therefore confirming, the finding that the museum visit enhanced school learning (Cresswell, 2003). This finding is concordant with findings from previous museum studies (for examples see Falk & Storksdieck, 2002; Giese et al., 1993). Although it has been suggested that concept mapping is a better way to capture the complex and varied learning that occurs in the interactive museum context (Anderson et al., 2003; Falk et al., 1998; Hein, 1999; Novak, 1993), it seems that both measures do capture content knowledge gains (albeit concept mapping captures integration as well).

The t tests for both Content Knowledge and Concept Map Scores support the hypotheses (1 and 2) that museums can enhance school learning by providing hands-on (and minds-on) activities. The results support the idea that museums encourage peer cooperation in a contextually embedded activity that can better fit the cultural learning style of children from low-income, African American backgrounds (Allen & Boykin, 1991; Ogbu, 1995; Quinn, 1999; Resnick & Chi, 1988). Constructivism, sociocultural Vygotskianism, and situated learning theories support these results. The learning that occurred from pre- to post-Museum Visit can be explained by

constructivism and situated cognition, which both suggest that if learners are physically and mentally active, learning is more likely to occur (cf. Boykin & Allen, 1988; Boykin & Cunningham, 2001; Lave, 1990). The importance of participatory communication and social interaction amongst peers is highly regarded by constructivists, such as Piaget; contextualists, such as Vygotsky; and contextual Vygotskianists (Cobb et al., 1993; Cole & Griffin, 1987; Miller, 1993; Moll & Whitmore, 1993). Rater comments regarding the children's behaviors while at the exhibits often referred to teamwork, questioning, and answering of questions, which Piagetian theory would hold as evidence of equilibration and Vygotskian theory would hold as evidence of scaffolding. All of the above theories suggest that learning might be enhanced by recontextualizing information that is oftentimes decontextualized by the schools (Brown et al., 1989; Lave, 1990; Nelson-Barber & Trumbull Estrin, 1995). The museum visit may have reestablished a context for the understanding of the concepts covered in the science curriculum. These theories also aid in the interpretation of the large statistical effects, even after only a single visit occurred.

Although Falk (1999), Hein (1998), and Price and Hein (1991) have suggested that a single visit may not be enough to bring about better understanding, it is possible that coordinating the museum visit with the school curriculum helped make the museum visit more conducive to learning about acids and bases. For example, many researchers from a variety of theoretical backgrounds suggest that if a topic is covered repeatedly or in divergent contexts, that topic is more likely to be integrated and

understood (Brown et al., 1989; Gibson, 1969; Quinn, 1999). For example, Gibson (1969) posits that diverse learning contexts can help students to generalize the understanding of a concept, and situated cognition theorists posit that repeated experiences help the student to re-shape, re-assess, and more deeply understand a concept (Brown et al., 1989). The significant results after only a single visit suggest that interactive museums are potent venues for enhancing understanding and knowledge, especially when the visit is coordinated with classroom curriculum topics.

The hypothesized interactions between Pre/Post-Museum Visit and children's level of Engagement while at the museum on the learning variables, Content Knowledge Scores (hypothesis 1A) and Concept Mapping Scores (hypothesis 2A), were not supported. The students, regardless of how engaged the chaperones perceived they were, learned while at the museum. These findings are counter to past museum research findings (Falk & Storksdieck, 2002) and past education research findings (Greenwood & Terry, 1994; Skinner et al., 1990). There are two possible explanations for this finding: (a) The information was so well disseminated through the exhibits, even those children who were distracted during the visit learned enough to make significant gains in knowledge and understanding; and/or (b) The measurement of engagement was not well implemented. Most likely, the results are due to a mixture of both explanations. Even those youth who were distracted were sufficiently on-task and engaged at least part of the time; none of the engagement ratings included a rating of one (engaged less than 25% of the time). This means that all of the children were

engaged at least a portion of the time they were in the Chemistry Lab. This finding suggests that the exhibits are educational even for visitors who are only moderately engaged.

It is also possible that there were problems with the engagement ratings. The construct (an overall rating) may have been too broad and in the future may need to be broken down into specific ratings on the variety of actions that are indicative of engagement. The need for more specific observations is evidenced (at least on the four-level ratings) by the low inter-rater agreement. It is possible that time on task may need to be included in the estimation of engagement levels, as suggested in past museum literature (Falk, 1983b; Falk & Storksdieck, 2002). Finally, the small sample size was not conducive to averaging over rater differences; future researchers with a larger sample size can easily address this limitation.

The interaction between Pre- and Post-Museum Visit and children's Previous Visits to a science center was the only interaction where the findings from the two knowledge measures differed. Interestingly, the results were expected to differ, but the expectations were counter to the results. The hypothesized interaction between Pre/Post-Museum Visit and Previous Visits on Content Knowledge Scores (hypothesis 1B) was not significant. It was anticipated that for those students who had previously visited a science center, novelty would be reduced, while the level of novelty would be rather high for children who had little or no experience at a science center, thus affecting their attention to exhibit information. As previously mentioned, past studies

have found that high levels of novelty lead to increased levels of off-task behavior, which negatively affected learning (Balling & Falk, 1980; Falk, 1983a; Kubota & Olstad, 1991). However, the current study included a pre-visit orientation to try to curb the effects of novelty on learning; therefore the null results are not surprising. The positive effects of pre-visit orientation on reducing novelty and enhancing the likelihood of gains in understanding are supported by past museum research (Anderson & Lucas, 1997; Falk, 1983a; Kubota & Olstad, 1991). It is likely that the orientation helped to create a moderately novel environment for students with all levels of previous experience in the science center and, therefore, created an environment more conducive to content knowledge gain.

The significant interaction between Previous Visits and Pre/Post-Museum Visit on Concept Map Scores was not expected (hypothesis 2B). The interaction is especially perplexing when considered in conjunction with the non-significant interaction on Content Knowledge Scores. Concept mapping involves recall and integration rather than rote skills; it is possible that even moderate levels of novelty (even after pre-visit orientation) had more of an impact on the youths' ability to recall and integrate information and less of an impact on recognition (the type of learning needed for content knowledge tests). Concept mapping is a fairly new assessment technique and there has been a call for research that helps to better understand the inherent limitations (Ruiz-Primo & Shavelson, 1996). Future researchers may want to

investigate whether concept mapping is a proper tool in novel, or even moderately novel, learning situations.

Neither knowledge outcome measure indicated significant interactions with children's Prior Knowledge and Pre/Post-Museum Visit. The results are counter to the hypothesized interaction between Pre/Post-Museum Visit and Prior Knowledge on Content Knowledge Scores (hypothesis 1C). As previously mentioned, visitors with lower levels of entering knowledge tend to show the most significant gains in knowledge after a museum visit (Falk & Adelman, 2003). It is possible that these results do not support the a priori expectations because current science grade may be a poor indicator of level of entering knowledge. The disconnect between current science grade and level of prior knowledge is especially apparent when considering the focus of the content knowledge test on acids and bases rather than general science knowledge (as is the focus of science grade). The effect, though small, is indicative of a possible interaction. Future researchers may want to employ pretest scores as a measure of level of Prior Knowledge and control for those scores in analyses.

The Pre/Post-Museum Visit and Prior Knowledge results on Concept Mapping Scores, consistent with expected results (hypothesis 2C), indicate that all youth, regardless of their Prior Knowledge, can learn from field trips to informal educational venues, such as hands-on museums. The concept mapping results are supported by concept mapping and constructivist literature. Concept maps allow for gains in a variety of areas, rather than content knowledge gains that are predetermined by the

teacher or researcher (Novak, 1993). Therefore, all students regardless of prior knowledge were able to make additions to their maps after the learning experience.

Finally, the results of the exploratory analysis regarding the interaction between Pre/Post-Museum Visit and children's Home Support on Content Knowledge Scores (hypothesis 1D) was not significant. And, concordant with hypothesis 2D, the interaction between Pre/Post-Museum Visit and children's Home Support on Concept Mapping was not significant. These results indicate that all youth, regardless of the amount of support they receive at home, can learn from field trips to informal educational venues. As noted above, the concept mapping results are supported by concept mapping and constructivist literature. Therefore, all students regardless of home support were able to make additions to their maps after the learning experience.

Attitude Toward Science and Toward Target Topic

The t tests for Attitude Toward Science Scores were not significant, yet t tests for Attitude Toward Target Topic Scores, acids and bases, were significant. Although specific hypotheses regarding the Pre- to Post-Attitude Toward Science Scores were not proposed (hypothesis 3), the increases in Pre- to Post-Attitude Toward Target Topic Scores were (hypothesis 4). These seemingly contradictory results (significant gains in Attitude Toward Target Topic Scores and non-significant gains in Attitude Toward Science Scores) were anticipated and may be explained in a variety of ways. As previously mentioned, people are more interested in topics to which they have been previously exposed. Therefore, the classroom curriculum, which introduced the target

exhibit topics a priori, may have paved the way for the visit to improve attitudes toward *that* particular topic. Additionally, attitude toward science as a whole may be too broad for a *single* museum visit to alter; while the children were focused on the target topic, allowing them enough exposure to sufficiently improve attitudes toward that topic. In contrast to past museum research (Finson & Enochs, 1987; Flexer & Borun, 1984; Paris, et al., 1998; and Rix & McSorley, 1999), Attitude Toward Science Scores did not improve after the informal learning experience. There are several reasons for this discrepancy: some of the studies included a broader focus during the informal learning experience (Paris, et al., 1998); some included measures that did not focus on attitude but on other affective learning dimensions such as motivation and enjoyment (Flexer & Borun, 1984); some included measures that combined general and topic specific science questions on a single attitude toward science measure (Rix & McSorley, 1999); and some included experiences that were longer-term than a single museum visit (Paris et al., 1998). Finally, it is important to note that the non-significance of Attitude Toward Science Scores from Pre- to Post-Museum Visit may be largely a function of the small sample size, given that eta squared is indicative of an effect. Future researchers may want to assess the effects of a museum visit on Attitude Toward Science Scores with a larger sample or after students experience more than one museum visit.

Contrary to hypotheses 3A and 4A, no significant interactions were found between Pre/Post-Museum Visit and children's level of Engagement while at the

exhibits on Attitude Scores (Toward Science or Toward the Target Topic). This finding suggests that the youth's Attitude Toward Science Scores remained fairly stable regardless of their level of engagement, and their Attitudes Toward Target Topic Scores increased regardless of their level of Engagement. These results suggest that exhibits can improve topic-specific attitudes. It is also possible, as explained in the knowledge and understanding section above, that there were problems with the engagement ratings, therefore creating difficulties in identifying any interactions between level of Engagement and attitudinal changes.

The interaction between Pre/Post-Museum Visit and Previous Visits on Attitude Toward Science Scores was not significant, nor was the interaction between Pre/Post-Museum Visit and Peer Attitudes on Attitude Toward Science Scores. The magnitude of the effect for both analyses was also quite small. These results were part of exploratory hypotheses (3B and 3C, respectively), and both suggest that attitudes from pre- to post-Museum Visit of the participating Inner-City Middle School children toward science were not affected by the number of Previous Visits to a science center or the student's perceptions of Peer Attitudes toward science.

Exploratory analyses did not reveal interactions between Pre/Post-Museum Visit and Previous Visits on Attitude Toward Target Topic Scores (hypothesis 4B) or between Pre/Post-Museum Visit and Peer Attitudes on Attitude Toward Target Topic Scores (hypothesis 4C). Results suggest that students' Attitude Toward Target Topic Scores can increase from pre- to post-Museum Visit for students who have had a

variety of previous experiences at a science center in the past two years and for those who have not, alike. Additionally, students' Attitude Toward Target Topic Scores can increase from pre- to post-Museum Visit regardless of whether they perceive their peers as having high or low attitudes toward science. These results are encouraging because they suggest that some of the factors out of the control of the museum do not alter the experience enough to counter the positive effects of a museum visit on youth attitudes toward a designated target topic.

Relevance

The qualitative relevance results suggest that the OMSI Chemistry Lab has successfully created a relevant experience for the majority of the students who participated in this study. The primary ways in which the students perceived the exhibits as relevant were through past experience with the experiment concepts or materials. Specifically, the students related most often to materials that they had at home, such as foodstuff.

As suggested by the students, there is room for improving the relevance of the exhibits to this particular group. The suggested experiment alterations often included adding different, more familiar materials to the experiment (i.e., using more familiar foods as the indicators in *Natural Indicators*). Additionally, the students commonly suggested adding more of the same materials to the experiment to create a stronger reaction. The students recommended the inclusion of additional sensory experiences, such as taste, to make the experiments more relevant to them. Finally, some of the

students felt that the experiments could be more personally relevant (i.e., by allowing them to choose the color of the balloon in *Reaction, Yes or No?*).

Results did not support the first part of the informal fifth hypothesis (5A and 5B) that the youth who found at least one of the exhibits relevant would also be more likely to have experienced significant gains in knowledge from pre- to post-Museum Visit. However, given the largely uneven sample sizes in each cell and the small sample size in the study, it is difficult to make conclusive statements about this finding. It would be worthwhile for future researchers to explore this idea further with a larger sample. In the context of this small study, the results do not support the constructivist, Vygotskian, and apprenticeship theories that posit that information must be relevant to the learner in order for learning to occur (Hein, 2001; Kozulin, 1998; Lave, 1990). Additionally, concept maps did not reflect many personal references. It may be worthwhile for future research to assess situations in which students are asked specifically to include as many personal references as possible or even just encouraged to put themselves in their maps.

Results partially supported the second portion of the informal fifth hypothesis (5C and 5D) that the youth who found at least one of the exhibits relevant would also be more likely to have experienced attitudinal gains from pre- to post-Museum Visit. The interaction between Relevance and Pre/Post-Museum Visit on Attitude Toward Science Scores was not significant (5C). As stated earlier, it is more difficult for a single museum visit to affect attitudes toward science in general; it is likely that these

results reflect this same problem. However, the magnitude of the effect, although small, does suggest that this interaction warrants further exploration with either a larger sample size or more than one museum visit. The interaction between Relevance and Pre/Post-Museum Visit on Attitude Toward Target Topic Scores was significant (5D); Attitude Toward Target Topic Scores remained stable from pre- to post-Museum Visit for children who did not find any of the exhibits relevant, while the same attitudes increased from pre- to post-Museum Visit for children who found at least one of the exhibits relevant. These results are also based on uneven sample sizes amongst cells and a small study sample, thus results must be interpreted with caution. However, this finding does support the idea that if pedagogy is meaningful to a student, that student will effectively gain interest in the subject matter (Nelson-Barber & Trumbull Estrin, 1995).

Limitations and Implications

Limitations

There are several inherent limitations to this research. Limitations are generally focused in three main areas: power, internal validity, and external validity. Several limitations are explored below along with the precautions taken by the researcher to try to reduce their effects.

Power.

The major limitation regarding statistical power is the small size of the sample included in the study. A small sample of students was chosen to accommodate the

limited funding available for the research project. Low power (the probability of correctly rejecting a false null hypothesis) was especially detrimental to the interaction analyses.

Internal validity.

The major limitations underlying internal validity are the lack of random assignment of students and the lack of a control group design. Both of which make it difficult to ensure that the results are due to the museum visit and not due to history, maturation, or instrumentation (as previously described), teacher's style, or the particular set of students who participated in the study (Cook & Campbell, 1979). A few of the threats to validity are described in further detail below.

Students' responses on outcome measures could have been influenced by the preceding measures (cueing effects). However, the measures were administered in the same order both pre- and post-visit, thus, any influence would have been accounted for in both pre- and post-scores and are not likely to have influenced the change in scores. Concept maps were administered first, thus, the same argument does not hold for this measure of learning. The fact that the pre-visit concept maps were not preceded by the additional measures allows for the possibility that students may have incorporated their knowledge from the preceding measures (especially the content knowledge measure) in addition to their knowledge from the field trip into their post-visit maps. As previously mentioned, the two measures of knowledge assessed very different types of learning and understanding, therefore, the likelihood that gains in

understanding from the content knowledge measure transferred to the post-visit concept maps is small.

The researcher tried to counter additional instrumentation effects due to the within subjects design (missing control group) by creating parallel pre- and post-versions (using different examples in the same basic question structure) of the content knowledge instrument. However, it is not possible to statistically distinguish between alternate explanations for content knowledge gains—cf. museum visit, memory, cuing, and degree of difficulty between versions. Additionally, pre-attitude toward science questionnaires were administered two weeks prior to attitude posttests to decrease the likelihood of instrumentation effects.

External validity.

The limitations related to external validity arise because students were not randomly selected from the general population of low SES, African American students across the nation (Cook & Campbell, 1979). Rather, the students came from one school in one U.S. city and had the same teacher. The participating school was compared to surrounding schools of similar makeup, and no important differences were identified.

External validity is also jeopardized because the study was conducted under a particular set of circumstances. Each of the events that occurred surrounding the museum visit could each be viewed as separate, unintentional treatments (history effects). That is, the museum visit occurred after a coordinated class lecture, a pre-visit

orientation, a pretest, and several concept-mapping practice sessions. Other factors, such as the visiting researcher or even the bus ride could have impacted the change in the dependant scores from pre- to post-visit. The researcher visited the school for months in advance to try to familiarize students with her presence and reduce the impact on students' outcome scores. Additionally, the bus trip could have influenced students' knowledge and attitudinal measures; however, the data do not support this claim. Given that gains were stronger for topic-specific measures (content knowledge, concept mapping, and attitude toward target topic) and weaker for the general science attitude measure, it is likely that the topic-focused exhibits (rather than the non-focused bus ride) influenced the research results. Considering the limitations regarding external validity, generalizability of the results is impractical without future replication as the results may only replicate with like participants or in like situations.

Future research.

Future researchers may want to gain a larger subject pool; many of the results, such as Pre/Post gains in Attitude Toward Science Scores, indicated promising effect sizes that warrant further investigation (see Figures 17 and 18). Researchers interested in pursuing similar topics may want to employ a control group design, visit the museum more than once, and use a larger number of teachers and schools in a wider range of school districts, counties, and states. Researchers may also want to focus on gender differences within ethnicity or other ethnic groups, such as Latinos and Native Americans.

Implications

“It makes sense for science centers to collaborate, to pool resources, to seek additional outside funding...” (Ramey-Gassert, 1997, p. 445).

The results of this research help to identify interactive museum exhibits as relevant pedagogical tools for children from a lower-SES, African American culture. This research identifies hands-on museums as useful experiences that could not only add to the education of underrepresented students, but also improve attitudes toward curriculum topics—both outcomes could aid in reducing the achievement gap. Well-planned field trips are a cost-effective way to enhance learning and attitudes for underserved children; the entire cost of the field trip (\$15.84/student) was less than the cost of a weeklong lecture at the lowest per-student expenditure (\$16.66/student) in the United States (see Biddle, 2001 and Kozol, 1991 above). The results suggest that field trips are an effective way to improve attitudes toward science topics for children in seventh grade (or higher). Perhaps field trips could be used to increase attendance of children in this age group to OMSI’s after-school science clubs. This study suggests that the Chemistry Lab exhibits at OMSI are relevant to this particular group while providing suggestions to enhance that relevance. Given the results of this study, it is imperative that we find a way to get more low-socioeconomic status, African American students into interactive science museums. One way to do this may be for museums and other free-choice learning programs, as well as Portland Public Schools, to use this information to increase funding for class field trips and changes toward

enhancing exhibit relevance from organizations invested in the advancement of underserved youth.

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Appendix A

Permission slip/ Informed consent

Dear Parent/Guardian,

Your child's Seventh grade science class will be taking a fieldtrip to the Oregon Museum of Science and Industry (OMSI). This trip is part of a study conducted by me, Toni Dancu, as partial requirement for a master's degree in Developmental Psychology at Portland State University and is under the supervision of Dr. Miller-Jones. Toni Dancu, Ann Maxwell (the teacher), ICMS* staff, and OMSI staff hope to discover the benefits of fieldtrips to OMSI and the relevance of OMSI exhibits to students who attend Inner City Middle School*.

As part of the study, children will be asked to complete approximately an hour and a half of typical classroom activities and tests during class time. The activities and tests will be used to identify whether the visit to OMSI has increased understanding of classroom material and attitudes toward science. This study will help OMSI develop exhibits that are relevant for children from ICMS (or similar schools); your child's participation will be critical in aiming to increase OMSI exhibits aimed at your child's interests, and fieldtrip funding in your local Portland area. A small class party, with juice, cupcakes, and chips, will be provided at the end of the study.

Please note that participation in the fieldtrip and/or the class party is not contingent on participation in the study. Participation in the study is voluntary and students may quit at any time without penalty. Students will be assigned a number and the information they provide will be kept confidential.

If you have any questions regarding your child's participation or rights as a participant, please contact the Human Subjects Research Review Committee, Office of Research and Sponsored Projects, 111 Cramer Hall, Portland State University, (503) 725- 4288. If you have any questions about the fieldtrip, or the study itself, please contact Toni Dancu at Portland State University Department of Psychology, P. O. Box 751, Portland, Oregon 97201, (619) 865-8020, or tdancu@pdx.edu.

Your signature does not waive any legal claims, rights or remedies. Please sign and date both copies of this form; the second copy of this form is for your records.

Your signature is required twice for full participation:

I, _____, allow _____ to participate in the Portland State
Your Signature Print child's name
University study. Date:_____.

I, _____, allow _____ to participate in the fieldtrip to _____.

Your Signature _____ Print Child's name _____

OMSI. Date: _____.

Thank you.

* Names have been changed to protect the anonymity of the participating school and students.

Appendix B

Informed Assent

The following statement was read to each child prior to gaining verbal assent:

I am conducting a study, which is a special way to find out something. This study will help OMSI and me find out how fieldtrips to OMSI can make learning in school easier or more fun and how to make better exhibits. This study will involve your feedback and cooperation prior to and after your fieldtrip to OMSI. I will ask you to fill out questionnaires, do a couple of concept maps, and give some feedback to OMSI and me about the exhibits you see—we want to hear your opinions. The information you provide may help make more fieldtrips possible in the future. You will be able to stop participating at any time, and Ms. Maxwell will have you do different assignments while others are filling out the questionnaires. You do not have to participate in my study in order to go to OMSI. Do you want to participate? Please let me know if at any time you change your mind.

Appendix C

NUMBER _____

Pre-content knowledge quiz

1-3. Please draw a line matching the items across columns.

Cabbage	Base
Spinach	Acid
Soap	Indicator

4. Please check all that apply:

An acid:

- ☐ a. is always an acid
- ☐ b. can be made neutral
- ☐ c. can be made into a base
- ☐ d. can not be made neutral

5. Please answer True or False:

An indicator measures the pH of a solution. _____

6. Fill in the blank:

What will you observe (see) if you put an indicator into a highly basic solution?

7-9. Multiple choice, please circle the best answer:

7. If something has LOW pH (ex. 2.0), it is a(n):

- a. Base
- b. Buffer
- c. Indicator
- d. Acid

8. When acids are mixed with carbonate compounds, what happens to the mixture?

- a. It changes color
- b. It produces gas
- c. It turns into salt water
- d. It melts

9. When baking soda, calcium chloride, and phenol red are mixed, what happens to the mixture?

- a. It turns blue
- b. It gets cold
- c. It produces gas
- d. It turns into salt water

Appendix D**KEY***Pre-content knowledge quiz*

1-3. Please draw a line matching the items across columns.

Cabbage	Base	+1 [comparable to posttest # 3]
Spinach	Acid	+1 [comparable to posttest #1]
Soap	Indicator	+1 [comparable to posttest #2]

4. Please check all that apply:

An acid:

- ☐ a. is always an acid +.5
☒ b. can be made neutral +.5
☒ c. can be made into a base +.5
☐ d. can not be made neutral +.5

5. Please answer True or False:

An indicator measures the pH of a solution. TRUE +1

6. Fill in the blank:

What will you observe (see) if you put an indicator into a highly basic solution?

List color or color change = +1;
change or reaction +.5

7-9. Multiple choice, please circle the best answer:

7. If something has LOW pH (ex. 2.0), it is a(n):

- a. Base
 b. Buffer
 c. Indicator
d. Acid D= +1

8. When acids are mixed with carbonate compounds, what happens to the mixture?

- a. It changes color
b. It produces gas B= +1
 c. It turns into salt water
 d. It melts

9. When baking soda, calcium chloride, and phenol red are mixed, what happens to the mixture?

- a. It turns blue
 b. It gets cold
c. It produces gas C= +1
 d. It turns into salt water

Total Possible: 10

Appendix E

Number _____

Post-content knowledge quiz

1-3. Please draw a line matching the items across columns.

Orange juice	Base
Ammonia	Indicator
Red onion juice	Acid

4. Please check all that apply:

A base:

- ☐ a. is always a base
- ☐ b. can be made neutral
- ☐ c. can be made into an acid
- ☐ d. can not be made neutral

5. Please answer True or False:

An indicator measures how acidic or basic a solution is. _____

6. Fill in the blank:

What will you observe (see) if you put an indicator into a highly acidic solution?

7-9. Multiple choice, please circle the best answer:

7. If something has HIGH pH (ex. 13.0), it is a(n):

- a. Base
- b. Buffer
- c. Indicator
- d. Acid

8. When acids are mixed with carbonate compounds, what happens to the mixture?

- a. It changes color
- b. It produces gas
- c. It turns into salt water
- d. It melts

9. When baking soda, calcium chloride, and phenol red are mixed, what happens to the mixture?

- a. It turns blue
- b. It gets cold
- c. It produces gas
- d. It turns into salt water

Appendix F**KEY***Post-content knowledge quiz*

1-3. Please draw a line matching the items across columns.

Orange juice	Base	→ +1 [comparable to pretest #2]
Ammonia	Indicator	→ +1 [comparable to pretest #3]
Red onion juice	Acid	→ +1 [comparable to pretest #1]

4. Please check all that apply:

A base:

- ☐ a. is always a base +.5
☒ b. can be made neutral +.5
☒ c. can be made into an acid +.5
☐ d. can not be made neutral +.5

5. Please answer True or False:

An indicator measures how acidic or basic a solution is. TRUE +1

6. Fill in the blank:

What will you observe (see) if you put an indicator into a highly acidic solution?

List color or color change = +1; change or reaction = +.5

7-9. Multiple choice, please circle the best answer:

7. If something has HIGH pH (ex. 13.0), it is a(n):

- a. Base** A= +1
 b. Buffer
 c. Indicator
 d. Acid

8. When acids are mixed with carbonate compounds, what happens to the mixture?

- a. It changes color
b. It produces gas B= +1
 c. It turns into salt water
 d. It melts

9. When baking soda, calcium chloride, and phenol red are mixed, what happens to the mixture?

- a. It turns blue
 b. It gets cold
c. It produces gas C= +1
 d. It turns into salt water

Total Possible: 10

Appendix G
Concept Mapping Introduction

The following instructions will be given verbally, and displayed on a screen :

- 1) Create a list of terms (concepts) related to Plants.
EX: Flowers, Fruit, Soil, Water, Sun, Food, Roots
- 2) Write the terms (concepts) down on sticky notes, or cards (Provided).
- 3) Arrange the notes in any way that makes sense to you. (I will do this with them on the board/projector).
- 4) Draw arrows between the terms (concepts) to show how they are related, terms may be related with several other terms. Label all of your arrows.
- 5) Consider your map, are there any other terms (concepts) you can add? Are there any other arrows or relationships you can add?
- 6) What about adding: Animals and Humans?

**See the next page to view this concept map.

Now let's try it together with music:

Can you suggest a few concepts: (I will begin this process if necessary)?

What arrows should I add?

How should I label these arrows?

I am going to add two more concepts and two more arrows.

Now, are there any more concepts or relationships we should add?

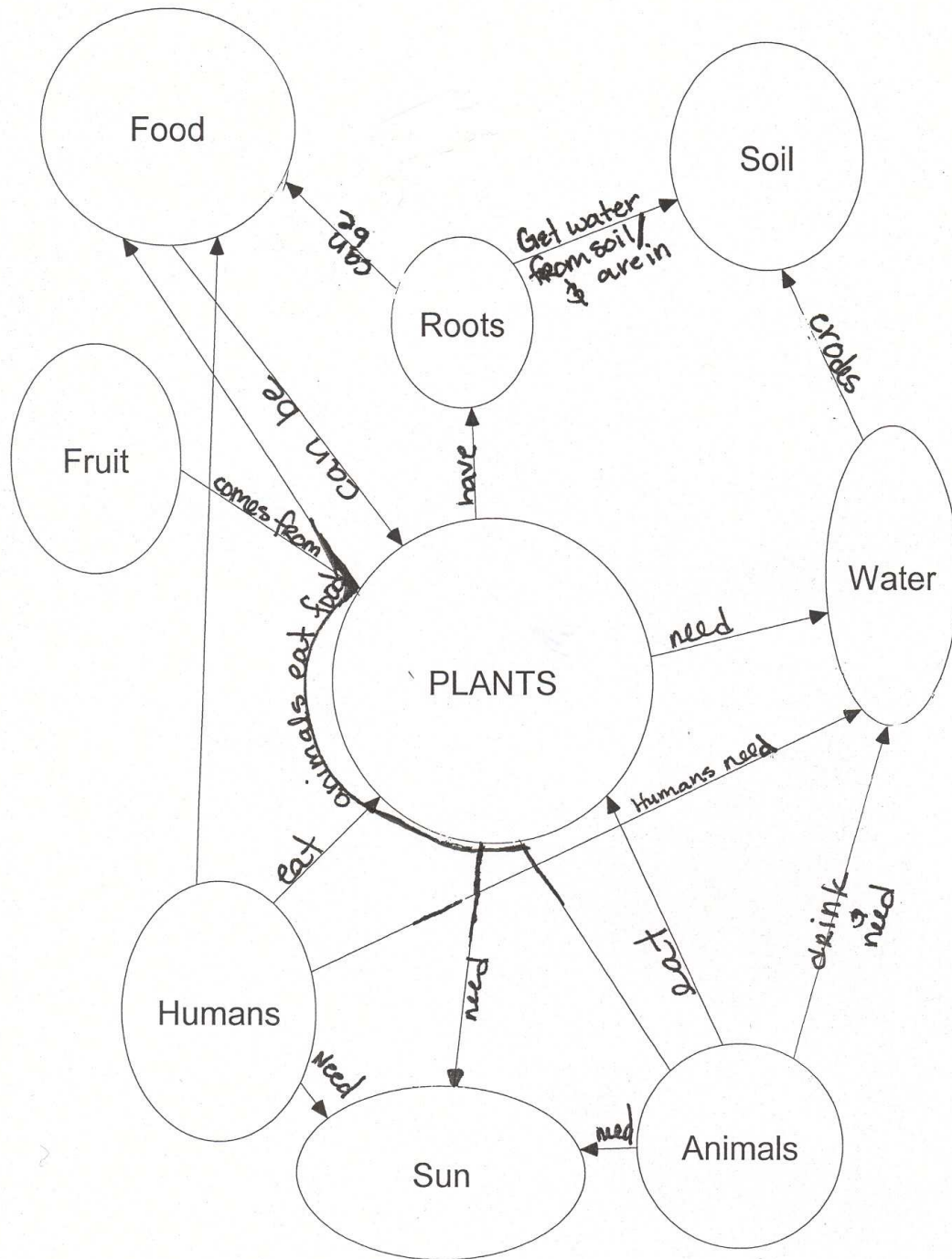
Feedback (suggest more relationships, etc.)

One more :

You just had class about (for example) energy, let's use that. You guys tell me to write whatever you want, we will make a class concept map about energy

What concepts do we need ?

Ex: Kinetic, Potential, electrical, thermal, chemical, mechanical, fossil fuels, toaster, truck



Appendix H

Number

Attitude Toward Science Questionnaire

1. Science is something that I enjoy very much.
Strongly Disagree Disagree Agree Strongly Agree
2. I enjoy talking to other people about science.
Strongly Disagree Disagree Agree Strongly Agree
3. I like the challenge of science assignments.
Strongly Disagree Disagree Agree Strongly Agree
4. Science is one of my favorite subjects.
Strongly Disagree Disagree Agree Strongly Agree
5. I have a real desire to learn science.
Strongly Disagree Disagree Agree Strongly Agree
6. I am good at science.
Strongly Disagree Disagree Agree Strongly Agree
7. I understand most of what goes on in science class.
Strongly Disagree Disagree Agree Strongly Agree
8. If I had a choice, I would not study any more science.
Strongly Disagree Disagree Agree Strongly Agree

How do you feel about....

9. Studying science?

It's weak It's not cool It's OK It's cool It's tight

10. Becoming a scientist?

It's weak It's not cool It's OK It's cool It's tight

11. Going to museums to learn more about science?

It's weak It's not cool It's OK It's cool It's tight

12. Working on science projects and activities alone?

It's weak It's not cool It's OK It's cool It's tight

13. Working on science projects and activities with others?

It's weak It's not cool It's OK It's cool It's tight

14. Doing science experiments?

It's weak It's not cool It's OK It's cool It's tight

15. Creating ideas for science projects and experiments?

It's weak It's not cool It's OK It's cool It's tight

16. Learning more about science after school?

It's weak It's not cool It's OK It's cool It's tight

17. Looking at books to learn more about science?

It's weak It's not cool It's OK It's cool It's tight

18. Telling friends and family what you did in science class?

It's weak It's not cool It's OK It's cool It's tight

19. Writing about your daily science activities?

It's weak It's not cool It's OK It's cool It's tight

Appendix I

Number_____

Attitude Toward Target Topic

How do you feel about....

The following is an example using energy as the target topic.

1. Learning why indicators change color in different solutions?

It's weak It's not cool It's OK It's cool It's tight

2. Exploring different types of natural indicators?

It's weak It's not cool It's OK It's cool It's tight

3. Studying how to identify the pH of a solution?

It's weak It's not cool It's OK It's cool It's tight

4. Changing acids into bases and back into acids?

It's weak It's not cool It's OK It's cool It's tight

5. Drawing pictures of the pH scale and items that fit at high and low points?

It's weak It's not cool It's OK It's cool It's tight

6. Finding out how different substances mix and create gas?

It's weak It's not cool It's OK It's cool It's tight

7. Watching the colors of a solution change as you alter (change) the pH level?

It's weak It's not cool It's OK It's cool It's tight

8. Comparing acids and bases (pH, feel, taste, and reactions with other substances)?

It's weak It's not cool It's OK It's cool It's tight

Appendix J*Chaperone Training for Engagement Ratings*

Each of you will be asked to rate each child's level of engagement while at three target exhibits. Ratings will range from Low Engagement (1) to High Engagement (4). Moderate Engagement is broken into two categories—Moderate-High (3) and Moderate-Low (2). Below are operationalized definitions of the ratings to guide you in your ratings:

0%	(1)	25%	(2)	50%	(3)	75%	(4)	100%
----	-----	-----	-----	-----	-----	-----	-----	------

High Engagement (4). These children will be on task 75% or more of the time while they are interacting with the exhibit. On task behaviors will include asking questions of (or talking with) you, OMSI staff, or each other; looking at the exhibit; manipulating properties of the exhibit; and/or reading the text that accompanies the exhibit. High Engagement children will exhibit positive emotions, interest, and concentration while interacting at the exhibit.

Moderate-High Engagement (3). These children will be engaged to a lesser extent than the High Engagement children. On task behavior will be exhibited more than 50% of the time, but less than 75% of the time. Emotions, interest, and concentration will likely be mixed (high at times and low at times) but more often reflect that of High Engagement children than that of Low Engagement children.

Moderate-Low Engagement (2). These children will be engaged to a lesser extent than the Moderate-High Engagement children, but at a greater extent than the Low Engagement children. On task behavior will be exhibited less than 50% of the time, but more than 25% of the time. Emotions, interest, and concentration will likely be mixed (high at times and low at times) but more often reflect that of Low Engagement children than that of High Engagement children.

Low Engagement (1). These children will be on task less than 25% of the time. These children will rarely ask questions, manipulate properties of the exhibit, or read the accompanying text. These children will often create distractions, show negative emotions, and will exhibit little interest or concentration while at the exhibit.

Appendix K

Rater Name _____

Please rate each child's level of engagement at each target exhibit.

1= Low Engagement, 2= Moderate-Low Engagement,
3= Moderate-High Engagement, 4= High Engagement.

Forwards and Backwards

Child's # Engagement rating Comments

Reaction, Yes or No?

Child's # Engagement rating Comments

Natural Indicators

Child's # Engagement rating Comments

Appendix L

Number _____

Participant Information Form

Have you been to a science museum (such as OMSI) in the past two years?

YES NO

If yes, how many times?

1 2 3 4 5+

Peer Participation:

CIRCLE ONE ANSWER FOR EACH STATEMENT

My friends discuss things they have learned in science class...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

My friends talk about science outside class...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

My friends enjoy doing science-related activities outside of class....

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

My friends are interested in science...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

My friends work on science projects...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

Home Information

CIRCLE ONE ANSWER FOR EACH STATEMENT

**Information in parentheses was stated verbally after each question was read and students were informed before they began filling out this measure to rate it with any subject, not just science, in mind.

At least one adult in my home helps me with my science homework (or any other homework)...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

At least one adult in my home asks what I am learning in science class (or any other class)...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

At least one adult in my home makes me do my science homework (or any other homework)...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

At least one adult in my home helps me work on my science projects (or any other school projects)...

- (1) Less than once a month
- (2) Once a month
- (3) More than once a month, but less than once a week
- (4) Once a week
- (5) More than once a week

Appendix M

Number _____

Qualitative Attitude and Relevance Questions

- 1) Did you identify with any icons (images, pictures) or texts (written passages) throughout OMSI?
- 2) How were the icons you recognized or identified with relevant (does it have meaning) to or for you? Please list any icons or texts you saw and describe why they are meaningful to you and/or why not.

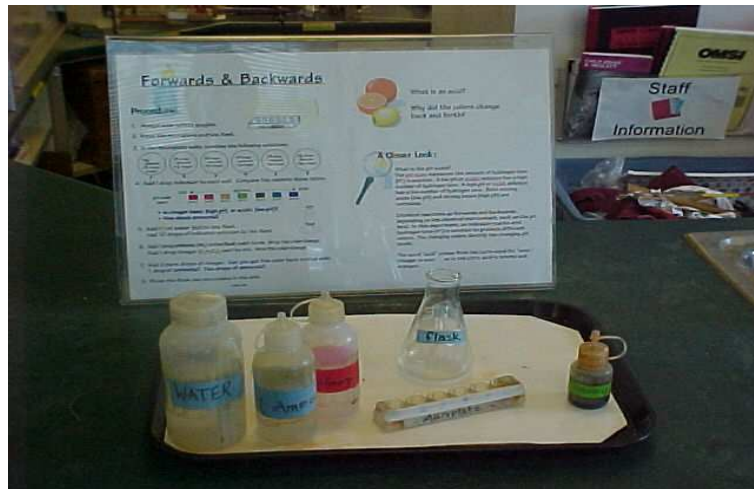


Figure 1 Forwards & Backwards

- 3) Did the exhibit *Forwards and Backwards* remind you of anything you have at home, or anything you have done or seen before? If yes, please explain.

- 4) How would you change *Forwards and Backwards* to make it more personal, meaningful (or even more fun) to you?



Figure 2 Natural Indicators

- 5) Did the exhibit *Natural Indicators* remind you of anything you have at home, or anything you have done or seen before? If yes, please explain.

- 6) How would you change *Natural Indicators* to make it more personal or meaningful (or even more fun) to you?



Figure 3 Reaction, Yes or No?

- 7) Did the exhibit *Reaction, Yes or No?* remind you of anything you have at home, or anything you have done or seen before? If yes, please explain.
- 8) How would you change *Reaction, Yes or No?* to make it more personal or meaningful (or even more fun) to you?

- 9) Are there any other exhibits, images, or texts you would like to comment on?
- 10) Of the three exhibits in the Chemistry Lab, which one was your favorite and why?

Appendix N

Overview of Schedule of Procedures.

	Monday	Tuesday	Wednesday	Thursday	Friday
Week one 2/23–27					•Concept mapping training
Week two 3/1–5					•Concept mapping practice
Week four 3/15–19		•Concept mapping practice			
Week eight 4/12–16					•Fieldtrip permission slips
Week nine 4/19–23		•Pre-attitude toward science •Personal information form		• Concept mapping practice	• Concept mapping practice
Week ten 4/26–30	•Acids and bases curriculum	•Acids and bases curriculum	•Acids and bases curriculum	•Acids and bases curriculum	•Acids and bases curriculum
Week eleven 5/3–7		•Pre-concept maps •Pre-content knowledge •Pre-attitude toward target topic •Orientation	•Fieldtrips •Engagement ratings	•Post-concept maps •Post-content knowledge •Post-attitude toward science •Post-attitude toward target topic •Qualitative questionnaire	•Party