

TRAN, LYNN UYEN. The roles and goals of educators teaching science in non-formal settings.
(Under the guidance of Dr. John Penick)

ABSTRACT

Recognition of informal institutional settings as educational resources to supplement and compliment school science teaching and learning has increased in the last 25 years. Research examining how people interact with exhibits or the natural environment, and the benefits of preparing classroom teachers to use informal settings to enhance student experiences is extensive. It is the free-choice, non-evaluative, non-threatening, social nature of these settings that may drive people's intrinsic motivation to learn. While many informal settings also provide numerous learning opportunities through educator-led programs like classes, lectures, and demonstrations, literature regarding learning and instruction from the perspective of these non-formal educators and the educational programs they provide remain deficient. Thus this exploratory study investigated three questions pertaining to instruction of science classes offered to visiting school groups: (1) How do educators at informal settings teach science to school groups?; (2) What role do non-formal educators take in K-12 science instruction at informal settings?; (3) What are the observable teaching behaviors of non-formal educators in science classes taught to school groups?

In this qualitative investigation, eight non-formal educators from eight informal settings in North Carolina were observed teaching regularly scheduled science classes to visiting school groups. Four types of data (field notes; modified SATIC plus addendum to code student-teacher verbal interactions and student activities; self-perception surveys; and semi-structured, open-ended interviews) were collected, and each was validated against the other three in order to improve credibility of the findings and interpretations. Seven major findings arose from constant comparison of the four data sources: (1) Prompt assessment of learners' prior knowledge is a

critical skill for teaching in non-formal settings. (2) Lesson plan repetition was an inherent advantage. (3) Variability in job duties generated opportunities for collaboration among colleagues. (4) Physical participation was used to create lasting memories. (5) Programs and teaching practices were teacher-centered in nature. (6) Classes at informal settings shared characteristics of science labs in formal classrooms. (7) Apprenticeship-style teacher education is the norm for non-formal educators.

The roles and goals of educators teaching science in non-formal settings

by

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Dedicated to Dr. Gordon Hendler

My mentor, colleague, and dearest friend.

I have yet to stop learning from you.

You are a true teacher.

BIOGRAPHY

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

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

from Dr. Penick, and the extraordinary faculty here at State, I am beginning my trailblazing journey into the world of non-formal science education.

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CHAPTER 1. INTRODUCTION

The growing perception of need for improved science education (National Council on Excellence in Education, 1983; TIMSS, 2001), and the desired inclusion of out-of-classroom experiences in school science curriculum (National Research Council, 1996; National Science Teachers Association, 1998) has prompted non-formal institutions to play a more active role in science teaching and learning. Consequently, in the last 25 years there has been a slow but steady increase in research on student cognitive and affective gains from experiences at non-formal settings (Melber & Abraham, 2002). Recognition of the value and potential for science learning from non-formal settings is indicated by the National Science Teachers Association's 1998 position statement, recommended by the *National Science Education Standards* (NSES, NRC, 1996), and supported by special interest groups in professional organizations like NARST and AERA.

In this thesis, non-formal settings encompass educational institutions like museums, nature centers, zoos, and aquariums. As defined by Maarschalk (1988, p.137), "non-formal education is education that proceeds in a planned but highly adaptable way in institutions, organizations, and situations." Furthermore, Heimlich (1993, p. 3) explained that

"non-formal learning is that in which the individual controls the objectives of learning but not the means. ... In responding to client needs, an organization maintains control over the educational program through the means of structuring the program, determining how the information will be shared, presented, or provided to the learners, and operating within the constraints of the organization and its own sets of beliefs, values, and attitudes."

Using these definitions, non-formal educators in this study are those individuals teaching in non-formal settings.

Visits to non-formal settings provide experiences that extend learning beyond the initial encounter. This is demonstrated over and over again as individuals reflect upon their interactions with the exhibits, artifacts, and programs over their lifetime. It is the free-choice, non-evaluative, non-threatening, social nature of these settings that may drive people's intrinsic motivation to learn (Csikszentmihalyi & Hermanson, 1995; Falk, Koran Jr., & Dierking, 1986). Along with the exhibits and natural settings themselves, many institutions also provide numerous learning opportunities through educator-led programs like classes, workshops, lectures, and demonstrations (Bierbaum, 1988).

Research examining how people interact with exhibits or the natural environment is extensive (Falk *et al.*, 1986; Ramey-Gassert, Walberg III, & Walberg, 1994). However, most studies at non-formal settings relate to visitor behavior and time spent at exhibits, while literature regarding learning and instruction from the perspective of educators and the educational programs they provide remains deficient. But, we do know that preparing classroom teachers to use non-formal settings enhances student experiences (Chesebrough, 1994; Olson, Cox-Peterson, & McComas, 2001; Smith, McLaughlin, & Tunnicliffe, 1998).

Most non-formal institutional settings provide 30 to 60-minute, on-site, structured classes to teach various science topics that target visiting school groups. Usually, these are related to concepts and subjects featured at the institution. Classes are taught indoors and/or outdoors (depending on the topic and institution), and sometimes a nominal fee is charged per session (e.g. \$25 per class or \$3 per child). Since school groups need to go to the institution to take part in these programs, they are generally offered in the morning so that students and the school buses are able to return to their campus before the school day is over.

As a result, the institutions are usually able to accommodate up to three group programs per day. Sometimes this structured class program is the only activity the school group participates in during a visit to the non-formal setting. Staff educators or volunteer docents teach the classes depending on their availability and interest in the class subject.

The educators who lead these classes tend to have a varied science and teaching background. Some educators have extensive experience in science and science teaching in both formal and non-formal settings, while others do not. Those without formal training may acquire both their content and pedagogical knowledge from on-the-job experiences. In most cases, educators teaching in non-formal settings say that they enjoy science and teaching, but prefer doing both outside of the traditional classroom. Without the need to formally assess student understanding coupled with the assortment of resources available to non-formal settings (e.g. river, live specimens, expert scientists, and trails), educators are encouraged to physically involve students in the learning process. This is consistent with current science teaching goals and practices nationwide.

The *NSES* advocates science learning as an active process. “Learning science is something students do, not something that is done to them” (National Research Council, 1996, p. 20) because learning is a mentally and physically active process. Teaching science through inquiry engages the learner by giving her or him the opportunity to make observations, pose questions, examine resources, plan investigations, use tools to gather, analyze, and interpret data, propose explanations, and communicate those findings. In so doing, the learner is building her or his own understanding.

Consequently, from a constructivist perspective, the role of the educator is to facilitate and mediate the learning process, rather than to simply dispense information (Driver, Asoko, Leach, Mortimer, & Scott, 1994; von Glasersfeld, 1984). As the mediator of learning, the educator interacts with the students, establishing a dialogue that can reveal student thinking (Mintzes & Wandersee, 1998; Tobin, Tippins, & Gallard, 1994). While free discovery affords the opportunity to construct knowledge, literature regarding classroom practices also reveals that guidance from the teacher is a necessary part of this knowledge construction (Linn, 1980; Rice & Linn, 1978). Research in formal settings indicates that teachers effectively use a variety of strategies from expository teaching to hands-on interactive experiments to assist students with the construction of knowledge (Tobin & Fraser, 1990; Tobin & Garnett, 1988; Tobin *et al.*, 1994).

In non-formal settings, teaching structured classes to school groups is analogous to science teaching in formal classrooms. The non-formal educator leads the class, and is responsible for the learning that takes place. Consequently, the contention in this model is that teaching is teaching regardless of where it is done, and the strategy changes or is modified according to the audience and setting. In addition, the multitude of published research regarding traditional classroom practices should provide valuable insight to educators teaching in non-formal settings. The non-evaluative and non-threatening nature of science classes at non-formal settings could render some classroom best practices as potentially effective teaching practices in these settings. However, the constraints of classes at non-formal settings, e.g. short lessons, one-time interactions with the students, and not knowing students' prior knowledge antecedent to developing and delivering the lesson, might

require some modifications of these approaches. Nonetheless, the potential for transferability of best teaching practices in formal classroom to the non-formal setting is there. To take advantage of this possibility, an understanding of the teaching strategies educators are using at non-formal settings must first be established. Thus, this study has investigated documents the science instruction that takes place at non-formal institutional settings by employing observation instruments commonly used to record classroom behavior.

This exploratory investigation describes how educators at non-formal settings teach science to visiting school groups by coding and characterizing observable teaching behavior, and analyzing personal statements. It examines non-formal educators' perceptions of their roles as teachers, and their personal teaching goals for the science classes taught at their institution. Thus this study investigates the following questions:

- How do educators at non-formal settings teach science to school groups?
- What do non-formal educators believe is their role in K-12 science instruction?
- What are the observable teaching behaviors of non-formal educators in science classes taught to school groups?

To thoroughly examine these questions, three approaches are indicated. (1) One must first understand the role non-formal settings play in science learning and teaching, and the potential outcomes of their actions; (2) the framework from which learning is to be viewed should also be determined since this influences teaching practices; (3) in addition, best teaching practices in traditional classrooms that are consistent with this learning framework will shed light on to teaching behavior that educators at non-formal settings could use in their classes. This includes teacher verbal behavior, teacher questions, active physical

participation, and the use of free exploration. This exploration examines whether educators at non-formal settings employ these practices, and how they are used.

An understanding of the opportunities, constraints, and strategies of educators teaching at non-formal settings could help science teachers (formal and non-formal) and science teacher educators maximize upon all potential science learning and cognitive development opportunities. From this awareness, those interested in teaching in traditional classrooms could better understand and use non-formal settings to supplement and complement their science curriculum. Meanwhile individuals teaching at non-formal settings can improve upon their cognitive and affective impact; educating the public scientifically while serving the needs of classroom teachers.

CHAPTER 2. LITERATURE REVIEW

The Call for Science Education at Non-formal Settings

Historical Setting

Science museums, initially modeled after art museums as depositories for scientists and the elite upper class in order to preserve their collections samples (Melber & Abraham, 2002), not for the curiosity or edification of the public, have evolved tremendously (Caro, 1996, August). Science museums began expanding in the 1930s to include public education, especially programming for school children. Opening of the Ontario Science Center and the Exploratorium of San Francisco in the 1970s demonstrated early models of child-oriented facilities, and the incredible potential and contribution non-formal settings could have on science learning. This new generation of science museums extended the education process from simply exposing the public to scientific concepts and phenomena to involving them in the discovery and construction of their own understanding. Thirty years later, we are experiencing yet another evolutionary turning point in science education at non-formal settings.

With comparative measurements and test scores, science education in the American school systems has been recognized to be weaker and less effective than anticipated (National Council on Excellence in Education, 1983; TIMSS, 2001). Scientists, science teachers, and science teacher educators are calling for more inclusion of out-of-classroom experiences in the formal school curriculum as one strategy to improve science teaching. This position can be evidenced by recognition of the value and potential for science learning from non-formal settings indicated by the National Science Teachers Association position

statement (NSTA, 1998), recommendations in the *National Science Education Standards* (Collins, 1998; National Research Council, 1996, NSES), support by special interest groups in professional organizations like NARST and AERA, and funding opportunities from the National Science Foundation's Division of Elementary, Secondary, and Informal Education (ESIE).

The NSES (1996) recommends that teachers of science (Teaching Standard D) and K-12 science programs (Program Standard D) provide opportunities for students to engage in science inquiry activities outside of the school environment. Listed among the out of school resources that all K-12 students should experience are non-formal institutional settings. An NSTA (1998) position statement advocates the value of and need to include non-formal institutional settings in school curriculum as a way to supplement and complement school children's science experiences. Using the term "museum" very loosely to include all non-formal institutional settings, Falk, Koran Jr., and Dierking (1986) argued that museums are extremely important for communicating science. Museums are free-choice, non-evaluative, non-threatening, social environments that are conducive to nurture learning.

Csikszentmihalyi and Hermanson (1995) suggested that these same characteristics drive the intrinsic motivation of learning at all museums. They contend that humans, especially children, have an innate desire to learn. All the structure and bureaucracy of schools may dampen this desire in some children, while the casual, self-paced nature of museums may spark that same passion. Frank Oppenheimer, physicist and founder of the Exploratorium in San Francisco, commented about the benefits of non-formal settings as a place of learning, "... no one ever flunks a museum or television program, or a library or a park while they do

flunk a course - they do ‘flunk out of school’” (1975, p. 11). Csikszentmihalyi and Hermanson (1995), Falk *et al.* (1986), and Oppenheimer (1975) suggest that with the fear of failing or being evaluated by someone other than yourself eliminated or at least greatly reduced, learning (science in particular) becomes less intimidating and more enjoyable.

Learning in Museums

That experiences from non-formal institutional settings extend beyond the initial encounter can be demonstrated repeatedly as individuals informally reflect on their own interactions with the exhibits, artifacts, and programs over the years. While these settings are incredible learning environments, the question arises as to what the children are actually learning. There are cognitive gains to be achieved; whether these gains are those intended by the institutions’ educators and exhibit designers is questionable. As Falk *et al.* (1986) pointed out, the unstructured, free-choice nature of non-formal settings makes assessment of cognitive gains difficult. These experiences also have a potential life-long learning effect that is difficult to measure with traditional post tests. Nonetheless, countless researchers have endeavored to understand and explain the learning that takes place at non-formal institutional settings.

Educational Opportunities at Non-formal Settings

Regardless of their size and operating budget, non-formal institutional settings offer educational opportunities beyond the exhibits and settings themselves (this study). Ninety four per cent of the 138 museums surveyed by Bierbaum (1988) provided additional

education programs aside from tours and the exhibits. On average, museums had 13 different kinds of educational programs, including workshops and classes available to patrons, and structured science classes were among the commonly offered programs. However, literature in support of school children learning in museums has generally concentrated on the impact of interactions with exhibits (Flexer & Borun, 1984; Gottfried, 1980; Wright, 1980) and classroom teacher use of museums (Olson *et al.*, 2001; Smith *et al.*, 1998). While research about visitor interactions in museums dates as far back as 1928 (Ballantyne, 1988), they have primarily focused on attendance, visitor behavior, and time spent reading signage (Kimche, 1978; Ramey-Gassert *et al.*, 1994). From the perspective of the educators at the non-formal settings and the educational programs the institutions provide, literature regarding learning and instruction is meager.

Gottfried (1980) examined children's behavior during school field trips to the Lawrence Hall of Science Biolab. With minimal instruction and supervision, students were set free to explore in an environment that offered opportunities to touch, manipulate, and experiment. He observed that in the course of interacting and exploring, students made discoveries that they were quick to share with their peers. In many cases, students conducted original experiments and inquiries that stemmed from their own curiosity and imagination. Thus science was associated with fun and playful activity rather than drudgery.

Researchers also have investigated whether interaction with museum exhibits enhanced learning (Flexer & Borun, 1984; Rix & McSorley, 1999; Wright, 1980). In his study, Wright analyzed the effect of a museum experience at the Kansas Health Museum on the biology achievement of sixth graders. He found that students who reviewed their health

unit at the Museum had superior comprehension and application of knowledge and concepts compared to students who reviewed the content in their classroom. He concluded that the hands-on, interactive, multi-sensory experience at the museum provided students with concrete ways to assimilate complex concepts. Flexer and Borun (1984), however, examined the entire learning experience at the museum. They assessed the effectiveness of participatory museum exhibits and lecture-style lessons at the Franklin Institute Science Museum in communicating science content and facilitating subsequent classroom learning. They found that a structured, lecture-style lesson designed specifically for the study and in congruence with the exhibits, and taught at the museum was a more effective brief learning experience than the exhibits alone. While interaction with the exhibits only was superior to the control for conveying science concepts, museum experience that included the structured lesson was more effective at communicating vocabulary and application. The structured class in this study was not a regular educational program provided by the museum. However, students thought they learned more via the exhibit which promoted more interest and encouraged an appetite for further science learning.

Rix and McSorley (1999) simulated school children's experience with interactive science exhibits by creating a "home-made" mini-museum to explore what, how, and why seven physics concepts occurred at a school in the United Kingdom. They examined how children interacted with and learned from these hands-on exhibits, and whether they could be incorporated into schools. The authors found that while the interactive exhibits had a positive affective impact, worksheets seemed to hinder student learning. They found that although some students made cognitive gains on how the phenomena happened, the majority did not

understand how or why it occurred. Rix and McSorley pointed out that prior knowledge could potentially hinder development of new concepts by focusing the students' attention on certain features of the exhibit rather than encouraging them to explore the phenomena being communicated. Students' inquiring behaviors were driven by "what they needed to do" in order to make the exhibit work, rather than "why was this happening?" Students tended to "play" with the apparatus, and did not learn the intended science concept. However, there was evidence of all children at some point in their exploration manipulating factors of an exhibit and observing effects of the change. Thus, the authors questioned whether it was necessary and appropriate to expect children to comprehend in a few minutes of "playing with an apparatus," a concept that has taken scientists years to understand.

Effects of Teacher Preparation

There is also growing interest in preparing classroom teachers to use museums, and how such preparation affects teacher attitude towards teaching science and student learning. Olson *et al.* (2001) examined teacher educator preparation of in-service and pre-service teachers to incorporate non-formal settings into their lesson plans, while Smith *et al.* (1998) and Cheseborough (1994) reviewed the impact of teacher preparation by museum educators. Pre-service teachers were initially unsure of their own ability to take students out of the classroom, and found the task overwhelming (Olson *et al.*, 2001). However, aid from their cooperating teacher helped reduce that fear. Thus, Olson *et al.* concluded that the task of taking students on excursions to museums was less intimidating if teachers were provided

experiences modeling effective field trip strategies, and guidance from their cooperating teachers and the university.

In regards to teacher preparation from museums, Smith *et al.* (1998) revealed that brief professional development in a museum can have a positive effect on teachers' instructional practices by providing them with ideas and examples to teach science concepts in their classrooms. Thus trained teachers were better able to incorporate their lesson plans into zoo-related instruction, which affected the students' zoo experiences later in the school year. Results from interviews immediately following their viewing of a zoo exhibit indicated that students of both trained and untrained teachers made low level irrelevant, descriptive, or identification comments about their experiences at the exhibit. Both teacher and volunteer docents commented that students of trained teachers were able to apply concepts learned in classroom, and make observations and comparisons about animals studied in the classroom and those viewed at the zoo. Meanwhile, Chesebrough (1994) found a positive attitude change towards science and science teaching by pre-service elementary teachers as a result of a science methods course taught at a museum by museum educators who held masters degree in education. The course focused on pre-service teachers engaging in and conducting hands-on activities, observing children engaging in free-choice science activities, and interacting with the museum's scientists, exhibits, and other special features.

Structured Museum Programs

As previously pointed out (Bierbaum, 1988), workshops and classes are common educational programs provided by museums. Despite the classroom structure of some

programs offered to school groups at non-formal institutional settings, they remain non-threatening and non-evaluative because the educators leading these lessons will not grade or test the students' acquisition of the information at the conclusion of the lesson. Nor will the students and educators necessarily interact with one another under these conditions again, since most of these classes are one-time opportunities. In such a casual learning environment how can the educators effectively mediate and facilitate the learning process? Investigations into the mode of instruction by museum educators in such educational programs, and their impact on student learning may shed more light on the whole museum experience.

Unfortunately, there is little literature pertaining to teaching and learning from the perspective of the educators at the non-formal institutional settings. However, if one contends that teaching is teaching regardless of where it is done, and it is the strategy that changes or is modified according to the audience and the setting, then the *corpus* of research about classroom practices can provide incredible insight to educators teaching at non-formal settings. As Schauble and Bartlett (1997) stated while reflecting on designing a new science gallery for the Children's Museum of Indianapolis, "studying forms of student learning often makes little sense without studying forms of teaching" (p. 790).

A Constructivist Approach to Learning

The learning theories proposed by Piaget, Vygotsky, and other cognitive scientists took into account the socio-cultural context and developmental readiness of the individual in the processing of information. From their work arose a school of thought that meaning is made by the learner, and relies upon the learners' existing knowledge (Driver *et al.*, 1994;

Novak, 1998; Pope & Gilbert, 1983; Rosenshine & Stevens, 1986; Staver, 1998; Tobin *et al.*, 1994; von Glasersfeld, 1989). New information is assimilated into the learner's existing mental framework. Information that contradicts, conflicts with, or is unfamiliar places the learner into a state of disequilibrium, or cognitive conflict. The learner's cognitive framework must change in order to accommodate the new information (Barba, 1995; Driver *et al.*, 1994; Novak, 1998; Wadsworth, 1979). Learning takes place when resolving the disequilibrium requires internal mental activity and modification of existing understanding. Thus knowledge cannot be passively received (von Glasersfeld, 1984) or "... transmitted directly from one knower to another ... but is actively built up by the learner" (Driver *et al.*, 1994, p. 5).

Knowledge building and learning is a process that requires the learner consciously to connect new knowledge with existing knowledge, and testing its viability within one's own cognitive framework (Mintzes & Wandersee, 1998; Novak, 1998; Rosenshine & Stevens, 1986). As a result, the role of the educator is to facilitate the learning process, rather than to simply dispense information (Driver *et al.*, 1994; Tobin *et al.*, 1994). As the mediator of learning, it is important for the educator to interact with the students, and ascertain what they know and what they are thinking (Mintzes & Wandersee, 1998; Tobin *et al.*, 1994). David Ausubel stated it well in the epigraph of his 1968 work, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (1968, p. iv). In this way the educator focuses the learners' thinking in productive directions, and encourages the learners to build upon extant knowledge.

Effective Teaching Practices

Mintzes and Wandersee (1998) described favorable teaching approaches that lead to knowledge building and meaningful learning as involving “. . . active participation, intensive interaction, and thoughtful reflections” (p. 52). This could involve school class activities and demonstrations, as well as cooperative group work and hands-on laboratory work. The goal is to provide the learner with opportunities to generate her or his own understanding.

Nussbaum (1998) pointed out that teachers should use a variety of strategies in order to help students construct the desired meaning of scientific concepts, and undergo conceptual changes. In their review of science teaching strategies, Tobin *et al.* (1994) asserted that teaching should be flexible and modifiable to what’s appropriate to the classroom or situation. From the classrooms of the exemplary science teachers they reviewed, the authors found that verbal interaction was the key to teaching with understanding because it enabled the teachers to monitor their students’ comprehension of science concepts. The use of stimulating and probing questions coupled with clear and concise explanations were operative verbal behaviors demonstrated by exemplary science teachers (Goodrum, 1987; Tobin, Treagust, & Fraser, 1988). The exemplary elementary science teachers in Goodrum’s study (1987) posed quality questions that facilitated student understanding, both in small group and whole class activities.

Tobin and Fraser (1990) conducted an extensive qualitative study to observe and describe the practices of exemplary science teachers in western Australia. This was developed in response to the Search for Excellence project in the U.S. in which researchers assessed exemplary science education programs in schools all across the United States (see

Penick, 1983; Penick & Bonstetter, 1983; Penick & Lunetta, 1984; Penick & Meinhard-Pellens, 1984). The 13 exemplary teachers Tobin and Fraser studied actively managed student behavior and learning individually and over a whole class, thus demonstrating good classroom management. The teachers emphasized the development of autonomy and independent work, and they took care in explanations and directions so that students knew what to do, and how to do it. They used verbal interaction to monitor student understanding of a concept. This was done through posing questions that stimulated thought, probing student responses for elaboration and clarification, and clear and concise explanations to expand upon ideas. They created an environment for students to feel safe to participate in learning activities by treating them and their contributions with respect. By endeavoring to work with student responses, the teachers encouraged students to be intellectual risk takers. And finally, these teachers maintained favorable learning environments that favored both the teacher and the students. Thus the exemplary teachers studied by Tobin and Fraser had extensive knowledge of how students learn, and subsequently of what to do and how best to teach them.

While encouraging students to think at higher cognitive levels is a goal in science teaching (Tobin, 1988), Gallagher and Tobin (1987) concluded that students tend to resist extensive cognitive challenges. Secondary findings from an extensive study of the exemplary classroom science teachers in Western Australia (Tobin & Fraser, 1990) reported that students exhibited task avoidance behaviors when cognitive demands were too high. This led to classroom management problems. Thus the authors suggested interspersing high and low cognitive demands in the lesson, and to reducing the risks associated with high demand tasks.

Tobin and Gallagher (1987a) in a separate publication from the same large study reported that teachers tended to ask low level questions at random, but tended to direct high level questions to target students. Many of these teachers felt that the class should benefit from student responses. Thus they felt justified in posing high order questions to particular students whom they knew would be able to give the proper responses from which the teacher could then provide further elaboration.

Verbal Behavior

After examining teacher verbal behavior, specifically directions and structure, Penick and Shymansky (Penick & Shymansky, 1977; Penick, Shymansky, Matthews, & Good, 1976) determined that teacher behavior had a tremendous effect on student behavior. Their studies deliberately controlled the amount of teacher directness and structure in an activity-centered science classroom. They found that students in teacher-structured classes tended to watch and mimic the teacher rather than engage in their own independent thoughts and ideas. Penick and Shymansky (1977) noted that classes with reduced teacher directions yielded less off-task student behavior, and that students identified and solved problems in their own way.

Penick (1976) measured the impact of teacher directness and control on student creativity in a group of fifth graders at the Florida State University Developmental Research School. He controlled for all of the variables that were influenced by instruction, such as curriculum material, physical components of the classroom, and teacher behavior. The type of teacher behavior, structured/directed and unstructured/relaxed, distinguished the teacher-structured learning environment and student-structured learning environment. By controlling

the amount of teacher praise or evaluation, rejection and/or discouragement, and statements to students on what to do and how to do it, Penick concluded that allowing for a student-structured science class led to significant gains in student figural creativity with no loss or gain in verbal creativity.

Asking Questions

Roth (1996) attributed development of students' discourse regarding civil engineering and bridge building upon their teachers questioning skills. The exceptional questioning ability by a teacher arose from a larger 3-year study of a teacher initiated effort to improve science teaching. Repeated acknowledgement and focus on this teacher's questioning technique during observations and data collection in this larger study prompted Roth to take a closer look at her approach in a student-centered engineering curriculum. He identified her motivations for questioning to be driven by her desire to help students make connections between their thoughts and ideas with canonical knowledge. She called on specific students in order to draw attention to particular ideas or experiences that the students had which she wanted to expand upon. Thus, she connected student experiences within her discussions. She modeled good questioning strategies for students to develop through her own queries in small group and whole class discussions. The teacher believed that questioning was a way to teach in the student-centered manner without compromising content knowledge.

Roth (1996) pointed out that the teacher posed scaffolding questions with each question expanding on the previous question, eventually leading to student centered discussions. The teacher nested higher order questions to elicit student explanations and

justifications within questions related to knowledge and facts. From her nested questions and query modeling, the students began to provide more detailed and justified responses and explanations without the teacher's prompts. Eventually discussion was dominated by student conversation independent of teacher scaffolding. The conversations became self-sustaining around student initiated questions posed at each other as well as to the teacher. While student interests and knowledge influenced her questions, the teacher maintained control of the underlying topic by her contingent and nested queries. Roth found that none of this teacher's discourse served an evaluative function; the student-teacher conversations had the quality of exploratory talks, and the purpose of her questions extended beyond fact assessment or served a disciplinary function. The author concluded that his findings underscore the complexity of questioning in classroom practices, and proposed that more attention be allotted to question skills in teacher education programs.

In an extensive case study over many months, van Zee, Iwasyk, Kurose, Simpson, and Wild (2001) collaborated to examine student-teacher dialogues about the phases of the moon with elementary, high school, and college level students. Playing the role of teacher researcher at different levels of school education, the authors investigated teacher dialogue and questions that nourished student thinking and questioning about science, and encouraged students to express their ideas and explanations in discussions. All five teacher researchers operated under the belief that "students learn by engaging in spirited discussions about topics that interest them" (p. 160). After careful analysis of classroom discourse across five independent classes, the authors concluded that students: (1) asked questions when they were invited to do so; (2) posed insightful questions about familiar situations; (3) asked questions

in an environment where they felt safe and comfortable about sharing their ideas and developing their thoughts; and (4) asked each other questions while working in small groups in the absence of the teacher. In reflection of their own behavior that allowed for this desired student engagement, the authors asserted that they asked questions to elicit student experiences in order to draw on prior knowledge, or student clarification and elaboration on their thoughts and comments. Most importantly, the authors reported that the teachers listened carefully and remained silent while the students spoke so that they could learn and understand how and what the students were thinking.

Content Knowledge

From Tobin and Fraser's (1990) comprehensive study of exemplary Australian science teachers, Tobin and Garnett (1988) uncovered that teachers' understanding and knowledge of content within their disciplines also contributed to their exceptional teaching practices. When teaching outside of their disciplines, exemplary Australian science teachers exhibited non-exemplary behavior. Tobin and Garnett identified science content knowledge as the primary barrier for effective teaching strategies of primary school teachers. They described and compared science teaching of two primary and two secondary exemplary science teachers. While all four teachers had sufficient pedagogical knowledge, the primary teachers lacked depth in understanding of the science content, and thus were unable to provide necessary feedback to students or effectively discuss the content in different class environments.

Active Physical Participation

Along with direct instruction, quality questioning, reduced teacher control, and good classroom management, instruction that allows for active physical participation should also give students opportunity to act upon and manipulate objects. As Jean Piaget has stated in regards to children's cognitive development, "to know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify it, to transform the object, and to understand the process of this transformation and as a consequence to understand the way the object is constructed" (Piaget, 1964, p. 176).

In an analysis of the effects of hands-on laboratory versus teacher demonstration on student content acquisition and reasoning ability, Glasson (1989) found that hands-on activities enhanced student reasoning strategies, but was not a factor in improving the acquisition of concepts. Two classes of ninth grade students were randomly assigned to two treatment classes, teacher demonstration and hands-on laboratory. Lesson plans, time on task, material to be discussed and read by students regarding pulleys, planes, and levers were identical in both class. The classes differed in the laboratory component as to whether students or teacher manipulated the equipment to gather the data. Students in the hands-on laboratories worked in groups of 2-3, while those in teacher demonstration watched the teacher manipulate the apparatus and copied the data recorded by the teacher.

Glasson (1989) compared student reasoning ability and prior knowledge of the subject with their declarative and procedural knowledge achievement at the end of this 3-week study. He concluded that while there was no measured difference in declarative

knowledge between the two treatment groups, students having conducted hands-on activities scored higher in the procedural knowledge assessment because they actively manipulated the relationships among the variables. The hands-on activities also encouraged peer interaction. He explained that the peer interaction was an important component of Piaget's equilibration process because it allowed students to stimulate cognitive conflict. Since teachers were more experienced in the laboratory procedures, they might not be able to create conceptual conflicts for the learners.

Student Exploration and Direction Instruction

Despite the contention by some educators (Bruner, 1977) that if given the opportunity, children will explore and challenge themselves to higher levels of thinking on their own, Linn and her colleagues (Bowyer, Chen, & Thier, 1978; Linn, 1980; Linn, Chen, & Thier, 1977; Rice & Linn, 1978) have found that students in "free-choice" learning environments do not necessarily make cognitive gains. This is consistent with Rix and McSorley's (1999) findings, and is one of the major criticisms of free student exploration at interactive science exhibits (Neighbour, 1997; Shortland, 1987).

Linn, Chen, and Thier (1977) investigated fifth and sixth grade students' abilities to control variables in a free-choice environment over a 10-week period at an urban elementary school. Students were given the opportunity to engage in a set of experiments that challenged them to identify variables, describe the experimental effects on the variables, and then design their own experiments. The goals were to determine how students function, and what they learned in environments where they were only given overall instructions to complete a set of

experiments with written directions for each experiment to get them initially started with the task. Students were allowed to choose the tasks and amount of time to spend on each task. They found that students were able to follow printed directions, were best able to investigate the effects on variables with which they were most familiar (i.e. weight, height, temperature), and most interested in tasks involving concrete objects. The students were able to operate responsibly in this free-choice environment, criticize experiments, and were clearly motivated to engage in scientific inquiry. However, the students did not challenge themselves to move on to more advanced intellectual levels. The majority of students did not take the challenge to design their own experiments, but chose to only carry out experiments described in the printed directions. Students in this 10-week study did not make large cognitive gains.

Linn further examined student learning and behavior in free-choice learning environments by comparing their performance with those students who received direct instruction regarding experimentation and controlling variables (Linn, 1980; Rice & Linn, 1978). The free-choice learning treatments were the same as those used in the Linn *et al.* study (1977). Rice and Linn (1978) investigated whether training students in experimentation or whether student prior knowledge of experimentation affected student behavior and learning in the free-choice environment. They found that direct instruction alone and direct instruction plus free-choice was more effective in teaching students to control variables than free-choice alone. Students who received instruction about experimentation were also the most task oriented. Students who had prior knowledge about experimentation, and thus did not receive direct instruction in this study, were not eager to apply their knowledge in the

free-choice environment. This further supports the findings from her 1977 work that students in free-choice learning environments do not necessarily make large cognitive gains, or are motivated to challenge themselves mentally without guidance. Nonetheless, the free-choice environment had positive motivational affects.

Linn (1980) further strengthened these findings with a study that compared students' cognitive gains with direct instruction, in the form of a lecture/demonstration about identifying variables, criticizing experiments, and designing controlled experiments, before, during, or after the free-choice learning opportunity. Again, the free-choice treatment was the same as the Linn *et al.* (1977) study. She found that students profited and tended to be more task-oriented during the free-choice experience after having had direct instruction. The lecture/demonstration provided them with concrete illustrations with which to mentally manipulate during their free-choice time.

Thus, in the process of facilitating student learning, it seems direct instruction is as necessary as free discovery. David Ausubel (Barba, 1995; Novak, 1998) and Joseph Novak (Mintzes & Wandersee, 1998; Novak, 1998), strong proponents of direct instruction, contend that the expository lesson must be delivered within the context of learning that is meaningful to the learner, and that concepts are connected with one another. They argue that the learner will not retain instruction that emphasizes rote learning with ideas presented as individual unrelated concepts. For learning to be meaningful, and thus retained, it must encourage the learner to integrate it with her or his existing cognitive framework.

Evidence in support of integrating direct instruction and student exploration has been demonstrated in three decades of research on the learning cycle. The learning cycle as

described by Robert Karplus and Herbert Thier (1969) consists of three phases (Exploration, Invention, and Expansion) that give the learner a chance to investigate, question, and experiment with a concept, and is consistent with Piaget's theory of cognitive development (Abraham & Renner, 1986; Karplus & Thier, 1969; Purser & Renner, 1983; Renner, Abraham, & Birnie, 1988). In this way the learner is given the opportunity to explore and assimilate new information into their current mental framework. The investigative process in the Exploration Phase prior to any intervention from the educator enables the learner to utilize any prior knowledge to generate an understanding, and enter into a state of cognitive conflict if the activities in which they are engaging do not coordinate with their existing understanding. The students are thus in a state of disequilibrium. To make sense of the new information, the students will need to adjust their mental frameworks to accommodate the new experiences because these experiences do not fit into any preexisting schema. The educator facilitates the sense making process in the Invention Phase with discussions and term introduction. The learners are given guidance and vocabulary so that they are able to verbalize their own thoughts, and formulate their understanding. This is followed by application of the newly invented concepts (Expansion Phase) to new situations, text, or activities, which enables the students to organize their recently acquired thoughts with their already existing understanding.

Students have demonstrated cognitive gains when instruction incorporated student exploration and inquiry along with direct instruction from the educator. Abraham and Renner (Abraham & Renner, 1986; Renner, Abraham, & Birnie, 1985; Renner *et al.*, 1988) carried out a series of studies to test the significance of the order and purpose of student exploration

and teacher instruction on conceptual understanding. Abraham and Renner (1986) found that when considering the sequence of the phases, the Invention Phase was most important. If the concept was new to this students, the Invention Phase after an introduction and before the expansion was optimal for achievement. In the case when the concept was a review, concrete-operational students learned best if the Invention Phase was last, while formal-operational students performed better when Invention was first.

To test the necessity of each phase of the learning cycle, Renner *et al.* (1988) found that Exploration alone was insufficient in producing maximum learning. In fact, allowing students to invent their own understanding from discovery experiences without guidance was inefficient, and lead to development of misconceptions, thus further supporting Linn's conclusions regarding free-choice learning opportunities (Linn, 1980; Linn *et al.*, 1977; Rice & Linn, 1978). Allowing the students to explore on their own, and then following it up by guided instruction from the educator helps students develop a stronger understanding of the concept than simply telling them the concept at the start of the lesson. This further supports the significant role the educator plays in helping students generate their own understanding.

Renner *et al.* (1985) examined the significance of active student participation in data acquisition. They discovered that level of student achievement was the same regardless of method of data acquisition. This is consistent with Glasson's (1989) findings comparing teacher demonstration versus hands-on laboratories. However, students felt that they learned more when actively collecting their own data. Delayed post tests also revealed that students retained more when they actively obtained their own data.

Lavoie (1999) published more evidence in support of the learning cycle pertaining to student conceptual understanding. Aside from strengthening the significance of student exploration and teacher direction, Lavoie proposed an additional step prior to the initial exploration phase. He found that students given the opportunity to predict and reason prior to Exploration had significantly greater gains in science process skills, logical thinking, and conceptual understanding. The act of predicting encouraged students to construct and deconstruct their understanding, make their ideas explicit prior to exploring and becoming disequibrated, and the need to explain and defend their initial thoughts.

In reinterpreting the learning cycle from a social constructivist framework, Glasson and Lalik (1993) documented changes in teachers' beliefs and practices as they learned to use and incorporate the learning cycle into their lessons. They described in detail one teacher's gradual transition from using strictly expository teaching and equation application at the beginning of the year to an incorporation of short 10 minute lectures embedded within exploratory and hands-on experimentation that elicited more student questions and comments. While the teacher continued to use lecture and direct instruction, she reduced her talk time, which she found allowed and encouraged the students to talk more, and "students learned scientific information more quickly when they were engaged in dialogue" (p. 201).

Summary

Consequently, in classrooms with positive affective and cognitive gains, educators use a variety of teaching strategies to mentally and physically engage the learners. The educator plays the role of facilitator and mediator of the learning process. In so doing, the learners are given the opportunity to process the information and develop it within their own

cognitive frameworks. The amount and cognitive level of teacher questions (Gallagher & Tobin, 1987; Roth, 1996; Tobin & Gallagher, 1987a, 1987b; van Zee *et al.*, 2001) and directions (Penick, 1976; Penick & Shymansky, 1977; Penick *et al.*, 1976) have tremendous impact on student learning and creativity.

While all the literature cited in this review arose from research in traditional classrooms, the non-evaluative and non-threatening nature of classes taught at non-formal settings would render these strategies as potentially effective teaching practices. The constraints of classes at non-formal settings might require some modifications of these approaches; nonetheless, the potential is there. However, understanding of teaching strategies employed at non-formal settings must be attained before further conjectures can be proposed. With the growing need for improved science instruction and learning (NRC, 1996; TIMSS, 2001), non-formal science institutions are actively contributing to science teaching and learning among school children with increased programs targeted at school groups, and designed to meet national and state science standards. This growing involvement calls for examination of the role educators at non-formal institutional settings play in student learning of science. To provide more data, this study will investigate and document the instruction that takes place at non-formal institutional settings.

CHAPTER 3. METHODS

The growing recognition of non-formal settings as a place of science teaching and learning raises questions regarding the science and instruction credentials of those teaching in non-formal settings. Along with the need to understand whether learning takes place in science classes offered at places such as museums and nature centers, awareness of the behavior of the educator leading the classes is also necessary. Thus this exploratory study investigated the following questions:

- How do educators at non-formal settings teach science to school groups?
- What do non-formal educators believe to be their role in K-12 science instruction?
- What are the observable teaching behaviors of non-formal educators in science classes taught to school groups?

Study Sample

Non-formal Settings

Size, annual budget, and attendance differed tremendously among non-formal settings. In order to capture major variations and identify common patterns, a stratified, purposeful sample (Patton, 1990) of eight non-formal settings throughout North Carolina was selected based on annual attendance published in the 1999 North Carolina Environmental Educators Guide (Table 1, Office of Environmental Education, 1999). Each non-formal setting selected offered science-related classes to school groups.

For the purposes of this study, non-formal settings were divided into two distinct groups, museums and nature centers, and defined as follows. Museums were characterized as

institutional settings that have a collection of artifacts, objects, exhibits or animals. These institutions showcase their collections, and include places such as natural history museums, science centers, zoos, and aquariums. Nature centers by definition were institutional settings that showcase the natural environment in which they are located. These include government operated parks, private for-profit nature parks, and private not-for-profit environmental centers. Nature centers could have a collection, but this was not the primary focus for visitations. Two small ($>50,000$ visitors/year) and two large ($> 200,000$ visitors/year) institutions from each group were chosen. Each non-formal setting was numbered in order of observation, and according to their respective group, i.e. M1 for the first museum and NC2 for the second nature center visited (Table 1).

Table 1

Operating budget, annual attendance, and staff size of three informal institutions in North Carolina for 2000 - 2001.

	M1	M2	M3	M4	NC1	NC2	NC3	NC4
Type of institution	city children's museum	private science museum	state natural science museum	private & county science center	state park	city park	county park	private for profit nature park
Annual operating budget	\$337,000	\$310,005	\$9.2 million	\$1.45 million	n/a	n/a *	\$365,543	n/a **
Annual attendance	30,768	26,712	770,750	95,000 - 105,000	355,181	n/a *	129,599	275,000
Annual education operating budget	\$4,500 (for supplies other part of general budget)	\$19,739	\$2.1 million	\$150,000	\$1696.14 (only \$1,608.14 spent before budget freeze)	n/a *	\$20,000	n/a **
Annual education program participation	18,800	12,782	749,689	32,000	9,427	n/a*	9,205	5,750
Education staff size	2 (1 in house; 1 outreach)	4 (1 full time; 3 part time)	47 (includes full & part time)	5 (3 full time; 2 part time)	6 (5 full time; 1 seasonal)	varies semi-annually from 8-20	5 (2 full time; 3 part time)	7 (4 year round; 3 seasonal)
Types of education programs offered	60	22	17	22	121	10	6	25
Types of school group classes/ programs offered	15	19	12	22	42	11	42	6
Total number of students participating in school programs	n/a	9,875	30,258	32,000	1,573	15,000	7,274	5,000

Notes: * NC2 is part of a 15+ park system managed by the city. This data was not easily extracted for the Nature Programs; ** budget data not available to the public.

Although categorized into two groups for this study, each institution had distinguishing characteristics. M1 and M4 did not have scientific research collections. Their collections consisted of displays and interactive exhibits for students to explore scientific phenomena. Visitors were encouraged to manipulate and interact with all the exhibits. M2 focused on geology, and primarily showcased its collection behind glass displays. There were exhibits, such as those using computers, drawers of rocks, seismograph, and relief maps with which visitors could interact and touch. M3 was a large natural science museum. It had a scientific research collection, as well as a large teaching collection of preserved and live specimens. While M3 displayed mounted specimens, it also exhibited a large percentage of live specimens. The organisms' natural environments were recreated in the museum, and were not hidden behind glass dioramas although there were boundaries that prevented visitors from entering the exhibit space. There were also specific spaces in which visitors could manipulate and interact with the collection in that room.

The nature centers also varied in the types of resources available to the public. Nature centers 1-3 were government-operated parks. NC1 was a state park created to protect a section of the river that ran through the park. State park rangers lived on-site and maintained the park. They were also responsible for teaching leading educational programs to school groups and the general public. NC2 was a city park. The city maintained over 15 recreational parks that varied in size and resources. However, environmental education programs were conducted at only two of those locations. City park educators brought their materials, and met the schools at the designated park. One park had a large pond that could potentially accommodate aquatic programs while the other featured nature trails into a woodland habitat.

This site also had cabins for overnight programming. NC3 was a county-managed park.

There was a newly built nature center on-site that had display exhibits that focused on conservation, and the natural biota of the local community. This nature center also featured trails, a man-made pond, a garden, and large grass area for outdoor activities. NC4 was a privately owned park that centered on a prominent natural feature. There were 4.5 miles of trails cutting through the park that allowed visitors to get up close to this natural feature.

Subjects

Educators observed in this study were selected by their supervisors based on availability due to parameters of the research design discussed in the next section of this chapter. As a result of their small staff size, observed educators at M1 and M2 managed the school programs as well as taught these classes. Out of scheduling convenience, the educator observed at M3 was a classmate of the researcher. Pseudonyms were used to identify each educator. The educators had varied teaching and science content backgrounds (Table 2). Almost all of the educators had received a bachelor's degree in the sciences, while only one had a degree in teaching, which was a masters of education. Their overall teaching experience ranged from two years to 30 years, and primarily involved teaching at non-formal institutional settings. Only one educator had experience teaching science in a formal classroom environment. Teaching science programs to children, including school, scout, and after school groups, was among the primary duties for these educators. However, the daily tasks of their positions also included law enforcement (as a state park ranger), program development, and administrative duties (as director of the institution; see Table 2).

Table 2

Education and teaching background, and job duties of educators teaching at informal settings.

Educator	College degree	Teaching background	Job duties
Museum 1 (M1) Julia	M.A. Teaching	30 yrs @ Mus 1; nature centers throughout college	Not submitted by educator.
Museum 2 (M2) Karen	B.A. Geology	2 yrs @ Mus 2; 20+ yrs @ elementary, middle, & special needs schools; science specialist at elem. science magnet	Plan curriculum, teacher's guide, distribution of information; purchase supplies; teach; plan special events, camps, & teacher workshops; write education grants; organize & oversee outreach programs; promote earth science education in the community; make
Museum 3 (M3) Caitlin	B.S. Nursing (currently pursuing M.S. Science Education)	5 yrs @ Mus 3; 17 yrs Emergency Room nurse (included teaching patients & peers)	Not submitted by educator.
Museum 4 (M4) Ioana	B.S. Environmental and Forest Biology	5 yrs (sporadically) @ state park, nature center, museum, 4H center	Develop & implement programs for K-12 school groups, week-long summer & winter camp, and weekend programs; handle live animals for programs; represent NC4 at different local events; revise & develop exhibit text.
Nature Ctr 1 (NC1) Annie	B.S. Parks, Recreation, & Tourism Management	6 yrs (sporadically) @ state park, nature center, & museum	Law enforcement; natural resource management; park maintenance; teach educational programs to public & organized groups; search & rescue; wildfire suppression; volunteer coordination; first responder
Nature Ctr 2 (NC2) Melanie	B.S. Fisheries and Wildlife	1+ yrs @ NC 2; 2 yrs @ Mus 3	Teach <i>Science Afield</i> programs; attend regular training for new & old programs; help revamp & provide suggestions for new programs & old programs
Nature Ctr 3 (NC3) John	B.S. Wildlife and Fisheries Biology (currently pursuing Master's in Seminary)	3 yrs @ NC 3; Sunday school	Educator & program preparation; bulletin boards, flyers, brochure production; phones and reservations; light maintenance; Habitat Enhancement Monitoring (wildlife boxes); coordinate with outside groups;
Nature Ctr 4 (NC4) Calvin	B.S. Biology	7 yrs environmental education programs @ NC 4	Plan & prepare activities; present programs (slide shows, guided hikes, etc.); build displays & exhibits; train & oversee education staff; monitor rare plant populations; oversee trail construction & maintenance.

General Procedures

Educators at non-formal institutional settings teach programs to K-12 grade students. To capture the variability in their teaching styles with students at different developmental levels, educators at each institution were observed twice; once teaching lower elementary students (K-3; Younger), and again teaching upper elementary/middle school students (4-8; Older). The observed classes were regularly scheduled programs provided to visiting school groups, and required pre-registration. Each class session ranged from 30 to 60 minutes in duration. Teachers were sent confirmation letters, and sometimes provided with pre-visit material to prepare students for the visit. The classes focused on a particular concept, e.g. water tension, forest succession, stages of animal development, and essentials of hiking, or characteristics of objects and organisms, e.g. reptiles, rocks, and vertebrates. Scheduling was arranged with staff supervisors. The educators were told in advance that a visitor would observe their classes. All observations were made during March and April 2002, which was peak field trip time for all eight non-formal settings. The researcher met briefly with the educator immediately before the lesson to discuss the data collecting procedure. The educator was also reminded that this was an exploratory study, and was not intended to evaluate or judge the educator's teaching practices nor would it effect their job security.

Validation of this qualitative study came from four sources: field notes, coded observations, survey, and interview. "The uncertainty principle demonstrates that the act of measuring or observing affects the action of whatever is being observed or measured" (Goetz & LeCompte, 1984, p. 56). Thus, the probability of credible findings and interpretations was improved by triangulation of four different data sources (Lincoln & Guba, 1985). Each data

set was individually analyzed, and then compared with the others. In this way, each data source was validated against the other three.

First, the researcher took field notes as a non-participant observer (Goetz & LeCompte, 1984; Spradley, 1980) in order to obtain an extensive and representative account of the educators' classroom behavior. The lessons were audio-taped, and the educators' verbal interactions were later coded with a modified Schlitt Abraham Test of Interaction Coefficients (SATIC, Appendix 1, Abraham & Schlitt, 1973; Clough, May, 2002) and one addendum (Appendix B). Since the educators' verbal interactions with their students were the focal point of these codes, video tapes were not needed. This also alleviated the complicated logistics of obtaining parental consent forms from students taking part in the lessons via a class field trip. Coding was initially done via the Training and Assessment System (TAS, Bonstetter & Bonstetter, 1986), a DOS-based computer program that allowed for easy coding, organizing, and generation of time data. Unfortunately due to unforeseen medical circumstances, the researcher was not able to continue use of this research tool, and the coding was done by hand. The researcher created the addendum during the pilot study to categorize the cognitive level educators elicited with student participation opportunities. The addendum underwent three iterations of observation and coding of similar classes at other non-formal settings to define parameters of the categories.

Second, to supplement the classroom observations, educators were asked to complete a survey, and then participate in an interview conducted by the researcher immediately after the first observation. These data were collected after the second observation for educators from M3 and NC4 since both observations were made on the same day, and there was not

sufficient time between classes. The survey targeted each educator's personal perception of her or his teaching (Appendix 3, Reiman & Thies-Sprinthall, 1998; Thies-Sprinthall & Reiman, 1998). This survey was created from two informal checklists used with teacher mentees to prompt reflection regarding their own teaching.

Third, the educators participated in a semi-structured, open-ended interview immediately following completion of the survey (Fontana & Frey, 1994) to inquire further about the educators' role in the learning process, how they affected student learning, and their goals for the programs (Appendix D). These interviews were audio taped, and ranged from 30 to 50 minutes depending on the educator's willingness to share her or his thoughts. They were later verbatim transcribed using a voice recognition software(IBM, 2000). The researcher listened to the interview through a headset, and repeated the questions and responses as they were heard. Turning up the volume to drown out the researcher's own voice during dictation enabled immediate recitation of the interview as the audio tape was played, and thus provided for continuous transcription capability. In order to establish credibility of interview interpretations, a member check was conducted following initial analysis of the interviews (Lincoln & Guba, 1985). Educators were sent a copy of the researcher's initial interpretations of their interview responses, and asked to comment on, change, or clarify in writing their beliefs on science learning and teaching that the researcher extracted from the interview (Appendix E). In addition, the educators were asked to respond in writing to three questions that addressed issues salient in all eight interviews (Appendix F).

Data Analysis

Field notes and audio recordings of the classes were used to determine classroom structure. Descriptions of the classroom set up, lesson plan design, and the educator's physical location during instruction were made based on field notes and replay of the audio taped lessons. Frequency of the modified SATIC teacher verbal behavior categories and cognitive levels of student participation elicited were computed as the total number of behavior and participation engaged. To determine level of teacher control in each lesson, the Coding Rate and Interaction Index was calculated for each class (Abraham & Schlitt, 1973). The Coding Rate calculated the number of codes per 15 seconds, and indicated the amount of student discussion and exploration time allotted in each class. Thus small values suggested students were allowed more discussion latitude. The Interaction Index compared frequency of teacher responding behaviors and initiating behaviors. A large Interaction Index indicated that the teacher responded more to student comments and queries. Some lessons required students to work in groups. Teacher behavior was not coded during that time. The entire activity was categorized as one participation opportunity, and duration of group work was noted. Thus teacher behavior was only coded when the educator addressed the entire class. Only frequency distributions were calculated in the observations, and descriptive accounts of each lesson were provided. This data gave an indication of the educators' verbal teaching behavior in their classes. Due to unavailability of upper elementary/middle school groups scheduling classes at M1, only observation data of a class taught to lower elementary students was collected. Nonetheless, survey and interview data were obtained.

Responses to the survey were used as a guide to determine the educator's teaching beliefs. Characteristics in which educators perceived to be *very important* in their teaching (Appendix C) were highlighted, and compared with themes that emerged from the interviews. The themes were identified using the constant comparison approach described by Glaser and Strauss (1967). Each individual interview was initially reviewed to identify any salient categories. Parameters of the categories were redefined as more statements were placed into each category. From that arose two types of categories; one relating to the educators' account of training and program development at their institution, and the second pertaining to the educators' perspective on science learning and teaching. The second round of reviews redefined the categories that applied to the educators' learning and teaching position. Description of these viewpoints were generated for each educator, and submitted to them for review. The categories were then reexamined across all eight categories to determine similarities and differences in their parameters.

Data arising from interviews and survey responses generated insight into program development and teaching preparation for educators teaching at non-formal settings. Along with responding to queries regarding personal perception of their teaching in the survey, educators also commented briefly on the sources of their teaching education. Coupled with their narration about the preparation they received to teach, the current state of teacher education for the eight educators observed was discerned. Program development at each institution was determined from the non-formal settings' education brochure, and educators' account of their involvement in the development of the programs that they taught at their respective institutions.

CHAPTER 4. RESULTS

In addition to permanent exhibits or the natural landscape, all eight non-formal settings provided programs to educate the public about science and the natural environment (Table 1). The educational programs offered included lectures and demonstrations for the general public, as well as structured science classes for visiting groups of students. Among the eight institutions, these programs educated 5,700 to 749,000 adults and children annually. The science classes targeting school groups highlighted a topic or concept related to the area of science featured at that setting, and were the primary education program examined in this study. These instructor-led classes accounted for a noticeable percentage of individuals participating in their education programs (Table 1) at M2 (77%), M4 (100%), NC3 (79%), and NC4 (87%). This percentage was markedly lower in the state governed museum and nature center, M3 (4%) and NC1 (17%), respectively.

The three questions that guided this exploration were addressed as follows. (1) How do educators at non-formal settings teach science to school groups? Class structure was physical descriptions of the instruction, and comprised of classroom layout, physical position in which educator led class, and general format of the lesson plan implementation. (2) What do non-formal educators believe to be their role in K-12 science instruction? The educators described their viewpoint on the purpose of teaching and the role of the educator in the learning process. (3) What are the observable teaching behaviors of non-formal educators in science classes taught to school groups? Coded observations of student-teacher verbal interactions provided an indication of the educators' teaching behaviors.

Along with identifying the teacher role and behavior of educators intended in this study, insight pertaining to teaching preparation and program development of these science classes also emerged. The educators reported parameters that guided development of the lesson plans, which encompassed personnel responsible for writing the lessons, and the desire to meet the needs of their primary audience. Constraints, such as student prior knowledge and the singular nature of these classes that needed to be addressed during the planning stages were also identified. The educators communicated the type of preparation they received in order to teach in non-formal settings.

1. How Do Educators at Non-formal Settings Teach Science to School Groups?

While teaching was not the only task for which these educators were responsible, it was a primary duty (Table 2). Additionally, these science classes were available to any public and private schools, thus thousands of school children participated in such classes annually (Table 1). Although educators at these non-formal settings only interacted with a class of students for 30 to 60 minutes, they could potentially teach more than 1,000 school children from grades K through 12 each year. The educators were responsible for conducting the lesson, overseeing student progress, carrying out activities, and assessing student understanding during class time. Classroom teachers relinquished authority to the educators during the lesson. Consequently, educators were the primary instructor, and accountable for management of student behavior during their lesson.

Class Structure

The physical layout of the classroom itself, position from which the educator orchestrated class, and design of the lesson plans were salient class environment characteristics identified in the 15 lessons observed in this study. Classroom layout included uses of the room, its general floor plan, and seating arrangement of the students during the lesson. However, classes were not always taught indoors. Regardless of age group, and whether class was taught indoors or out, educators conducted the lesson at the front of the class. Design of the lesson plan for these classes ranged from a structured, show-and-tell format to an educator-led discovery process. Although there was minor variability in the classroom layout and lesson plan design among the fifteen classes observed, the deviations were not unique to any one non-formal setting.

Classroom layout

The casual, non-evaluative nature of these non-formal settings and classes did not require workspace, such as individual chairs and desks, for each student. The students either sat in groups, or addressed as a whole class. In addition, since teaching science classes to groups of school children was not the singular objective of these non-formal settings, there was often limited space for teaching these classes. All four museums set aside one to two rooms as classroom space for conducting classes, which could include any type of class or workshop that the institution offered. This space served as a multi-purpose room at M1 and M2, but was primarily used for classes at M3 and M4.

Considering that each class topic required different types of animals, specimens, objects, artifacts, and/or equipment, and the classroom space was shared among the different types of classes offered, materials specific to the class were brought out as needed. Classrooms at M1, M2, and M3 were barely decorated with objects, posters, or artifacts. Their classrooms only contained chairs (and tables if needed for the lesson) and minimal posters or artwork on the walls. The classroom at M4 had storage closets along one wall filled with supplies for other educational programs, aquariums of fish and reptiles, other education program materials stacked against corners and walls, and an oversized stuffed doll at the top of the seats. The students were observed to be preoccupied with these materials during the free exploration portion of the lesson. There were no windows in any of these classrooms.

Of the four nature centers, only NC3 had a classroom component in both lessons observed. The classroom was decorated with diagrams, objects, specimens, and equipment related to native animals and their natural environments. Large windows overlooking into a stand of trees lined one wall of this classroom. Thus classroom layout for each non-formal setting could range from barely anything to elaborately decorated with related artifacts and objects. There was also variability in seating arrangement at all eight settings.

The students were arranged in a way to accommodate the needs of all. Seating arrangement of lessons conducted in a classroom generally placed students in circles or small groups with the classroom teacher and chaperones sitting in the back of the room. At M1, students sat in two rows of chairs arranged in a semi-circle around the room. Three long tables with chairs for 10 students at each table were set up for both lessons observed at M2.

The tables faced the front of the room lengthwise, thus no table of students sat in front of the other. Students sat in a semi-circle in the middle of the floor for their lesson at M3. M4 had stair step-like seats facing into the center of the room from a corner on which students were to sit. At NC3, the classroom was set up with two rows of three tables and four chairs at each table. Both classes observed at NC1, NC2, and NC4 were conducted entirely outside, while half of the class time was taught outdoors at NC3. In all class time taught outdoors, students did not use tables and chairs, nor did the educator have a large writing surface, e.g. chalkboard or sketch pad, on which to write. Students either stood or sat on the ground, depending on the nature of the activity in which they were engaging.

Class instruction style

Regardless of age group, and whether class was taught indoors or out, educators conducted the lesson at the front of the class (Figure 1 & 2). In classes taught in the classroom, a table of objects, artifacts, equipment, and/or animals to be used in the lesson was easily accessible to the educator at the front of the room. Items were immediately returned to this area after it had been discussed. Julia, Ioana, and John remained at the front of the class throughout the lesson. The students in Julia and Ioana's classes did not circulate the objects and artifacts for touch and closer examination. John used a slide projector and sketchpad in the classroom component of his lessons, thus there was nothing to circulate. Karen led whole class discussions from the front, but intermingled among the students when they were engaged in group activities. Students worked in pairs, and each pair had their own set of objects and equipment to manipulate and observe. Caitlin remained at the opening of

the circle, but moved around the circle when it was time to show the animal, object, or artifact to each individual student. Students were allowed to touch each item as Caitlin held them.

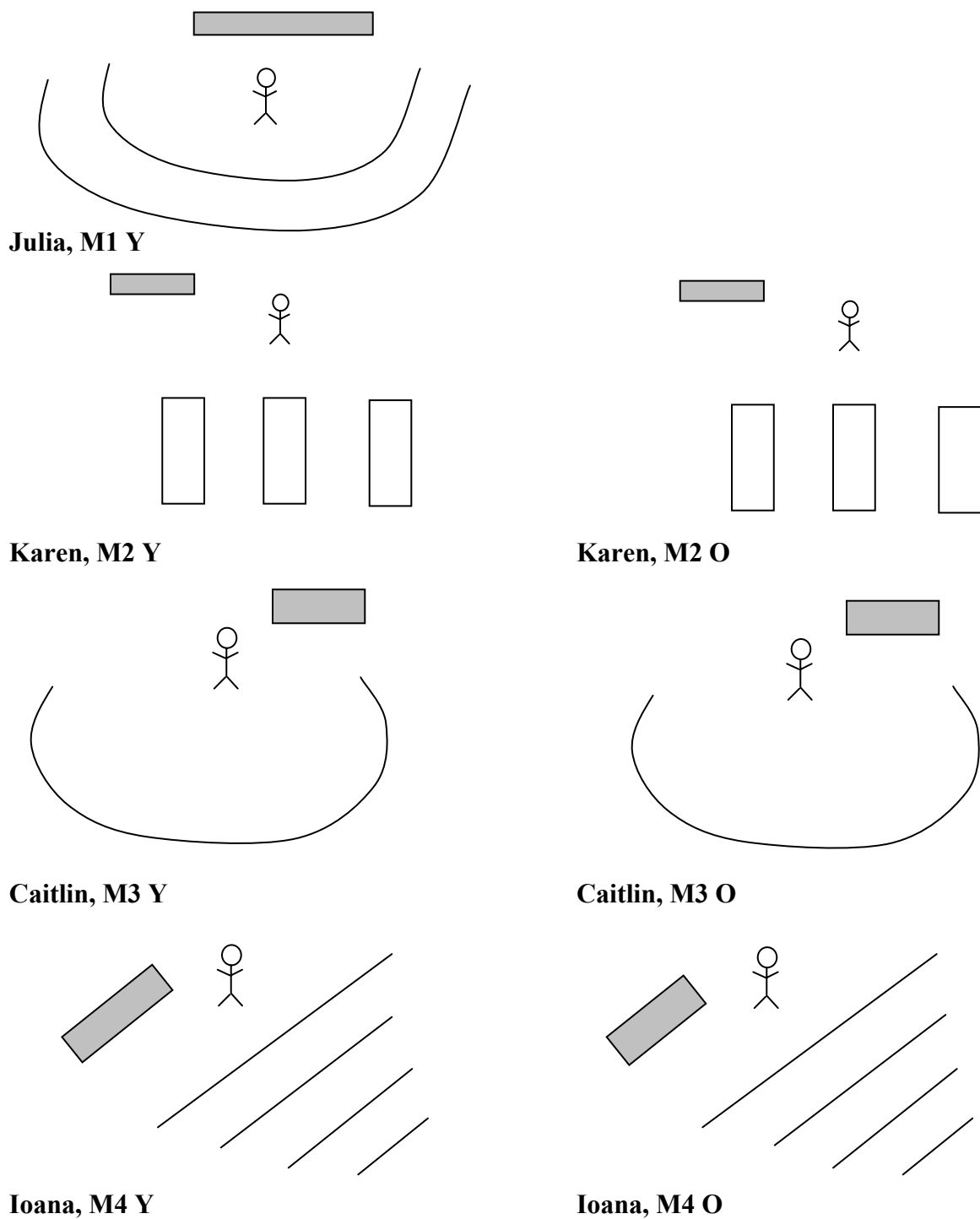




Figure 1. Arrangement of students and educator in lessons taught at Museums 1 to 4 for younger and older students.

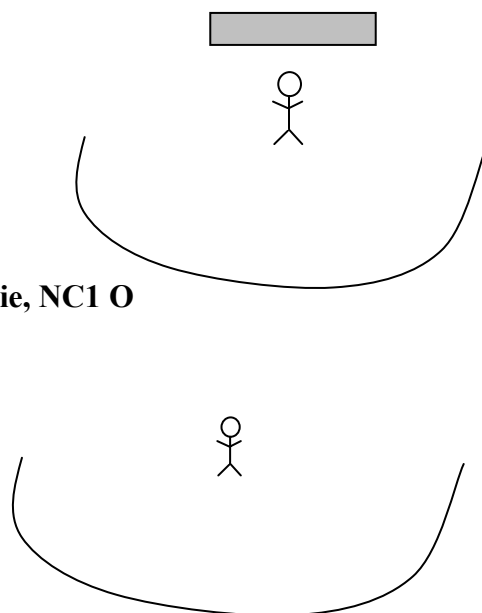
Note: Y = younger; O = older;  = Table of teaching material;  = Location of educator during most of lesson

**No observation
available.**

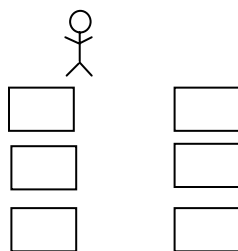
Annie, NC1 Y



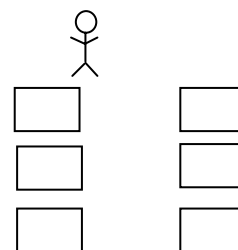
Annie, NC1 O



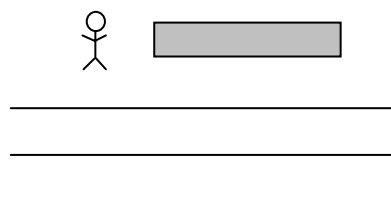
Melanie, NC2 Y



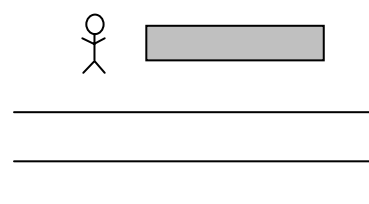
Melanie, NC2 O



John, NC3 Y¹





John, NC3 O¹



Calvin, NC4 Y

Calvin, NC4 O

Figure 2. Arrangement of students and educator in lessons taught at Nature centers 1 to 4 for younger and older classes when educator addressed the whole class.

Note: Y = younger; O = older;  = Table of teaching material;  = Location of educator during most of lesson; ¹arrangement during classroom portion of lesson. Students crowded around educator like in NC2 Y & O during outdoor component of lesson.

In classes taught outside, the educators at NC1, NC2, and NC3 arranged the students in a semi-circle or one line when they addressed the whole group (Figure 2) so that no child stood in front of another, and the educator could clearly see each individual student. In lessons that divided students into smaller groups, the educator circulated among the groups. Students in both lessons observed at NC4 sat on the ground under a tent in rows of 6-8. Calvin remained at the front of the rows with his table of objects and artifacts.

Lesson plan implementation

The lesson plan format and teaching approach had strong similarities among the eight non-formal settings. The educators introduced the subject matter at the start of class, and communicated information to the students. Educators posed questions to encourage students to participate in the discussion. Dialogue about the concept, object, or organism, whether it was solely from the educator or in the form of student responses to questions posed by the educator, preceded student manipulation and interaction with the items. All classes, except Julia and Calvin's, included physical activities in which students engaged. Both of Karen and Melanie's, and John's *Pond study* class divided students up into groups in order to participate in the activities. The lessons all ended at the conclusion of the last activity without wrap up of the major ideas or concepts presented. At M2, Karen ran out of time in both lessons, and had to rush through the last activity. Although educators at the other settings did not scurry through the ending of their lesson, students were sent on their way at the completion of the last activity. Only Melanie's *Woodland habitat* class gathered students together to talk about the major concepts following student activity.

All classes observed at the museums, except Karen's *What is soil?* lesson, had a show-and-tell lesson plan design, i.e. the educator shows the students an object, and then tells them information about or anthropological uses of it via educator-led discussion or lecture. In Julia, Caitlin, and Ioana's classes, the objects, artifacts, equipment, and animals remained at the front of the room. Each item was brought out when it was discussed, and then placed back on the table or put away after it had been discussed. Nonetheless, students showed interest and enthusiasm for the subject matter as the educator presented the materials. The 1st graders in Julia's *Bubbleology* class avidly watched and cheered as she created bubbles from an assortment of bubble makers, and talked about conditions necessary for bubbles to form. To involve students in the lesson, she posed questions prior to her demonstrations, encouraged students to hypothesize the outcome, and called upon students to physically participate in order to help her illustrate the concept. While she prefaced the participation with a question to investigate the concept, the student participant was told what to do and how to do it. She explained to the class what that student was going to do and why, and had the child demonstrate the concept to the class.

Rather than showing through a demonstration of the concept and then telling about it, both of Caitlin's and Ioana's classes and Karen's *Basic rocks & minerals* class simply displayed objects, artifacts, or animals to the students prior to or while the educator talked about the item. Caitlin and Ioana showed the item to the whole class as they led a discussion about it. In both of Caitlin's classes students were given the opportunity to touch and examine the item closer immediately after each object, artifact, or animal was discussed. The lesson plans for both of Ioana's classes allotted free exploration of the items, as well as stations of

other activities related to the topic, after all educator led discussions. Karen had students working in pairs, and thus the students were touching and observing the rocks during the discussion. All three educators asked questions to encourage students to share what they knew about the item, to make closer observations, and to make connections between the items they were shown and what they already knew. The educators generally followed the student responses with an explanation or information about the featured item. Once all information about an object, artifact, or animal was shared by the educator and requested of the students, the educator moved on to the next item.

Annie's *Talkin' turtles* and Calvin's *Hiking 101* followed this same lesson plan design and teaching approach. Student in Calvin's classes sat and watched him hold up each item. In Annie's class, students hiked on a trail along the river, and were encouraged to be on the look out for turtles. Annie led the hike, and stopped every four or five minutes to address the group as a whole. At this time, she pulled out specimens from her back pack to show the students, and then talk about the features of that specimen. Thus, in this "show-and-tell" design, student physical participation did not extend beyond seeing, and maybe touching (Table 3).

Table 3

Percent of activities eliciting three levels of cognition from students.

Educator	Class	Grade taught	Action ¹	Sensory ²	Experiment ³
Julia	Bubbleology	1st	23.91	76.09	0
Karen	What is soil?	3rd	0	50	50
Caitlin	Basic rocks & minerals	4th	0	100	0
	Animal life cycle	2nd	0	100	0
	Reptiles	4-6th	3.45	96.55	0
Ioana	Animal overcoats	1st	16.67	83.33	0
	Nature's rock stars	6th	0	100	0
Annie	Talkin' turtles	2nd	0	100	0
	Water bugs	8th	11.11	88.89	0
Melanie	Insects	K	0	100	0
	Woodland habitat	5th	0	95.24	4.76
John	Insects	1st	0	100	0
	Pond study	5th	4	96	0
Calvin	Hiking 101	1st	0	100	0
	Hiking 101	5th	0	100	0

NOTE: ¹Action-no mental participation required; ²Sensory-knowledge & comprehension cognitive domains; ³Experiment-application, analysis, synthesis & evaluation cognitive domains. Refer to Appendix B for detailed definitions.

Annie's *Water bugs*, Melanie's *Insects*, and both of John's classes also had the show-and-tell type design, but they involved the students in the collection of the animals to be shown. The educators led a dialogue about the subject matter prior to any physical activity. Annie explained what and why the students were going to collect aquatic macro invertebrates, demonstrated the collection procedure, and then led the group into the water to

begin collecting. Using a simplified dichotomous key, she helped them identify the specimens, and then calculate the health of the river based on the types of organisms they found.

Melanie and John's insect classes were almost identical, and very similar to Annie's class. They began class with a discussion about insect anatomy and types of insects. Students participated in the discussion via questions posed at them by the educator as well as student-initiated questions and stories. Melanie quickly showed plastic models of insects to reinforce the different types of insects, while John drew a diagram to strengthen student comprehension of insect anatomy. Following the discussion, students were given the opportunity to collect insects from a grassy area and under decaying logs. There was no dialogue regarding the purpose of searching for insects from those particular areas. The educator kept the insects in clear plastic boxes, identified them, and then showed and told the students what they found. John's *Pond study* class had this same format, except students were initially shown slides of what they would find, and then worked in groups of four or five to collect aquatic organisms from NC3's manmade pond. While physical participation in these show-and-tell type classes was also limited to the senses, students had an additional experience of finding what they were going to be shown and told.

Karen's *What is soil?* and Melanie's *Woodland habitat* classes were different from the others in that they required students to collect data, and make interpretations. Similar to all the other classes, Karen and Melanie started their lessons by introducing the subject matter. Again, the educators involved the students in the discussion by posing questions along with telling them information. The educators' explanations generally followed student

response to an educator-initiated question. Students in Karen's class worked in pairs, while those in Melanie's class worked in teams of four or five. In both lessons, students were given a task that required careful observation and data collection. The tasks were centered on a question posed to the class by the educator, and students were instructed on what data to collect and how to collect them.

Both Karen and Melanie mingled with the students during group work to help students collect data, identify organisms, or keep them on task. All students collected the same type of data in Karen's class; thus she stopped group work and led a discussion about what students found after each type of data was collected. She asked students to share their data with the class, and helped them verbalize their descriptions. Students in the *Woodland habitat* class had to collect three types of data from two adjacent study sites. Melanie divided the students into groups so that two groups collected the same type of data, one in each study site. Thus all students did not experience the same thing. Students shared their findings with each other at the end of all the data collecting, and Melanie used their findings to explain the primary concept of the lesson. Consequently, lesson plans for classes taught at non-formal settings could range from show-and-tell of objects, artifacts, and animals, to guided discovery and data collection. These class formats and teaching approaches transcended age groups since they were used in classes for both age groups, lower elementary and upper elementary/middle school. In all cases, the educator played a significant role in what the students learned and experienced.

2. What Do Non-formal Educators Believe to be Their Role in K-12 Science Instruction?

All eight educators professed strong beliefs regarding science teaching and learning in non-formal settings. Their ideology evolved from personal experiences, past employment, personality, and their peers. Despite their different personalities, personal experiences, and peers the educators shared a similar philosophy on how children learn, strategies to ensure learning, the role educators played, and teaching goals for classes at non-formal settings.

Student Learning Involves Doing

Educators from all eight settings shared similar beliefs regarding how children learn. They consistently reported that students needed to be involved in the lesson in order for learning to take place. Individuals learned better and retained more knowledge if they had the opportunity to touch, feel, manipulate, and experience. Learning was an active process, which required mental and physical participation. This included engaging in the lesson mentally by asking questions and thinking about the concepts and content, as well as physically taking part in activities.

Julia (M1): *... basically I think that [students] learn by doing, and by seeing also. But by seeing and doing better than just having somebody lecture (4-6). ... for example choosing this young man that said, 'No. Yes, I can make a bubble out of just water.' ... He has made a guess, and now he's going to do exactly what a scientist does and test it. And so he's doing a good job of acting like a scientist.*

Caitlin (M3): *I do strongly feel that science ... is best done in an interactive style. I think that it's probably influenced [by] the way that I learned best. ... I certainly take in information better most of the time ... if it's something I'm interacting with. There are some things you need explained, but explanations I think are best reinforced by being able to*

ask, to do it, and [to] experience it. And that does influence how I teach.

Melanie (NC2): *I ask questions to get them ... thinking about what ever it is they already learned or what they don't know, and hope that it will stick with them better ... [and] they will retain it.*

John (NC3): *... when you're presenting things and a kid thinks about it, and they're asking questions, [you should] try to get them to think. Go ahead and use some of these visual things, take them outside and do hands on things. Anything like that just to keep things flowing to where it's not just, 'Sit down. You sit still, while I instill,' kind of approach to education.*

When probed further regarding the benefits and purpose of physical participation in the learning process, all educators alluded to the creation of positive memories associated with science as the ultimate driving force for inclusion of physical activities in their lessons. It was important for the students to identify science as a fun, enjoyable, and doable experience. The physical activity would give students the opportunity to manipulate and experience, in addition to preventing the lesson from being completely lecture-based. Overall, the educators believed this attitude influenced the choices students made later in life, nurtured an appreciation for nature and learning, and/or aided content retention and recall. They felt it was their responsibility as the educator to provide these experiences to their students, as well as role model the interest, enthusiasm, and appropriate behavior towards science and the natural environment.

Julia (M1): *... I want to show them ... that I'm having fun with [doing science]. ... I'm enthusiastic about it. ... Just to convey enthusiasm, enthusiasm for stuff, enthusiasm for the [scientific] process. ... And showing them that they can be this way. It never has to be yucky science stuff.*

Karen (M2): *... and so their interest and enthusiasm grows about science, then they may choose science as a career. They may not be afraid of it in high school, and might take more than what's required to get through high school or take more classes in college. And so I'm hoping to influence their choices and comfort about science.*

Ioana (M4): *To get them excited ... [because I think] a lot of the kids don't get that from their teachers. And I think even though they're only here for 45 minutes, an important role we have is to give them a positive experience to these topics so that they don't think that science is all boring stuff that is not worth their time.*

Annie (NC1): *... [T]aking part in something may have a big impact on your memory. ... A lot of our plants here have ... interesting textures, ... and that's another thing that I try to do with my programs is to play on all the senses. I think ...[it] creates an appreciation if you ... [allow the students to] have that type of interaction with the environment where [they] don't just view everything from the trail. ... [I]t all comes back to appreciating [nature], and thinking twice about making a bad judgment in relation to the environment. ... And if you can teach the kids to appreciate even the smallest bug or plant, they can take that home with them and teach their parents to appreciate it if the parents are doing poor land management practices*

Meanwhile, mental engagement was necessary for learning to take place. They repeatedly stated that in order for students to learn, they needed to think about what information was shared with them, what they were doing in the activities, and why they were doing these activities. Student initiated questions and recall of content were an indication that students were mentally participating in the lesson. The educator questions were intended to prompt student thinking.

Ioana (M4): *It's a chaotic thing where they just run around from table to table, 'Oh I want to look at this. Oh I want to do the streak plate.' ... If they're writing it down may be they're thinking ... over why they're choosing this rock to be an igneous rock. And then we come back and*

talk about it at the end of the class, and they have their sheets. They're looking at it, they can make corrections on it, they may throw it away at the end of class, but at least they used their brains.

Melanie (NC2): *... if you ask the students questions ... it gives them a chance to ... review what they already learned. It gives them a chance to say, 'Hey, I know that,' and that gets them excited that they knew the answer to the question. But also because it makes them think. And the ones who don't know, tend to... start think[ing] about it. ... And then when I tell them, they're more likely to remember than if I said, 'Insects have six legs.' So questions ... basically ... get them thinking about what ever it is they already learned or what they don't know, and hope that it will stick with them better. They will retain it.*

John (NC3): *I think that also in the learning process when [students] engage in the thinking process, as opposed to just taking in the information, [they] are going to remember that. ... I think that they enjoy it when they can ask the questions. [For example] when you give them a piece of information that ... toads don't have warts on them, a kid has a question, 'What about when you do this and this and this.' ... They're thinking, and ... the wheels are turning ... as opposed to just sitting and taking in the information. ... I think questions and answers are helpful to their memory, and also to actually learning what they want to know already.*

Calvin (NC4): *I try to get them thinking without totally blowing their minds. ... [On a hike] the other day with a middle school [group], ... we ... stopped every so often, ... and the first thing I [did was] ask questions. 'What do you see in here?... In what direction does the sun come up?' You know most people know that. Then we [related] that to something. ...[I] continued to [ask] questions so that I [could] get an idea of where they [were] with what they [knew], and then ... add a little something on top of that so they [came] away having learned something.*

Purpose of Teaching and Use of Physical Activities

Although beliefs about learning among all eight educators was consistent, disparity existed in their perspectives on teaching and parameters for physical participation. Karen believed teaching was providing opportunities for physical experiences that encouraged

mental participation, which was necessary for learning to take place. However, learners needed guidance from the educator via teacher initiated questions and structured activities in order to make the connection between the physical activities in which they were partaking, and the desired mental engagement. Melanie expressed similar uses of physical activities in teaching. Contrary to Karen, however, she believed that when given the opportunity students would engage in self-discovery in order to gain more information, and then develop an understanding of the concept from all that knowledge.

Likewise, Annie and Calvin proposed that learners were capable of developing an understanding of the concepts on their own if provided the necessary information. Thus teaching was using different approaches to provide information to learners. Physical participation was an effective way of presenting the information because it gave students personal and concrete examples that aided their information synthesizing process. Along with thoughts comparable to those of Annie and Calvin, Ioana added that the purpose of the activities needed to be understood by the students for the connections to be made. She believed that students were not able to make the connection between the information presented and activities offered to them. Guidance from the educator was necessary. Like Annie and Calvin, Caitlin believed that teaching was sharing information, and providing activities to reinforce that information. The educator facilitated the learning process by providing activities that verified the concept or content to the learners, and as a result learners generated their own understanding.

Role of Teacher

Consistent with their belief that teaching was sharing of information, most of the educators suggested the role of the educator to be the provider of knowledge. They had the knowledge, and would share that knowledge with the students as the class progressed. This also applied to misconceptions students may have developed. The educators knew the accepted information or interpretation of a concept, and would correct the students' understanding if they disagreed. The implication was the teacher is at the center of the learning and teaching process. Caitlin and Karen attributed this partly due to the time constraints of such programs. With only 30 to 50 minutes allotted for each class, and a pre-determined lesson plan based on the needs of the classroom teachers, they pointed out role of the educator had to shift towards a teacher-centered classroom.

Karen (M2): ... *[Y]ou have children ... for one hour. ... [Y]ou can't continue, you can't do a lead in and a post [activity]. ... [I]t seems to me not to be feasible to have a certain ... educational goal that maybe the teacher wants to accomplish ... and still make it ... inquiry-based. I don't see how you can have the children come in and ask their questions, and all of a sudden get at the materials they need to answer those questions in that time frame.*

Caitlin (M3): ... *I'm more like a facilitator. ... Let's face it, I only have them for 45 minutes, 30 to 45 minutes. So, the way I look at it is I'm there to try and give them new opportunities for new experiences and interactions with live animals and information according to those animals that they may or may not have had exposure to. I feel [more] like facilitator for that.*

Annie (NC1): *I would hope that we are able to enhance what the teacher had said, maybe in a new way from the sterile classroom environment. I would hope that we could either enhance it or hopefully fill in the missing pieces that maybe a teacher tried to convey a point but in a*

certain classroom environment maybe without the certain experience its missing.

John (NC3): ... *[D]efinitely exposing them to information, and changing viewpoint. ... We affect their education by dispelling myths, by exposing them to things they're not going to be exposed to in school like the pond, like the tree, like the trail and stuff like that.*

Calvin (NC4): *For me it's really being a facilitator. Being someone that can point out things, ... and ... call somebody to ask a question, "Why does this do this," and it allows me to have a chance to explain it. ... Making [information] available. Here it is, and you can do what you can with it.*

Teaching goals

Although the educators felt sharing information was a large component of teaching, they also felt that retention of content was not the primary objective in the classes they taught. Nurturing an interest and appreciation for science and nature were ranked as the two most important goals for teaching science classes at non-formal settings (Table 4). As mentioned above, the purpose of the physical activities were to provide students with experiences that promoted their confidence and interest in doing science, and thus creating a positive related to science. Nonetheless, this did not take away from their responsibility as an academic institution to provide information.

Table 4

Personal goal for teaching science classes at non-formal settings to school groups ranked in order of importance.

	Remember content	General concept understanding	Nature & science appreciation	Science & nature interest	Develop skills
Julia*					
Karen	3	2	1	1	2
Caitlin	5	2	1	3	4
Ioana	5	3	1	2	4
Annie	5	2	1	3	4
Melanie	4	3	1	2	5
John	3	2	1	4	5
Calvin	3	4	2	1	5

NOTE: *Julia did not submit responses.

Julia (M1): ... *obviously we want to impart some knowledge, but if we could get the kids to leave here saying, 'Science is really cool. This is something I'm interested in,' ... then we've done ... what we need to do. I mean regardless of whether they go out with the huge body of knowledge or not.*

Karen (M2): *The content ... is important, but it's not the top priority. It's more like an understanding of how important observation is, how important recording is, how important sharing is, how important tracking your numbers accurately and giving the right data. Those basic skills probably are as important. And the attitude of respect towards living things, ... those are the kinds of things to me that are as important as the content. I do think that we have a bigger responsibility being an educational museum to have [a certain amount of] content ... that they can carry away.*

Caitlin (M3): *They're not going to remember everything I tell them about reptiles or animal life cycles. Maybe there's one piece that they could take back. ... All I'm trying to do, I think, is to help them develop an appreciation for things.*

Annie (NC1): ... *[M]y goal is always for each person to walk away with one new piece of information ... [because it] could be very important in the future. ... [I]f nothing else I'd like to establish an appreciation for the natural world that hopefully they will pass on to each person, and to make a connection.*

3. What are the Observable Teaching Behaviors of Non-formal Educators in Science Classes Taught to School Groups?

Educator dialogue and student physical participation were two common teaching behaviors observed among all eight educators. They noted that the value of physical participation and mental engagement via educator initiated questions necessary for learning influenced their teaching behavior. Each lesson engaged the students in a number of activities, which were categorized to determine the levels of cognitive involvement these activities elicited from the students. Types of questions the educators asked indicated the level of mental engagement the educators roused from their students. Whether the educators gave their students wide discussion latitudes, and control over the contents discussed were ascertained by calculations of a coding rate and interaction index, respectively.

Physical Participation

The educators' learning and teaching beliefs were reflected in the design of the lesson plans they implemented. Twelve out of the 15 classes observed prevented absolute teacher lecturing with the inclusion of activities that required students to physically interact with objects, artifacts, animals, and/or equipment. The remaining three relied on visual examples upon which students focused their attention during the educator-led discussion. Students in both of Calvin's *Hiking 101* classes listened to him talk and engaged in the dialogue when prompted, and then viewed the objects as Calvin held them up. Julia's *Bubbleology* class consisted of students watching her make bubbles, and predicting the outcomes. There were

four separate occasions where a student was asked to physically participate, but they only required the student to demonstrate the action.

Interestingly, physical student involvement among all 15 lessons primarily involved using the senses (Table 3). Only Karen's *What is soil?* and Melanie's *Woodland habitat* classes included activities coded as Experiment, which required students to engage in tasks that required higher levels of cognition (for definition, see Appendix B). Students had 6.1 and 18 minutes of uninterrupted Experiment activity in Karen and Melanie's classes, respectively. As mentioned above, students in these classes collected data, and shared their findings with each other. The educators used the students' findings as they directed class discussions about the subject matter. Meanwhile, five of the 15 classes involved students in Action (for definition, see Appendix B) activities (Table 3). This was in classes of younger and older students, as well as in museum and nature center settings.

Mental Engagement and Verbal Behavior

Although asking questions or giving students the opportunity to ask questions was the predominant method the educators believed would insure student mental engagement in the lesson, lecture and statements were the predominant educator verbal behavior for most of the lessons (Figures 3 & 4). With regards to asking questions, those requiring a Yes/No and Short Answer response from the students were the most common types of questions asked (Table 5). Only Karen in her *What is soil?* and Annie in her *Talkin' turtles* classes asked Extended Answer questions, 2.47% and 2.04%, respectively. Interestingly, educators tended

to ask more questions in the Younger classes than Older classes (Figures 3 & 4). This was consistent among museums and nature centers.

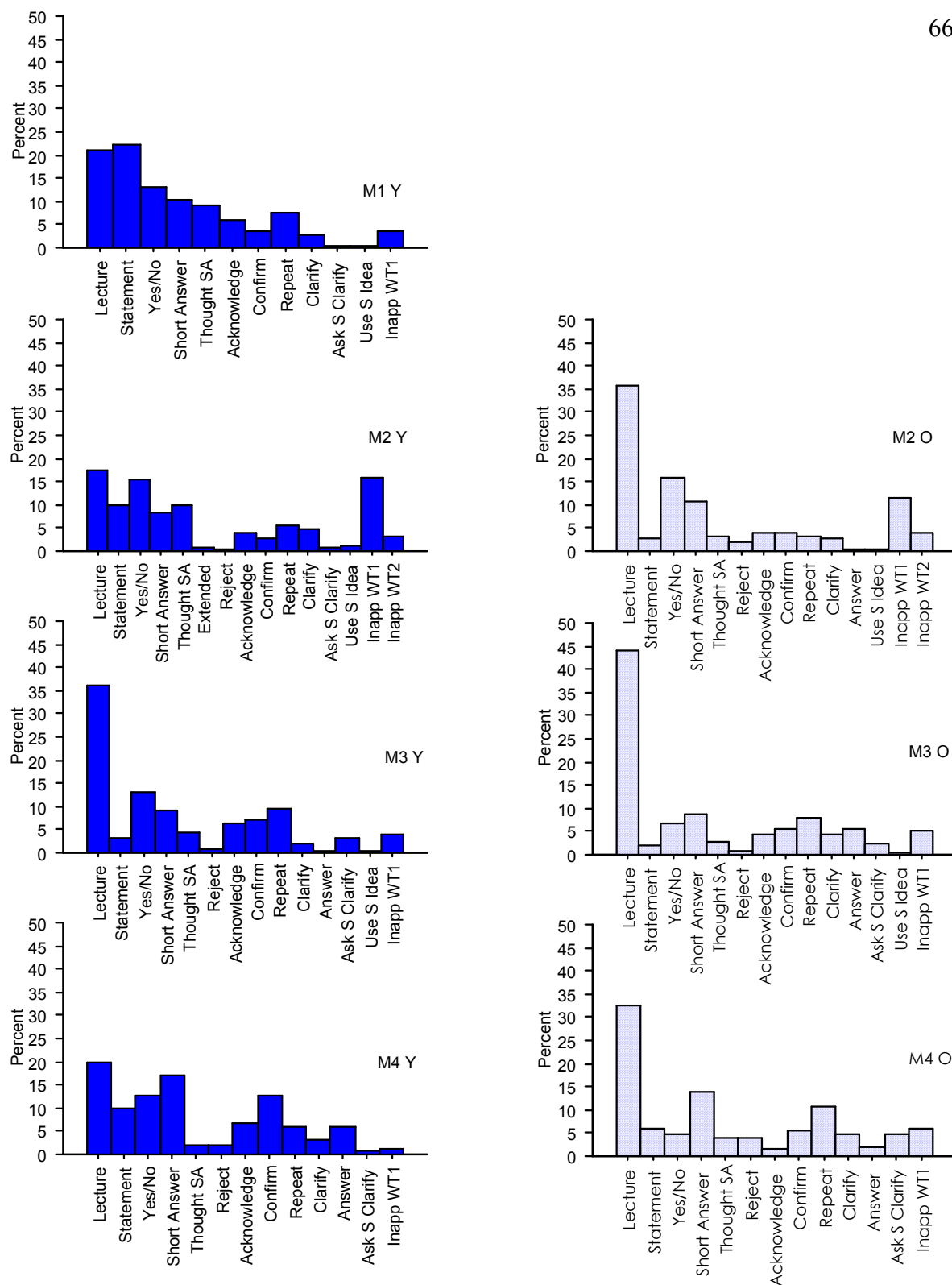


Figure 3. Frequency distribution of educator verbal behavior for M1-M4.

Note: Y-younger class; O-older class

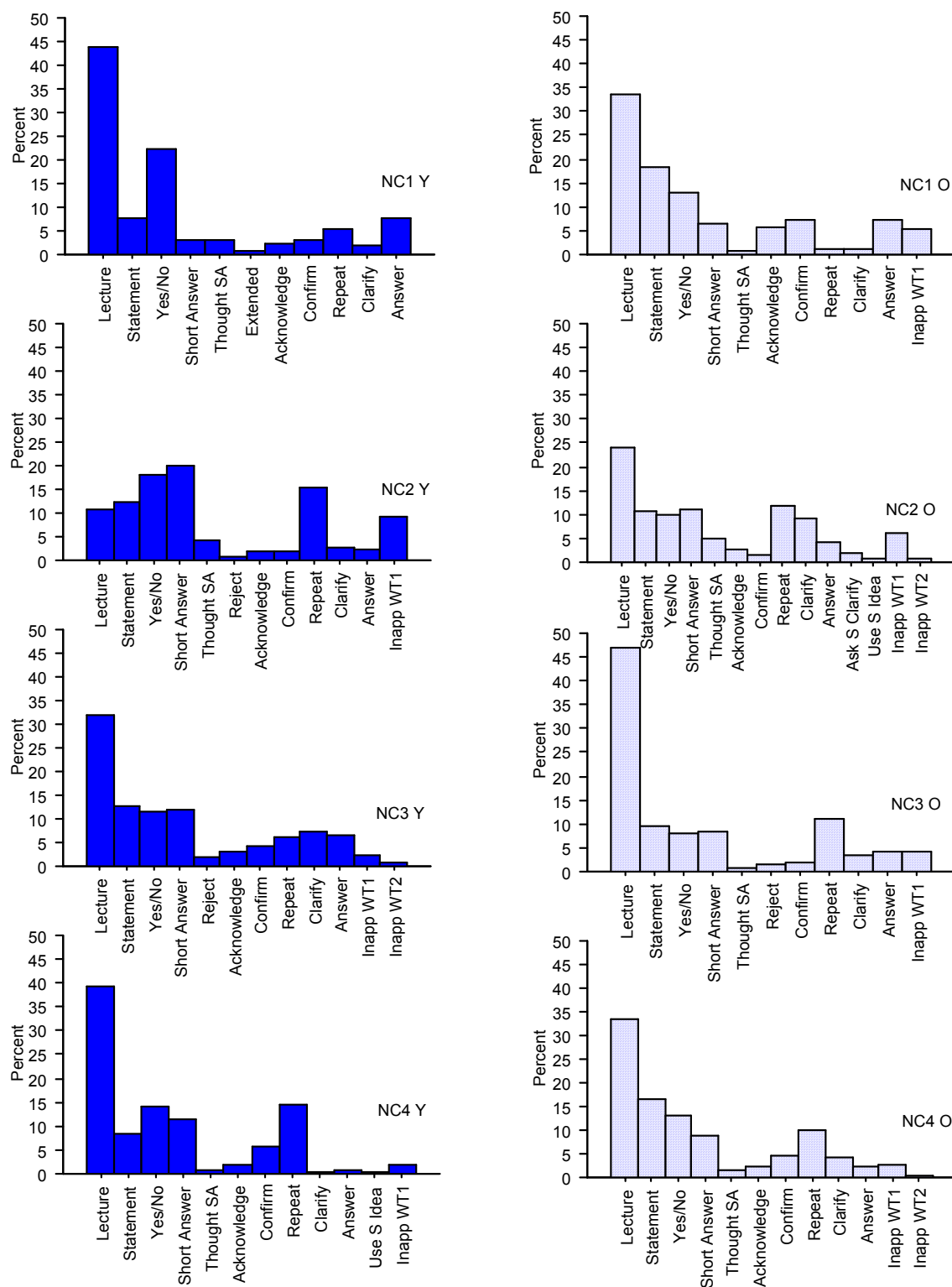


Figure 4. Frequency distribution of educator verbal behavior for NC1-NC4.

Note: Y-younger class; O-older class

Table 5

Per cent of questions requiring yes/no, short answer, thoughtful short answer, or extended answer responses from students. This codes for types of questions the educator asked, not how students responded.

Educator	Class	Grade taught	Yes/No¹	Short Answer²	Thoughtful Short Answer³	Extended Answer⁴
Julia	Bubbleology	1st	40.51	31.65	27.85	0.00
Karen	What is soil?	3rd	45.06	24.07	28.40	2.47
	Basic rocks & minerals	4th	53.40	35.92	10.68	0.00
Caitlin	Animal life cycle	2nd	49.09	34.55	16.36	0.00
	Reptiles	4-6th	36.67	48.33	15.00	0.00
Ioana	Animal overcoats	1st	39.58	54.17	6.25	0.00
	Nature's rock stars	6th	20.45	61.36	18.18	0.00
Annie	Talkin' turtles	2nd	77.55	10.20	10.20	2.04
	Water bugs	8th	67.74	29.03	3.23	0.00
Melanie	Insects	K	43.01	47.31	9.68	0.00
	Woodland habitat	5th	38.46	43.08	18.46	0.00
John	Insects	1st	48.72	51.28	0.00	0.00
	Pond study	5th	46.15	48.72	5.13	0.00
Calvin	Hiking 101	1st	53.13	43.75	3.13	0.00
	Hiking 101	5th	55.56	37.78	6.67	0.00

NOTE: ¹Yes/No-question requires yes or no answer; ²Short Answer-question requires recall, verbal true/false, or fill-in-the-blank; ³Thoughtful Short Answer-question requires short, but thoughtful response; ⁴Extended Answer-question requires student to think or synthesize

The educators' Coding Rates and Interaction Indices suggested teacher-centered classes, which were consistent with the educator's beliefs on teacher role. The Coding Rates tended to be close to or slightly greater than 1.0 (Table 6) regardless of age group or type of non-formal setting. Educators observed in this study made 0.9 to 2.1 comments every 15 seconds. Rates greater than 1.0 indicated a high amount of teacher structure. Calvin, Julia, Karen, and Caitlin had Coding Rates greater than 1.0 in both of their Younger and Older classes. Interaction Indices for all eight educators were low, ranging from 0.248 to 0.642 (Table 6). The index should typically be around 1.0 or greater. Low Interaction Indices showed that the educators initiated questions and comments more often than they responded to student questions and comments. Julia, Annie, John, Calvin, and Karen (in her Older class) initiated more than twice as much as they responded. Meanwhile, Caitlin, Ioana, Melanie, and Karen (in her Younger class) responded slightly less than half as often as they initiated a question or comment. This further suggested that these were teacher dominated classes.

Table 6

Coding rate and interaction index for observed classes.

Coding rate is the number of codes per 15 seconds; Interaction index is ratio of teacher response to teacher initiary verbal behavior

Educator	Class	Grade taught	Coding Rate¹	Interaction Index²
Julia	Bubbleology	1st	1.750	0.324
Karen	What is soil?	3rd	1.665	0.620
	Basic rocks & minerals	4th	1.504	0.466
Caitlin	Animal life cycle	2nd	1.576	0.518
	Reptiles	4-6th	1.580	0.558
Ioana	Animal overcoats	1st	0.899	0.624
	Nature's rock stars	6th	1.231	0.642
Annie	Talkin' turtles	2nd	0.972	0.248
	Water bugs	8th	0.939	0.387
Melanie	Insects	K	0.928	0.521
	Woodland habitat	5th	0.929	0.638
John	Insects	1st	0.922	0.469
	Pond study	5th	0.961	0.352
Calvin	Hiking 101	1st	2.086	0.352
	Hiking 101	5th	1.817	0.360

NOTE: ¹ Coding Rate (CR) >1: teacher dominates discussion; ²Interaction Index (II) <1: teacher initiates most questions & comments

Other Outcomes

The way in which these science classes were developed, and how educators were prepared to teach them also arose from this exploratory study. The educators briefly described the process by which their respective institution developed the lesson plans. This included discussion about the staff responsible for creating and maintaining the lessons, and the need to accommodate the concerns of their audience. In addition, the educators identified potential constraints that required special attention in the planning stages. The educators also spoke about the way in which they were prepared to teach in non-formal settings.

Program Development

Program development involved determining class topics offered at the non-formal setting, writing the lesson plans, creating and/or revising activities for each class, gathering the necessary materials and resources for the class, and updating the curriculum as needed or based on evaluation. Each class taught at the eight non-formal settings had a predetermined lesson plan that was used with a range of grade levels (Table 7), and modified as needed by the educator during instruction. These were generally created by the institution's education staff based on the educators' interests, needs of their target audience, and/or resources available at that non-formal setting. The purpose of the lesson plans was to keep the educator within time frame allotted, and they were organized so that students could undergo an educational and positive experience despite brevity of the lesson. Aside from a time limit of one hour, program development was also constrained by the unknown broad knowledge base with which students came, and the one-time interaction between the class and educator.

These constraints required educators to create succinct classes that capitalized on the strengths of the educators and the institution's resources.

Table 7

Concept and time duration for classes taught by each educator.

Educator	Date	Title (targeted grade level)	Concept and/or Topic Area	Grade taught	Length (minutes)
Julia	6-Mar	Bubbleology (K-6)	making bubbles; water tension; molecular tension between water & soap molecules	1st	35
Karen	15-Mar	What is soil? (1-6)	components of soil; sedimentation rate & texture of soil types (humus, clay & sand)	3rd	71
	28-Mar	Basic rocks & minerals (2-4)	types of rocks & rock cycle; difference between rocks & minerals	4th	57
Caitlin	19-Mar	Animal life cycle (2)	stages of development for five major animal groups (birds, amphibians, reptiles, insects & mammals)	2nd	33
	19-Mar	Reptiles (K-8)	reptile features, characteristics, & behavior	4-6th	53
Ioana	25-Apr	Animal overcoats (preK-2)	animal coverings (fur, feather, scales) and patterns	1st	42
	22-Mar	Nature's rock stars (3-5)	types of rocks & rock cycle; identify rocks	6th	40
Annie	26-Mar	Talkin' turtles (All)	turtle characteristics and behavior	2nd	44
	17-Apr	Water bugs (3 & up)	types of aquatic macro invertebrates; assessing health of aquatic environment via macro invertebrates	8th	41
Melanie	12-Apr	Insects (K-5)	types of insects; ways to collect insects	K	59
	16-Apr	Woodland habitat (K-5)	forest succession; scientific tasks of soil scientist, wildlife biologist, & dendrologist	5th	67
John	23-Apr	Insects (K-5)	insect types & insect characteristics; ways to collect insects; camouflage	1st	45
	15-Apr	Pond study (1-5)	types of aquatic organisms; dip netting	5th	58
Calvin	18-Apr	Hiking 101* (1-5)	hiking essentials including equipment necessary, important things to keep in mind, and how to hike	1st	29
	15-Apr	Hiking 101* (1-5)	hiking essentials including equipment necessary, important things to keep in mind, and how to hike	5th	26

Note: * These were part of a week-long Earth Day celebration. Grades 1-5 from schools around the community participated in this paid program. Students rotated among five 25-minute programs, and then were free to explore the non-formal setting. Educators taught the same program all week to different visiting school groups.

Parameters

While class lesson plans were often developed by past staff educators, they were usually updated regularly at the discretion of current staff rather than completely recreated with each staff turnover. This strategy was primarily due to the tremendous time and resources invested in the original design of each class. For this same reason, different school groups requesting that lesson topic were taught with identical lesson plans. The target audience for these classes were visiting school groups, thus content and concepts discussed were driven by classroom teacher needs. In order to address the spectrum of prior knowledge students brought, the lesson plans were designed with incredible flexibility, and the educators learned to interpret and respond to different groups of students regularly.

Personnel responsible for creating programs. An extensive amount of time was spent on initial development of a lesson. Once created, the same class outline was taught to the different school groups requesting that class topic. As a result, educators had the opportunity to reflect upon the lesson plan, activities, and their teaching approach, and apply any necessary modifications immediately.

Ioana (M4): *I really haven't had time to actually work it out in my mind, and change it to what I like, to what I want. ...I'll change it to what I think will serve my purpose, serve my goal. ... I haven't taught this one enough that I have gotten a very clear idea of what I want.*

Annie (NC1): *... we get so many different kinds of people out here, you almost have to use each group as a test to see how to teach. Because I'll definitely go back today and reevaluate today's group, and how I would do differently.*

In both museums and nature centers development of new and updating of existing class programs either was done by special staff program developers whose primary responsibility was to write and update lesson plans, or by the educators teaching the lessons. In the former program development situation, the lesson plan, general content discussed, resources used, and activities were the same each time the lesson was taught regardless of whom leads the class. Class variability came about from the teaching approach the educator employed using the set lesson plan as a guide. Educators were encouraged to provide feedback for improvements to the program developers.

However, in the latter condition, a lesson with the same topic and description could discuss different content and include different activities depending on the educator writing and updating that lesson. In such cases, there were general descriptions of the science subject matter that the institution featured, and the educators created their lessons within the parameters of those general descriptions. Thus in this situation, there was variability in content discussed and activities provided, as well as teaching approach. M1 and M2 had small education staff sizes, two and one full-time + two part-time, respectively. As a result, educators taught the programs they created and revised. M3, M4, and NC2 had educators on staff responsible for designing and reviewing the curriculum material while staff educators and/or volunteers taught the classes. While non-formal settings with larger education staff size tended to have separate program developers and program educators, that was not always the case. Educators from the remaining non-formal settings were responsible for developing the classes that they taught. However, there were some lesson plans that educators have adapted for a particular class because it “worked best.”

Ioana (M4): *I think that it's important that if we're going to be teaching the classes over and over again to have somewhat of a format so that the new educator coming in knowing nothing, they can look at it and say, 'OK I know what I'm supposed to do.'*

Melanie (NC2): *... it's one of the programs that they have on the curriculum there at [NC2]. ... I'm not exactly sure of who created it because it's been around for a while, but [staff program developers] who work downtown with the nature department has all worked on updating the curriculum over the past couple of years. I didn't design that program, but ... I just learned it, as ... they have a set curriculum that you kind of go by ... but then you know ... we do our own style of teaching for it.*

John (NC3): *You might do a piedmont community class with [an NC3 educator], and then do one with me. ... [Y]ou might not recognize them as the same program. And so it does vary somewhat between interpreters. But the one you saw today doesn't ... it's one they've been doing for a long time, and it's the best way to do it. And so structure is imposed on it because we found that's the best way to do it, not so much because it's policy here at [NC3] that we only do the pond study this way.*

Lesson plan content driven by classroom teacher needs. Content discussed in each lesson was driven by the needs of the classroom teachers and the flexibility necessary to accommodate the varied knowledge base of the students regardless of who created the class program. M2, M3, NC2, NC3, and NC4 addressed this issue by correlating their lessons to the North Carolina state science standards. NC1, NC3, and NC4 determined teachers' needs during the initial scheduling, and made changes to the lesson plan for that particular class accordingly. In addition, NC1 provided one program designed by the state's environmental education agency created specifically for the river at NC1. The state agency program developers correlated this lesson plan to the state's science standards. As a result, teachers could justify their field excursions to the non-formal settings to their school administration.

Caitlin (M3): ... *we have developed classes that correlate with [state] science curriculum. ... Some [classroom teachers] have to use that to justify field trips. Some schools won't even allow them to come here unless they have something concrete like that.*

Calvin (NC4): ... *we have certain programs that we can do that are laid out, and have all the specific things. But for us we tend to be a more on demand kind of thing. What is the teacher working on right now, you know ... what is she wanting them to learn by coming to [NC4], so that way... we are real flexible and try to work with them, and try to figure out what their needs are.*

Constraints

Science class programs offered at these non-formal settings were 30 to 60-minutes, one-time experiences for the visiting school groups. Consequently, there were constraints all eight educators recognized that needed to be factored into their teaching as well as program development. Educators were not able to meet with and get to know their students prior to designing their lesson plans or deciding on their teaching approach. Nor did they have the opportunity to prepare the students prior to the visit, or expand and follow up on the lesson afterwards. They were usually unaware of their students' prior knowledge until class time. In addition, these class programs needed to accommodate a large age range of students. While some non-formal settings may provide classes targeted to specific grade levels, most of the classes were designed to cater to most grade levels (Table 7), i.e. a reptile class that was available to 2 -12th grades or K-6th grades. Thus program developers and educators teaching the classes devised strategies to undertake such limitations in their class development and implementation.

Variety of prior knowledge. The lessons were created with tremendous flexibility to accommodate a variety of potential prior knowledge the students would bring. This was of primary concern for most of the educators, and was assessed immediately so educators were able to determine the cognitive level they should target for that class.

Caitlin (M3): *I think sometimes it makes the class flow better. I don't like coming in and didactically deciding this is what I am going to present no matter what because if they have a lot of knowledge about something, we don't need to spend ad nauseam time talking about butterfly metamorphosis because they have had this drilled into them. ... There are other things I can offer that they would have limited experience. So I won't beat it to death with a topic that they know a lot about.*

Ioana (M4): *I don't like to just go in and teach a class to third graders with information that's way above their heads that they will get nothing out of. So I'll simplify it to their level so they can say, 'Oh, I see why that happens!'*

Annie (NC1): *If you're doing a program on wild flowers, and you have a senior botany professor from the local university, you need to be careful what you say. You want to know the background of your group because you can either rely on that person to help you ... [or] if you have a whole group of people who have a basic knowledge of a species ... you don't have to keep it at a second grade level. ... It's kind of an 'on the fly' thing because you never know 'til before you begin the program who you're working with.*

In order to make a particular lesson cognitively appropriate to a particular class, the educators determined their students' prior knowledge on the subject matter by asking the classroom teacher when they scheduled the visit lesson, or questioned the students directly at the start of class. Student understanding could also be gauged via student responses to initial content questions or student questions. The educators believed these were effective ways to

quickly and informally assess cognitive levels to which they were teaching. Student knowledge did not change the activities available for the class to participate in, but it could change the way content was presented, type of content discussed, pace of class, and which activities actually completed at the end of the session. If the class was not late or there were no major behavior problems, there were usually 45 to 60 minutes of instruction available. Therefore, the educators needed to make the initial assessments quickly.

Caitlin (M3): *Sometimes you can be very blunt and just ask the teacher. I've said, 'So does the class know what they've come to talk about today?' She'll say, 'No,' and then I'll be like great this will take forever. Sometimes she says, 'Yes. We've been studying it,' or sometimes she'll say, 'No. We studied it last fall so this could be kind of a review.' It's nice to do that when you think of it because it gives you a framework to start from. And then you could test them out on your own with questions. And you can tell from how they respond how much they know, how much they remember, how much giving you have to do. And that's fine. And ... you can modify as you go along. You may also hit a point they have never had, or they never heard of before.*

Ioana (M4): *I ask them at the beginning of class. I might ask the teacher when they come in. I think it's important to know what their background is so you know what information to come to them with. I'm not going to start talking about really complex things to somebody who does not have any background in it.*

John (NC3): *well all of our groups register before hand, so we get an opportunity to talk to the teachers previously. As well as in the initial clues ... you can get some kind of idea of whether they're getting it or not by their faces or the questions they asked.*

Unknown student interests and abilities. Along with prior knowledge, specific student physical and cognitive abilities and interests were unknown to the educators antecedent to design of the lesson plans. Thus the educators needed to be adaptable and flexible in their

teaching approach and lesson plan in order to accommodate the variability in their students' abilities and interests, and the programs needed to be created with resilience to allow for this. In addition, lesson plans for the classes were developed to target a large grade range, e.g. K-12 (Table 7). Consequently, class lesson plans were also created with the versatility to accommodate this.

Karen (M2): *I worry about repeating classes, and teaching some of the same [lesson plans, but] ... we just have such a variance ... of classes so I don't get bored teaching them. And every group that comes through [has] a personality and different needs. And so I try to be very sensitive to those.*

Caitlin (M3): *... so I feel like I'm just trying to figure out the way to present this information or these topics in a way that's interesting to them, and relevant to them in some way ... in a way that I am sure that they could take away something.*

Annie (NC1): *Once you start to figure how to handle [a group], they're gone and you have to learn to deal with another one. And ... the tricky part of our job here ... is that you've got to be very adaptable and flexible in not knowing what you're getting ready to walk into with a group of kids. It becomes very nerve wracking; they'll knock you off your feet a lot of times.*

John (NC3): *I think we create them with a lot of flexibility in mind because we'll have the pond study (what we just did) ... we do one study with first graders, we do one study with fifth graders. We might take out some slides we do with fifth graders when we do the first grade programs. We would definitely change the information up, and stuff like that. So I think all of our programs were created with the mindset of flexibility that we do have to adapt to get an audience that is maybe a kindergarten or a middle school, or maybe adults. So I think there's a lot of flexibility in developing the program..*

One-time interactions. The one-time encounter with students made it difficult for educators at these non-formal settings to follow up on student understanding. For that reason,

some redirected that responsibility to the classroom teacher, while others simply hope the experience was positive enough for the students to pursue conceptual understanding on their own.

Julia (M1): *I mean many of them will remember things. ... [W]hen they're in 6th or 7th grade they remember what a molecule is, ... 'I know about molecules. I heard about that. I know everything is made of molecules.' ... [A]nd even more hopefully they will remember it was fun, it was science, it was fun. 'We went to the science museum, and we had a great time. ... [N]ow let's go to another museum. ... [T]his science [museum] is going to talk about something that I'm interested in. Let's go do that. Oh here is a science class I would like to take, man that would be fun. We can do that.' And again conveying that science is doable, [and] they can do it, as well as grown-ups can. It's fun.*

Karen (M2): *We'll oftentimes get teachers [to] follow-up things they can do in their classroom to try to ask the questions and then see where it's going. I'll say, "Well you can do an experiment on that in your classroom,"[and] then I've got the teachers to [do] the inquiry process in the classrooms.*

Caitlin (M3): *Trying to correct misconceptions is a small goal. And you can do that sometimes. But it's hard because they're going right back into the same environment. And then they believe you when they're here, but when they leave who are they going to believe.*

Teaching Preparation

The eight educators in this study primarily majored in the sciences as undergraduates (Table 2), and attributed personal and past job experiences, personality, application of college class assignments, and mimicking other educators as the principal process by which they were prepared to teach at non-formal settings. Two of the eight educators in this study, Karen and Julia, earned teaching certifications. However, only Karen taught as a classroom

teacher. Julia chose to teach in non-formal settings, and have been at M1 for 30 years. She also was the only educator to have a Master's degree (M. A. in teaching).

Source of Teaching Preparation

Ioana and Annie attributed their preparation to teach at non-formal settings to interpretation classes in college. These courses were part of their environmental science and parks & recreation curriculum, respectively, and addressed techniques for teaching about the natural environment in an outdoor setting to the general public. The remaining educators acquired teaching experience from employment primarily at nature centers, museums, and other non-formal settings during and after college. In addition, watching other educators teach, and incorporating their style was a valuable teacher education technique for these educators instructing at non-formal settings.

Annie (NC1): *And lots of times you mimic what you're taught you know, the styles you're taught. Or you might see how someone else does things, and try to mimic it. See how it works for them.*

Melanie (NC2): *And also I've got a lot of my teaching experience and attitude towards that from seeing other instructors and being around other instructors, and listening to what they have to say, and seeing how they interact with children.*

Calvin (NC4): *Basically just my predecessor. Watching them, [and] seeing how they approach things, seeing how they conduct talks. Just basically using their framework you know to form my own.*

Two of the eight non-formal settings required their educators to participate in programs that addressed teaching at non-formal settings. Educators at NC1 partook in two

levels of workshops provided by the state. Level one focused on public speaking, and preparing the educator to present information to the general public. Level two targeted "... interpretive techniques. How to get the message across for different types of groups." (Annie, 726 – 728). However, Annie noted that although the training was interesting, none of the techniques presented were applicable to teaching the programs at NC1. Although the frequency of these professional development opportunities available to prepare Annie and her colleagues to teach were not identified in this study, recent state budget cuts have reduced their accessibility overall.

Educators teaching school group programs at NC2 were required to participate in a one-day training program led by staff program developers. This involved watching other educators teach the classes offered by NC2 to a Girls Scout or church group in order to simulate a regular school class, or having the educators participate as the students themselves. In either format, the goal was to demonstrate the intended teaching approach for that class as written by the program developers. As a result, the educators were afforded the opportunity to ask questions about the content and delivery of the lesson plan, and had the chance to witness one way in which that lesson plan could be presented. Finally, prior to teaching a class on their own, new educators had to observe another experienced educator teach that class to an actual school group.

The remaining non-formal settings did not have any formal program to prepare their staff educators. Instead they relied on the individual's personal and past job experiences. NC3 depended heavily on volunteer docents to teach their school group programs, and thus required their docents to partake in preparation courses similar to that from NC2. However,

this did not apply to their staff educators. NC3 hired educators with extensive teaching experience from previous employment (both from formal and non-formal settings). They were given the lesson plan and an opportunity to observe the classes being taught by another educator before they were asked to teach them on their own. Consequently, observing how other educators interact with the students, and present the lesson plan were the primary ways educators at non-formal settings were prepared to teach.

Continued Science Learning Opportunities

On the contrary, two educators reported continued opportunities for science learning at their institution. Professional development in the sciences was available to these non-formal educators via the resources at their institution, and/or interactions with content experts.

Annie (NC1): *Instead of sitting at my desk and brainstorming and working so hard trying to understand something or learn something, I'll just do hike a trail, which is another [job] duty that we have [as state park rangers]. So I'm taking care of that aspect, but at the same time, all of a sudden BOOM, here comes the idea.*

John (NC3): *We'll get a biologist or a naturalist to come in the to help us out. And we also spend a lot of time ... walking the trails. ... [If] you see something that you [can't] identify, [then] ... you grab a field guide and ... look it up. [You] learn in a slow going process, but consistently when you work in a place like this. And so ... be out there is a part of our learning process here at [NC3].*

Summary

Consequently, class structure and observed teaching approach of science programs targeting school groups taught at eight non-formal settings had strong commonalities regardless of non-formal setting or age level taught. The education division infrastructure of each institution was unique to the organization's size, governing body, and mission statement. However, comparable practices and constraints drove the creation and design of the programs made available to school groups. Similarly, there were strong likeness regarding teacher education for the educators instructing at non-formal settings, as well as classroom climate of all 15 classes observed. Although there were variable approaches to development of the programs and the classroom climates, the variability was not consistent within any one non-formal setting or type of setting. While disparity existed among the educators' viewpoints on teaching and use of physical activities in their classes, the beliefs on learning, teacher role, and teaching goals were alike. Likewise, their verbal behaviors had strong resemblance with one another, and were also consistent with their teaching and learning beliefs.

CHAPTER 5. DISCUSSION

Teaching Science at Non-formal Settings

Regardless of size, type of governing body, and annual operating budget, non-formal settings offer science classes to visiting school groups as a way to make the field trip more enriching and productive. A staff of educators with varying expertise in science and instruction teaches these classes. In this study, eight educators from non-formal settings throughout North Carolina were observed and interviewed in order to gain perspective on how educators teach science in non-formal settings. Instruments and analysis procedures employed were consistent with research investigating teaching philosophy and practices of classroom teachers.

In science classes at non-formal settings, non-formal educators are the leading instructional figure. They instructed class much like a formal educator in the classroom in that they created and used lesson plans to guide their instruction, and incorporated physical activities and used verbal behaviors to engage students mentally. Similar to classroom teachers, non-formal educators desired cognitive and affective gains in science from their students, and believed that physical activities and mental participation were necessary to learning. However, there were conditions that make the teaching in both settings different from one another.

At non-formal settings, the following circumstances prevailed as characteristics that distinguished them from science teaching in traditional schools. Lessons taught by the educators were short, one-time student learning opportunities. Consequently, non-formal educators spent extensive time, resources, and effort in the development and implementation

of their science classes in order to maximize their impact. Formal assessments of student learning were not part of the lessons. The lack of evaluations and judgements in these classes led to a certain amount of latitude in their lesson plan design. However, non-formal educators informally assessed student prior knowledge and comprehension of the lesson, which influenced content discussed, amount of activities accomplished, and pace of the class. While there were no tests, there were also no follow ups. Thus the educators targeted creation of worthwhile memories via physical activities as a way to encourage students to continue their interest and pursuit of scientific knowledge. Although they did not teach the same students every day, they capitalized upon repetition of the same lesson plan to improve their instruction. Thus, the lesson plans may improve and be refined over time with the same staff member, and this intensified the little time they did spend with a group of students.

Prompt assessment of learners' prior knowledge is a critical skill for teaching in non-formal settings

While non-formal educators had no control over the knowledge of school groups, they learn to assess student prior knowledge at the beginning of the lesson, and then made accommodations to the pace and cognitive level of their discussion accordingly. This was concordant with the fundamental principles of David Ausubel's work (1968) that centered around determining learner knowledge in order to make teaching relevant and productive for the learner. Tobin *et al.* (1994) further supported this contention in their review of effective teaching practices.

Since students participating in science classes at non-formal settings arrived with such varying backgrounds, non-formal educators felt it was essential to establish their audiences' baseline knowledge promptly. Just as research identified the value of assessing student understanding preceding instruction in formal settings, non-formal educators discovered the advantages of establishing prior knowledge immediately through experience with thousands of students each year. Consequently, science class programs were created with generalizations to accommodate the majority, but had the flexibility to adapt to the individuality of each participating school group.

Classes at non-formal settings shared characteristics of science labs in formal classrooms

The sensory oriented lesson plans followed a show-and-tell format. In this way physical opportunities were used to reinforce content or concepts introduced by the educator as a way to create lasting memories. These were similar to cookbook experiments common in school labs intended to verify concepts rather than encourage students to discover and construct an understanding. In both types of lesson plan formats, the concepts and/or contents were introduced and told to students, followed by a hands-on experience that confirmed details discussed, and then sometimes reiterated with more instructor-led dialogue immediately afterwards.

Marek and Methven (1991) found that students learning science by a show-and-tell format exhibited significantly lower conservation gains and use of descriptive words than students taught via the learning cycle which took on an explore-talk-explore format. In these learning cycle lessons, students were initially given activities to explore a concept, engaged

in a teacher-led discussion to invent their understanding, and then further expanded on their comprehension of that concept with another activity. Unfortunately, student gains and reactions to the lessons were not measured in this study. Nonetheless, the current design of these observed science classes taught at the non-formal settings in this study might not necessarily be much different from the general design of science lab experiments in schools. In neither settings do students really get to experiment. Instead, the norm is to name, observe, or confirm ideas presented by the teacher or the book.

Furthermore, much like classes in formal school rooms, educators followed lesson plans created for the classes, and content discussed within the lesson plans were usually correlated with recommendations in state science standards. The lesson plan was used as an outline to guide the educators through the lesson in an organized and timely manner. Like a classroom teacher, time to talk about and explore a science topic was limited. Considerable forethought and planning was needed in order to maximize on the intended goals. In addition, since classroom teachers generally determined student attendance at these science classes, the teachers' curriculum needs were targeted. Thus, many science class programs at non-formal settings needed to address state science standards.

Lesson plan repetition was an inherent advantage

The educators' abilities to assess and adapt quickly resulted from experience teaching in non-formal settings, and also the frequency with which each lesson plan was taught. Regular delivery of the same class structure and activities to students of varying ages and knowledge enabled educators to refine their presentations of that class. Transitioning from

the formal classroom to non-formal settings, repetition was potentially a cause for concern for Karen. However, she quickly realized that each class of students arrived with their own needs, knowledge, and personality unique to that group of students. Ioana and Annie both used the lesson plan repetition to improve their teaching of that subject matter, to enhance interaction with a particular age group, and as a way to make their teaching more versatile. This was critical during regular periodic school group tardiness resulting from transportation mishaps. School groups could be half an hour or more late to a 30- to 60-minutes lesson, but the educators' familiarity with the lesson plans enabled them to respond quickly. Since they taught the same lesson plan regularly, they were able to shorten a lesson seamlessly, or elaborate on material as evidenced by Caitlin when only eight students took part in her *Reptiles* class, while her *Animal life cycle* class was 30 minutes late to their 45-minute lesson.

Much like a classroom teacher, these non-formal educators had a limited amount of time to present, explore, and discuss the scientific content and concept of their lesson. In the traditional classroom, formal teachers have the added advantage of working with the same students over an entire school year. Thus they have a better discernment of the students' prior knowledge, and can follow up on student understanding or misunderstanding. Educators at non-formal settings did not have the opportunity to improve their interactions with the same students. However, repeated delivery of the same lesson plan afforded them the chance to improve upon the presentation of that lesson plan so that they maximized on the little time they had with a given group of students.

Along with the opportunity to refine delivery of a lesson plan, frequent repetition of a lesson also permitted time for refinement of lesson plan design and resources. Since they

were constantly teaching different students, the same lesson plan for a particular topic was used over and over again. As a result, considerable time and money could be justifiably spent on planning and gathering objects, specimens, artifacts, and/or equipment for each class. The nature of these educational institutions, as a museum or nature center, gave non-formal settings access to resources not necessarily available to classroom teachers. This included large collections of live specimens, a variety of rocks and minerals, and natural features like rivers, ponds, woodland habitats, and grassy fields right outside their “front door.”

Furthermore, through frequent instruction of the same lesson plan to hundreds of students educators were able to informally identify and address the effectiveness of activities, order and flow of the lesson, and types of items used in the lesson plan immediately. The educators did not have to wait an entire school year to modify and implement components of or entire lessons. Thus the same lesson was constantly evolving. At institutions where the same lesson plans were taught by a staff of educators and volunteers, periodic review of the classes was a cooperative effort. The same lesson plan was not only taught to hundreds of students with an array of learning styles, but was also taught by a variety of educators with differing teaching approaches. Such a collection of data to improve one lesson plan heightened the collaboration to combat the constraints that bound these science classes, and maximize the potential impact of each lesson. This was truly one of the unique positive aspects of the non-formal educational systems when compared to K-12 schools.

Variability in job duties generated opportunities for collaboration among colleagues

There was no doubt that the eight educators in this study enjoyed teaching science in non-traditional settings. This was evidenced by their enthusiasm, the willingness of some to endure a significant salary reduction from their previous place of employment, or to remain and have the intention to remain in this field for 30 years. The flexibility, freedom, and opportunities innate to their positions played a significant role in this attitude. While teaching was a significant component of their job duties, it was not their only responsibility. These educators were also responsible for a wide spectrum of duties from law enforcement and nature trail maintenance to management and program development. The variability in their job duties made each day different from the next.

The educators were not teaching all day and everyday, thus there was time for reflection on class presentations and communicating with colleagues. Depending on the institution, multiple educators at one institution were teaching the same lesson plan or subject matter with the same parameters and criteria. Consequently, they could share strategies, or work on improving their approaches with the help of colleagues undergoing similar experiences. In addition, their personal interests were in science and nature, and the settings in which they worked specialized in this. As a result, materials and resources that further supported their interests surrounded them.

Furthermore, professional development in science was continually encouraged and made available to non-formal educators. Some non-formal settings went to the extent of periodically calling forth content experts to educate their staff. More commonly, continued science education arose from the non-formal educators' personal interest and curiosity

coupled with the resources and time available for them to pursue such inquiries at work. The non-formal settings were locations intended to educate, encourage inquiry, and nurture curiosity in a more casual, self-paced format. Thus the non-formal educators were immersed in an environment that allowed for their continuing education in science. However, there was no report of such professional development in education and pedagogy.

Physical participation was used to create lasting memories

In congruence with findings in the literature pertaining to active participation, non-formal educators incorporated physical opportunities in their lessons as a way to establish a more memorable lesson. Although the participation was predominantly sensory-oriented in a show-and-tell lesson plan format (Table 3), the intention was to create memories that associated science with enjoyment and doable activities. Their belief that physical activities generated a lasting memory of the events that took place in the lesson, and the content and concepts presented was supported by research on teaching and learning in formal classrooms (Glasson, 1989; Renner *et al.*, 1985), as well as explorations at non-formal settings (Flexer & Borun, 1984; Rix & McSorley, 1999; Wright, 1980) .

Considering the levels of cognitive engagement the activities elicited, knowledge acquisition and comprehension were most prevalent (Table 3; Appendix B). Only two of the observed lessons in this study, that required students to gather data, formulate hypotheses, and generate conclusions, had opportunities for higher order thinking. Cognitive domains elicited in activities of the remaining thirteen classes primarily asked for knowledge acquisition and comprehension. These were the show-and-tell format classes that featured

sensory operations for students to engage in that were not necessarily opportunities readily available in the classroom. These included touching and observing more than 10 different rock types and live specimens from four major animal groups , as well as collecting specimens to be identified by the educator.

However, sensory experiences in all these lessons were brief and controlled by the educator. Sensory operations invariably took place after the educator led a dialogue about the artifact, object, animal, or equipment. The items were either held up to the group or brought around to each individual student in a circle for closer examination and touchable opportunity. In one class, each pair of students was given a set of specimens with which to work. Meanwhile the educator led the exploration of each specimen, speeding through the lesson in order to “cover” all of the specimens in the box. Although the sensory opportunities were potentially hands-on because students were able to touch the item, they were not “minds-on” as they did not allot time and opportunity for students to interact with, explore, or inquire about the items. Thus these lesson plan designs were not consistent with what is supported in the *National Science Education Standards* (NSES, NRC, 1996). Even though students were given opportunities to make observations, they were brief and rushed. There was no time for students to generate questions and plan their own investigations. The same constraints that bound overall design of the lesson plans could also be responsible for these brisk tactile experiences. Nonetheless, if the overall purpose of the physical activity was to simply create a memory, touching a snake or tarantula could leave a lasting impression upon the students.

Teaching practices and programs were teacher-centered in nature

Pedagogical approach

The teaching practices of these non-formal educators were not always in consonance with effective classroom teaching published in the literature. Research demonstrates that student-teacher verbal interaction is an integral component to teaching with understanding by allowing the educators to monitor student comprehension (Goodrum, 1987; Tobin & Fraser, 1990; Tobin & Garnett, 1988; Tobin *et al.*, 1994). In using verbal behavior effectively, exemplary science teachers use questions to stimulate student thought, probe student responses for elaboration and clarification, and follow through by using student comments to expand upon ideas. Roth (1996), van Zee *et al.* (2001), and others supported these findings. They pointed out that teacher questions were most effective when they were connected with student comments and experiences, and that remaining silent and listening carefully while students spoke provided invaluable insight to how and what students were thinking.

While the educators in this study posed many questions, they were predominantly Yes/No or Fill-in-the-Blank questions that prompted memory recall. In addition, these educators rarely pursued student comments or questions with requests for elaboration or clarification. Their purpose for asking questions was primarily to mentally engage students in the lesson with the idea that such teacher behavior would prompt students to reflect on the subject-matter and “learn something.” The non-formal educators only engaged in the first part of effective verbal behavior notable among exemplary science teachers. The overall assumption was that students generated connections between concepts and content if provided the necessary information and prompts, which was consistent with their belief that

teaching was sharing of information, and the educator played the role of information provider in the learning process. This philosophy was not in accordance with teaching practices suggested by the *NSES* (NRC, 1996).

Most of these non-formal educators placed the pedagogue at the center of the teaching and learning process, and believed that the teacher played the role of information provider. This is not necessarily unique to non-formal educators. In an extensive study of the beliefs and behavior of beginning teachers, Simmons, Emory, Carter, Coker, Finnegan, Crockett, Richardson, Yager, Craven, Tillotson, Brunkhorst, Tweist, Hossain, Gallagher, Duggan-Haas, Parker, Cajas, Alshannag, McGlammery, Krockover, Adams, Spector, LaPorta, James, Rearden, and Labudaua (1999) reported that less than a quarter of the teachers in their study indicated a student-centered learning philosophy and teaching style.

Although contradictory to research describing effective teaching (Penick, 1976; Roth, 1996; Tobin & Fraser, 1990; van Zee *et al.*, 2001), the viewpoint held by non-formal educators could be driven by the constraints that bound science classes at non-formal settings. As Karen and Caitlin pointed out, the students participated in these classes as a one-time experience for 30 to 60 minutes. The non-formal educators did not necessarily know what knowledge students brought with them, how their lesson could correspond with what students were currently learning, nor were they able to follow up on what students did with the concepts and content presented to them in that ephemeral encounter. Consequently, these non-formal educators focused on disseminating information via experiences that created worthwhile memories.

Program and lesson plan design

The lesson plan design of the majority of classes observed at these eight non-formal settings further reflected a teacher-centered philosophy. Thirteen of the fifteen classes observed followed a show-and-tell format. In nine of these classes, taught in both the museums and nature centers, the lesson plan centered on a collection of items that included objects, artifacts, specimens, and/or equipment. The educators introduced a content area and led a discussion, showed an item related to the dialogue, and then moved on to the next item once dialogue and display by the teacher were complete. Students were usually allowed to touch and examine the item closer to further reinforce what was said, but this did not necessarily take place immediately following discussion about the item. The remaining four classes were created in much the same show-and-tell design, except they added an experiential element by requiring students to collect the specimens to be talked about and shown. Nevertheless, the educator remained at the focal point of the entire lesson. This was consistent with these non-formal educators' teaching beliefs and behaviors, as well as the nature of these science programs at non-formal settings.

The initial topic and inquiries of the classes in which students were participating were not necessarily driven by student interest. The classroom teachers determined the subject-matter of the lesson when they scheduled the class based on their needs and perception of student interest. Meanwhile, the non-formal educators decided on the experiences and activities they desired to convey in order to arrive at the general goals they had set forth prior to meeting the students. Thus these science classes offered at non-formal settings were not

designed as student-centered programs, which was consistent with the non-formal educators' belief and behavior that teaching was a teacher-centered event.

However, this could be attributed to the desire of educators at non-formal settings to accommodate the needs of their target audience in an attempt to remain competitive as a field trip destination. Non-formal settings were institutions established for the education of the general public, and they served a broad geographic range of schools and students. Classroom teachers usually had a choice among the non-formal settings in their community that best met their needs. One requirement to justify a class trip to an non-formal setting was the ability of the setting to meet state science standards. Therefore, design of the lessons needed to incorporate content and concepts in the science standards followed by the classroom teachers. Consequently, fulfilling these concerns to attract classroom teachers could direct the design of these classes away from the learner.

Apprenticeship-style teacher education for non-formal educators

Teaching preparation for individuals instructing at non-formal settings in this study primarily consisted of past experience, peer observations, and introduction to program outlines. The non-formal educators gained their teaching experience as a result of teaching at different non-formal settings. They built their pedagogical style and belief system from work and personal experience, and from veteran educators in their field. On the occasion that an institution prepared their educators prior to teaching, that format essentially consisted of learning the predetermined class outlines and observing seasoned educators. Consequently, most non-formal educators were generally educated informally about teaching science at

non-traditional settings. This method of teacher education could be likened to an apprenticeship, except there was not necessarily a master to guide or mentor the apprentice. The educators were learning teaching skills while they taught and observed each other teach. There was continued dialogue on improving the lesson plan design, which was influenced by the evolving teaching styles of the educators.

Apprenticeships have been used as a valuable teaching tool in many disciplines for centuries. Though traditionally used in vocational trades, internships and student teaching could be variations on this same principle. Harland (2001) described an apprenticeship-style pre-service teacher education program coupled with regular coursework and research requirements for doctoral candidates in the United Kingdom. He reported his experience from this two-year experimental program in the U. K. to provide teaching experience for their doctoral students interested in pursuing a career in academia. Though the program was intended to connect the apparent dichotomy between teaching and research, the experience doctoral students gained from teaching opportunities made them more competitive for academic positions and gave them confidence in teaching.

Apprenticeships gave the learner hands on experience, and practical application of what was learned. In the case of student teaching for pre-service undergraduates, the learning experience was brief, but framed within a formal curriculum that educated the individual about teaching and learning. Presently preparation of non-formal educators provide only the student-teaching component of teacher education. The educator, however, informally created this, and a singular mentor teacher was not necessarily present. While content area knowledge was an essential component to effective teaching (Tobin & Garnett, 1988),

extensive research and requirements for teacher education suggest that there was more to teaching than just knowing the “facts.” Additionally, if content area knowledge was the single most important factor in teaching, then it would not be necessary to require the new lineage of classroom teachers to pursue their teaching license. Therefore, non-formal educators teaching thousands of students each year could benefit from more formal education on teaching and learning.

While science knowledge and interest were consistent and prominent among the educators teaching at these eight non-formal (Table 2), teaching certifications, formal teaching experience, and even education coursework was not. This could be compared with the growing number of science teachers entering formal classroom settings with a collegiate background in the sciences, but no professional education courses. Holding only science, or content area credentials, such individuals have been entering school rooms to meet the demand for teachers all across the nation (North Carolina Department of Public Instruction, 1998; United States Department of Education, 1998). Although obligated to enter into an alternative program to obtain their teaching license, this new lineage of teachers entering the classroom and beginning teaching without formal education is growing in number (Barnes, Salmon, & Wale, 1989; Holley, 2002). Non-formal educators have not been required to hold or pursue teaching licenses. However, parameters of their job duties gave non-formal educators the added advantage of peer observations and collaboration that might not be readily available to alternatively licensed teachers.

CHAPTER 6. IMPLICATIONS & RECOMMENDATIONS

Implications

Educators teaching at informal settings interact with thousands of school age children each year. While the interactions are short-lived, they are long-lasting due to the memories they create. Many of us can attest to this with our personal memories and recollections of the field trips we experienced as students. These memories can nurture an attitude towards the subject matter, and provide a concrete example with which to associate content and concepts as we progress through our education. However, this does not mean that the attitude evolving within us necessarily reflects the intended goals. Likewise, the understanding we construct might not be the canonical interpretation in the scientific community.

Renner *et al.* (1988) stated that allowing students to invent their own understanding from discovery experiences without guidance was inefficient, and led to development of misconceptions. Additionally, Linn's work on free-choice learning (Linn, 1980; Linn *et al.*, 1977; Linn & Thier, 1975; Rice & Linn, 1978) asserted that students do not make cognitive gains on their own. While they engaged in the activities, without the presence of an educator, students did not necessarily challenge themselves mentally. The extensive research on teacher role, effective teaching practices, teacher attitude, and even the need to educate teachers on how to teach suggests that the educator plays a significant role in the understanding students constructed, and the attitude they generated. In science classes at informal settings, the classroom teacher handed over instruction to the non-formal educator. Consequently, despite the brevity of the lesson, these educators were responsible for the teaching and learning that took place.

As the leading authority in their classes, educators teaching at informal settings influence their learners in cognitive and affective ways. The quantity and quality of stimuli they provide coupled with the ephemeral nature of these classes intensifies that effect. The non-formal educators' rapport and teaching approach can impact the memory their students generate as much as the physical experiences and activities of the lesson. Thus, understanding how non-formal educators teach science is important in order to maximize student gains from experiences at informal settings.

Major findings from this exploratory study reveal that although there are constraints unique to science instruction at informal settings, they share teaching and learning philosophies, goals, and obstacles with classroom teachers. Much like formal educators, forethought in lesson plan design and instruction are given to meet their personal goals, state and national science standards, and address the needs of their audience. There is a desire for students to make cognitive and affective gains, and the shared belief that active physical and mental participation is essential to science learning. However, teacher education for those interested in teaching in non-traditional settings is minimal.

The current state of teacher education for non-formal educators takes place informally, and focuses primarily on experience. However, if value is placed on educating those interested in teaching regarding learning styles and effective ways of instructing, then why is this not carried over to educators teaching in informal settings? Although the lessons are short and singular, non-formal educators teach science lessons to thousands of students annually. Flexer and Borun's study (1984) revealed that instruction at an informal setting that complemented the exhibits improved students' comprehension and application of the

concepts. There is evidence that educating classroom teachers using informal settings in their curriculum improved teacher attitude towards field trips as well as student gains from those experiences (Chesebrough, 1994; Olson *et al.*, 2001; Smith *et al.*, 1998). The urgency to improve science instruction in tandem with increased recognition of science at informal settings to supplement school science calls for attention to be paid to the quality and teaching needs of non-formal educators.

Recommendations

Findings from this exploratory study suggest similarities in teaching belief and behavior among non-formal and formal educators. However, there is currently minimal support for non-formal educators and programs to support them in academia. While some graduate programs do exist, they primarily focus on outdoor education, and art and history museum education. Thus the following recommendations are made in an attempt to shed more light on the learning potential at informal settings:

- Pre-service and in-service opportunities in institutions of higher learning for non-formal educators. Knowing some of the existing constraints and teacher behavior, a more structured and systematic teacher education curriculum should be made available to address the teaching needs of non-formal educators, as well as introduce them to the teaching and learning styles established in the literature. This could begin as 2-day workshops introducing the need for pedagogy, and evolving into graduate and undergraduate teacher education programs, complete with apprenticeships.
- Professional development opportunities for non-formal educators to learn to incorporate inquiry methods when appropriate in lesson plans. Lesson plan designs should be

reexamined and rewritten to allow for more student-centered instruction. Although these science classes are inherently teacher-centered because classroom teachers choose the class from a predetermined list for their students, design of the lesson should be written in a way that allots more time for exploration. The learning cycle format has been consistently shown for three decades to encourage cognitive growth. Its feasibility in informal settings should be tested.

- Aside from content correlation with the *National Science Education Standards* (NSES), teaching practices of non-formal educators should also correlate with NSES. Currently, non-formal educators are primarily concerned with meeting science content standards in order to accommodate the needs of their target audience. However, their teaching practices do not reflect the student-centered instructional method that is also emphasized in these standards
- Taking the current apprenticeship for new non-formal educators one step further, these educators should be mentored by veteran educators or teacher educators, or paired with formal and non-formal master teachers or doctoral students. As a result, non-formal educators can continue the collaboration they receive from their peers, and receive guidance from experienced educators.

Further Research

As with all research, findings from this exploratory study also raised more questions to be answered:

- What cognitive and affective impact do these science lessons or programs have on students?
- Is a learning cycle lesson plan design feasible and productive in informal settings?
When is inquiry feasible?
- How should a teacher education program to address needs of non-formal educators be designed, and correlated with existing teacher education programs?

APPENDICES

Appendix A
Modified SATIC* Coding Sheet

Teacher: _____ Course: _____ Date: _____

Teacher Behaviors		Total
<i>Initiatory (talking)</i>		
1. Lectures or gives directions		
2. Makes statement or asks rhetorical question		
<i>Initiatory (questioning)</i>		
3. a) yes/no question		
b) short-answer question		
c) thought-provoking short-answer question		
4. Extended-answer question		
<i>Responding (teacher-centered)</i>		
5. Rejects student comment		
6. Acknowledges student comment		
7. Confirms student comment		
8. Repeats student comment		
9. Clarifies or interprets what student said		
10. Answers student question		
<i>Responding (student-centered)</i>		
11. Asks student to clarify or elaborate		
12. Uses student question or idea		
<i>Non-verbal Behaviors</i>		
13. a) Inappropriate wait-time I		
b) Inappropriate wait-time II		
15. Annoying mannerisms		

* A teacher behavior assessment devised by Dorothy M. Schlitt and Michael Abraham (modified by Michael P. Clough)

Appendix B

Modified SATIC Addendum 1 – Description and rationale for cognitive levels elicited for student participation.

Code	Name	Description	Rationale
PARTICIPATION			
A	ACTION	Holds an object; raises arm as in for counting; stands; partaking in a task simply to do something without having to observe, analyze, or judge, e.g. shake a bottle, stir mixture, or throw a ball	While the students may be actively taking part in the lesson, their involvement does not require any mental participation. Simple student participation can range from completing a task assigned by the instructor without explanation as to the purpose, to holding an object for the class to see while the instructor discusses the object or concept in detail.
B	SENSORY	Touch an object to experience what it feels like; make careful observation of an object or experiment	Such operations engage students in the knowledge and comprehension cognitive domains classified by Bloom et al. (1956). In touching and observing, students are advised to recall stored knowledge to specify what they feel and see. In their comprehension of the object, students are able to interpret what they sense and witness without necessarily relating it to other material or see its fullest implications. Bloom et al. classifies this as the lowest level of understanding.
C	EXPERIMENT	Manipulate and/or experiment with objects and collect data	Students given the opportunity to explore, experiment and manipulate objects as they create their own understanding of a concept tend to retain the information taught, develop better reasoning skills (Marek & Methven, 1991), and demonstrate higher thinking capabilities (Boylan, 1988; Linn & Thier, 1975). Through the manipulations and experimentation, learners engage in higher levels of understanding as they are granted the freedom to apply and analyze (Bloom et al., 1956).

Appendix C

HOW I PERCEIVE MY OWN TEACHING.**How would you rate yourself when it comes to your own teaching?****USE OF LESSON PLAN/PROGRAM OUTLINE**

Lesson plan is seen as a vehicle; modification and elaboration are made when and where appropriate.

Literal adherence to lesson plan/program outline; lesson plans set up what class **must** do. Teaches a lesson plan rather than the students. Ignores pertinent related ideas of students.

Flexible

Rigid

1

2

3

4

5

Display a variety of suitable teaching methods, e.g., inductive questioning, dramatization, role playing etc.

Rely one or two teaching methods.

Flexible

Rigid

1

2

3

4

5

TEACHING GOAL

Teaching for inquiry; interested in means as well as ends; explores where the students got off track. Can flexibly handle unfamiliar content.

Emphasis on ends; assumes a right answer that must be attained the teachers way. Deals ineffectively with unfamiliar content.

Flexible

Rigid

1

2

3

4

5

OVERALL RATING OF ATTITUDE

Use a variety of methods, uses flexibility in implementing plans, and employs inquiry for effective teaching.

Use few teaching methods, adheres to one or two formats in planning lessons and employs a prescriptive rather than inquiry teaching approach.

Flexible

Rigid

1

2

3

4

5

HOW I PERCEIVE MY OWN TEACHING.

How would you rate yourself when it comes to your attitude towards the students?

RESPONSIVENESS

Responsiveness to the class see, listen, and respond to discipline problems, inattention; learning difficulties; students' need for new knowledge and creativity.

Doesn't register "cues;" children's problems are tuned out. Call on bright students' too often and does not recognize when to call on the other children.

Flexible

Rigid

1

2

3

4

5

ATTITUDE

View students as a partner in educational process.

Look down on student; patronizes student intellectually

Flexible

Rigid

1

2

3

4

5

JUDGMENTS

Withhold judgments about students in ability and performance until I have adequate evidence. Use a balance of positive rewards and constructive criticism.

Make quick judgments and am unlikely to look for contradictory evidence. May tend to employ negative criticism, i.e. pick the students' answers apart.

Flexible

Rigid

1

2

3

4

5

OVERALL RATING FOR ATTITUDE TOWARD THE STUDENT AS A PERSON

Recognize important signals from the class; see student as having a substantive role; make judgments carefully.

Not sensitive to feedback. Look down on student, and make snap and categorical judgments.

Flexible

Rigid

1

2

3

4

5

HOW I PERCEIVE MY OWN TEACHING.

How would you rate each of the following:	very important	important	moderately unimportant
Listen to and response to students' learning needs and difficulties			
View students as reluctant learners who learn best from constructive criticism.			
Engage students as participants in educational process.			
Withhold judgments about students' ability and performance until there is adequate evidence.			
Literally adhering to the lesson plan as a guide for what the class will do.			
Rely on one or two teaching methods for the bulk of instruction			
Impart knowledge and skills			
View teaching and learning as a discovery process			
What is your teaching background? (How many years having you taught, and where?)			
What is your science background?			
What is your education background?			

Appendix D

Semi-structured, open-ended interview protocol.

How do you think children learn?

- What is your role as the educator in this learning process?
- What can you as the educator do to facilitate this?
- What can you do to hinder this?

What affect do these programs have on students?

- What affect do you as the educator with whom these students interact have on their learning experience?
- How does your teaching approach affect the students and their experience?

What is the goal of this program?

- What are you trying to communicate when you teach this program?
- What kind of preparation/training did you receive in order to teach this and other programs like this?
- How often do you teach these programs?
- What was your involvement in developing the program? If minimal, what would you do differently?

Appendix E

Researcher's interpretations of educators' science learning and teaching beliefs from interview and survey responses as a result of categories generated from constant comparison of their comments. Educators' reactions submitted in writing.

Julia (M1).

Learning is an active process that requires physical participation, and can take place anywhere and at any age. However, an interest in learning is necessary in order for learning to take place. Different learners learn differently, thus repetition of the concept with varying information and teaching style reinforces the scientific concepts.

Teaching is more than just conveying facts, although it is a goal. Giving students the opportunity to do science nurtures critical thinking skills, and makes learning fun and interesting. This is critical since learning cannot take place without interest in the subject matter. As a result, positive memories about science and learning are generated, and students gain confidence that science is doable by them. This would influence their life decisions to include science. Over time confidence and interest in science, coupled with continued inclusion of science in their life and retention of the concepts and information.

Karen (M2).

Learning is an active process. Physically participating in activities opens for mental engagement by prompting learners to ask questions about the concepts featured in the activities. However, guidance from the educator is necessary in order for learners to make the connection between the physical activities in which they are partaking, and the mental engagement necessary for learning the concept. Since there is an intended learning goal, and time constraints in these informal settings, learning cannot be completely controlled by the students. Students should be given the opportunity to explore, but the educator controls when and how much exploring takes place.

Teaching is providing opportunities for those physical experiences that encourage mental participation. It also requires interacting with learners to help them make connections between what they see, touch, and do and the scientific concepts the questions generated by the students. This approach brings forth misconceptions students may have for the educators to address. Students are thus involved in the scientific process, and are shown that science is doable by them. As a result, students gain confidence in doing science, and hopefully gain interest in science as well.

Teaching science in this way creates positive worthwhile memories about science and learning that can influence the student's decisions in life.

In the process of teaching, the educator's attitude and behavior is important. The educator models her interest and confidence in doing and learning science in her lesson plans, teaching style, and attitude in the class. The educator must also assess and be aware of the cognitive achievement and limitations of for students, as well as their interest in learning.

Caitlin (M3).

Learning requires physically partaking in activities. Students listened to facts and descriptions, and then engage in physical activities such as touching, observing, and doing in order to reinforce the information shared. In this way students are engaged in the learning process.

Thus teaching is sharing information, and providing physical activities to reinforce that information. The educator facilitates the learning process by providing these verification activities for the learner to generate their own understanding. This requires the educators to assess and be aware of students' cognitive abilities and comfort zones. This teaching approach creates worthwhile memories about science, and nurtures nature appreciation. The educator changes student misconceptions about organisms in the natural environment by role modeling of appropriate behavior, and thus generating a more positive memory upon which the learner can recall.

Ioana (M4).

Learning requires physical and mental participation. Physical activities that allow students to interact with, touch, and manipulate objects do not necessarily lead to mental engagement and subsequently learning. Learners need to partake in discussions and generate questions in order to mentally engage in learning. Having a clear purpose to a physical activity requires the student to focus on the intended learning goal of the activity, and thus would prompt mental participation.

Teaching is conveying facts and information by providing physical activities that encourage mental participation. The educator guides the transition from physical participation to mental engagement by asking questions. Questions make learners think about what they are doing. This approach creates a positive memory associated with science, and hopefully nurture interest in the subject matter. The generated memory from the activity could also trigger content matter from the class, and thus strengthening retention of facts and information.

Annie (NC1).

Learning requires listening and participating in physical activities in order to gain more information about a subject matter. Hands on activities such as doing, manipulating, experimenting, observing, and touching creates a memory associated with the information. Listening prompts learner to ask questions became more information and generate an understanding. As learners gain more information from

listening and physically partaking in activities, they make connections between the information and concepts.

Teaching is providing the information for the learner to make the necessary connections. It involves using different teaching approaches to communicate the information. Using analogies in talks provide concrete examples for learners to see it abstract science concepts. As a result, memories are created that can trigger recall of content, and provide positive experiences associated with nature appreciation.

Melanie (NC2).

Learning requires physical participation and mental involvement. Physical activities such as games and hands on activities provide concrete examples to abstract concepts, and thus help learners make connections between concepts. They also create strong positive memories about science and learning, which insure retention of information, and it interest in science. When given the opportunity students will engage in self discovery in order to gain more information Self discovery also aids retention of information because students generate a strong memory of the information simply because they discovered it on their own.

Teaching is providing the physical activities and encouraging mental engagement via Teacher questions. Students engage mentally when they are asked questions. This is

because questions require them to think about what they know and don't know about the subject matter, and generate an explanation that they will be more likely to remember.

John (NC3).

Learning is an active process that includes physical and mental participation. Students learn by physically partaking in activities that encourage them to use their senses. They also learn when they ask questions about the information given they are experiencing.

Teaching is providing hands-on activities that encourage sensory experiences. Hands on activities include visual aids drawings, demonstrations, role playing, and being outdoors. They make learning science enjoyable and create a positive worthwhile memories about science. Encouraging student questions from the information given helps to eliminate distractions, and involve the students in the learning process. This creates a worthwhile memory aids in the retention of the information presented.

Calvin (NC4).

Learning is a physical participation and mental involvement to remember the information. Tangible objects create concrete examples to aid in understanding abstract concepts. Mental engagement involves the learner asking questions about concepts and information presented to them.

Teaching is telling information and encouraging mental engagement. The educator uses objects and questions to create concrete examples for students to make the necessary connections. This also creates worthwhile memories about science, nature, and learning. It is important that the educator is aware of his students' interests and cognitive abilities because learning cannot take place if learners are not interested, or if the information presented is beyond or below the learners' level of comprehension.

Appendix F

Follow-up questions that addressed issues salient in all eight interviews. Submitted in writing along with interpretations in Appendix E.

- Is there a difference between an educator, a teacher, and an interpreter? If so, please explain the differences.
- Rank in order of importance as your goal in teaching these programs to school groups:
 - Remembering content
 - General understanding of concepts
 - Appreciation of science and nature of
 - Interest in science and nature
 - Developing skills
- Your analogy of teaching and learning. The role of the teacher in the learning process is analogous to ...

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