MEASURING CHANGES IN CONTENT COMPREHENSION AND ATTITUDES TOWARD INFORMAL SCIENCE LEARNING FROM THREE NEW LEARNING MODULES IMPLEMENTED AT THE TRINITY RIVER AUDUBON CENTER

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DEDICATION

This thesis is dedicated to my family, friends, colleagues, and mentors, especially my parents, Annie and Pete, for encouraging me to be who I am and to follow my passions, my siblings, Emily and Evan, for always believing in me, Thomas Ales for his patience and support, Reta “Smiddy” Foreman for being my most enthusiastic cheerleader and a phenomenal mentor in what it means to excel as an instructor, and all my former students who taught me so much more than I could ever teach them.

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ABSTRACT

SARAH E. WEHNER

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Informal science learning has the potential to engage, entertain, and educate learners of all demographics, and its merits have been increasingly recognized as a vital part of science education. This study sought to create and implement three new and unique field trip modules at the Trinity River Audubon Center in Dallas, Texas. Participants who embarked upon the field trip were assessed for enhanced content knowledge and improved attitudes toward learning in informal science learning environments. No statistically significant changes in content or attitude scores were detected, though the preliminary data collected was insufficient to confidently accept nor reject the proposed hypotheses.

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CHAPTER I

INTRODUCTION

For more than 200 years, students and educators have explored venues outside traditional classrooms in order to facilitate learning, but only in the past several decades has the importance of these interactions been scrutinized by educators and curriculum developers (NRC 2009, 14-15; Fenichel and Schweingruber 2010, xi). Science learning that occurs outside the classroom is termed *informal science learning*.

Environments in which individuals experience informal science learning are not limited only to *designed settings* such as museums, planetariums, zoos, aquariums, botanical gardens, and nature centers, but can also include more common places such as libraries, parks, and nature itself. Activities such as gardening, hiking, fishing, Girl and Boy Scouts, and even family discussions about science can all facilitate informal science learning (NRC 2009 14-15, Fenichel and Schweingruber 2010, xi). There are also many games that are founded on the principles of science: “Kerbal Space Program” and “Poly Bridge” are just two examples of games in which one solves problems while obeying the laws of physics. “Plague, Inc.” is a game in which one can design her own disease and attempt to exterminate the human race. Any of those situations provides a hands-on approach to learning science instead of a structured, “one-size-fits-all,” curriculum-driven, *formal* classroom setting (Hung, Lee, and Lim 2012, 1077).

Formal Learning and Informal Learning

Informal education contrasts strongly with *formal*, or *traditional*, education. In order to understand the differences between formal and informal education, the underlying concepts must be addressed. Formal learning most often occurs within a classroom in which students adhere to a prescribed curriculum and are assessed to gauge their progress. Students are motivated *extrinsically* to perform by the requirements defined by the state or national government rather than *intrinsically* by their own desire to learn (Eshach 2007, 174; Hung, Lee, and Lim 2012, 1072; Savic and Kashef 2013, 994). The increasing body of research regarding formal science learning versus informal science learning has revealed many shortcomings of traditional education. The most important of those shortcomings, perhaps, is that memorization of facts and vocabulary words does not form a cohesive picture of how science works in the natural world or how to think as scientists do (Holmes 2009, 264). In order to combat rote learning, educators must provide learners with the *tools* needed to think critically, rather than simply providing all the answers (NSTA 2003).

Little authentic learning occurs when science teaching focuses solely on the question, “What is it?” without including the questions, “How does it work?” and, “Why?” as well. *Authentic learning* occurs when students receive cohesive, contextualized, meaningful, and applicable knowledge of scientific phenomena, and not merely facts about them (Bain 2014; Hung, Lee, and Lim 2012, 1072, 1083; Mohr-

Schroeder et al. 2014, 293; Schreiber et al. 2013, 463-464; Swan, Hofer, and Swan 2011, 115, Wiggins and McTighe 2005, 3). The nature of science necessitates that students spend time *doing* science by engaging in hands-on activities. Indeed, Texas mandates that all secondary school students (sixth through twelfth grades) spend a minimum of 40% of their science course time performing laboratory and field investigations (Pickhardt 2015; TEA 2010a, 2010b, and 2010c). Whether authentic learning occurs during those investigations is difficult to measure because of both the nature of how activities are designed and how student learning is assessed in public schools (Hung, Lee, and Lim 2013, 1074; Wiggins and McTighe 2005, 3).

According to Wiggins and McTighe (2005, 16), traditional instructional design does little to provide authentic learning experiences for students. Traditional design has two distinct types: coverage-focused and activity-focused. Coverage-focused instruction aims to provide as many pieces of information as possible without necessarily providing context. Activity-focused instruction may be thought of as a more effective option, and it certainly can be, but special attention must be paid to establishing attainable learning objectives with respect to the activities (Wiggins and McTighe 2005, 16). Both of these educational designs often do not address three important questions: “What is important?” “What is the point?” and “How will this experience facilitate actual learning?” (Wiggins and McTighe 2005, 3). Though students may find activities engaging and fun, they may think the purpose of the activity is the *activity itself* rather than the *meaning* behind the activities. Students often ask the question, “What is the point of learning this?” Though it may seem impertinent, it is a valid question—the purpose, meaning, and application of any lesson should be explicit. When the meaning behind an activity cannot be derived, it is considered to be “hands-on without being minds-on” (Wiggins and McTighe 2005, 16-17). These activities may be considered informal within a formal setting, but students remain overshadowed by their academic requirements and often have little intrinsic motivation for learning.

American students often dislike science due to too much memorization, which can be tedious, and they find science mathematics difficult (Holmes 2011, 264). Generally, attitudes toward science decline as students progress through secondary school (Holmes 2011, 264). Recent data, however, show that more students than ever are enrolling in advanced placement (AP) Science, Technology, Engineering, and Mathematics (STEM) courses; in 2014 approximately 8.9% of high school students enrolled in AP STEM courses compared to only 3.5% in 2003 (College Board 2004, 2014; USCB 2004, 2014). In a study conducted from 1988 to 2000, researchers concluded that individuals who expressed interest in a career in science in eighth grade were 3.4 times more likely to earn a science baccalaureate degree than those who did not express interest in science in eighth grade when controlling for academic scores (Sparks 2011; Tai, Liu, Maltese, and Fan 2006, 1143). This suggests that interest, not academic achievement, plays a major role in whether students will pursue a career in science.

One of the persisting issues in science education is how to engage students in learning science (Fenichel and Schweingruber 2010; Holmes 2011, 264; NRC 2009). Informal learning experiences may provide opportunities to pique students' curiosity in science (Holmes 2011; Kisiel 2006, 48; NRC 2009, 128; NSTA 2012; Uitto 2006, 128).

Objectives of Informal Science Learning

The National Research Council (2009, 4) devised a set of six objectives of informal science learning called, "Six Strands of Informal Science Learning." Because informal learning does not mandate participation, the strands describe the development of individuals who cultivate their own scientific identity by sustained engagement with informal learning environments (NRC 2009, 46-47). These strands are sequential, though interdependent, goals of science learning (NRC 2009, 43).

Table 1. Six strands of informal science learning

Strand	Keyword	Description
1	Engage	become interested, curious, motivated to learn, and develop emotional engagement
2	Understand	learn, remember, and apply concepts, models, and arguments related to science
3	Explore	question, manipulate, test, observe, and evaluate phenomena to make sense of the natural world
4	Reflect	consider science as a way of thinking and how understanding of phenomena change over time
5	Practice	participate in scientific activities, master language and tools
6	Identify	consider oneself a scientific learner who knows, uses, and contributes to science

Source: Adapted from NRC 2009 box 2-2, 43.

Strand 1: Engage

The first goal of informal learning is to interest individuals in scientific concepts. Interest promotes engagement and motivation to learn (Dierks, Höffler, and Parchmann 2014, 98; Sparks, 2011). Curiosity is a motivating force behind what Dr. Ken Bain calls "deep learning." Deep learning addresses not only the meaning, but the implications, applications, and possibilities relating to phenomena (Bain 2014). Informal learning environments provide opportunities in which people of a variety of ages and knowledge levels can broaden and deepen their understanding of scientific concepts (NSTA 2012; Yoon et al. 2012, 520). Some of the reasons informal environments are so accessible are due to the variety of information available and the manner of presentation. Informal learning venues—designed or otherwise—allow students to be temporarily freed from the structured, curriculum-driven classroom setting. This freedom may automatically increase interest in learning due to its deviation from formal instruction (Holmes 2011, 265; Hung, Lee, and Lim 2012, 1077). Examples of non-designed activities that can interest individuals in the natural world (biology in particular) include watching documentaries and television shows, reading nature books and magazines, gardening, camping, and hiking (Uitto et al. 2006, 128).

There is a general consensus among those who study interest and motivation that there are two major types of interest: *situational interest* and *individual interest*. Situational interest is an emotional, temporary, and stimulus-induced response to a special situation (Dierks, Höffler, and Parchmann 2014, 98; Hidi and Renniger 2006, 113; Uitto et al. 2006, 124). Informal learning venues often elicit these responses due to the novelty of the situation, which is termed the *novelty effect* (Holmes 2011) and can increase interest, attention, focus, and motivation (Hidi and Renniger 2006, 113; Holmes 2011). Situational interest can eventually lead to individual interest, which usually develops gradually over a period of time. Individual interest is thought of more as a long-term predisposition, attraction, or personal orientation toward behaviors, objects, subjects, or situations (Dierks, Höffler, and Parchmann 2014, 98; Hidi and Renniger 2006, 113; Uitto et al. 2006, 124). Individual interest often influences academic motivation, effort, and persistence, and is frequently relevant to study or career choices (Dierks, Höffler, and Parchmann 2014, 98; Hidi and Renniger 2006, 113). Individual interest in eighth grade was likely the major contributing factor to the participants in the long-term study by Tai, Liu, Maltese, and Fan (2006) choosing to pursue careers in science.

Strands 2 and 3: Understand and Explore

In many informal learning situations understanding and exploration are concurrent. One of the main features that attracts young people to informal learning settings is a high level of exploratory freedom. Rarely are children permitted to touch and play with everything within reach, so a science museum, for example, represents a haven of sensory input that can have immense value in perpetuating science interest and knowledge by allowing them to "make sense of the messiness" (Holmes 2011; Hung, Lee, and Lim 2012, 1078). These interactions also facilitate the processing of information so related tasks may be performed instinctually and automatically (Holmes 2011).

Inquiry is the process by which individuals develop understanding of scientific principles through asking questions and using evidence to answer them (Colburn 2003, 19-21; NSTA 2004). Children naturally seek answers through inquiry: they explore their surroundings, ask questions, and attempt to answer them. This method of interest-triggered learning creates authentic, contextualized experiences on which they can build knowledge and understanding (NSTA 2004; Uitto et al. 2006, 124). The tactile experiences children have with informal venue exhibits often provide enough information to understand principles underlying scientific phenomena without having previously received guidance or explanation as to what they are or even what they are called (Yoon et al. 2011). Learning "the facts" *after* a personal experience with phenomena evokes much deeper and more meaningful learning experiences than receiving general knowledge prior to a hands-on experience (Bartley 2009, 93; Holmes 2011, 273; NRC 2009; Swan, Hofer, and Swan 2011, 115-116, Yoon et al. 2011). This process can also be called *discovery learning*: we learn best through the ideas we create via exploring and discovering (Colburn 2003, 13-14).

The difference between traditional learning and inquiry-based learning can be described by the terms *explicit knowledge* and *tacit knowledge*. Explicit knowledge is based upon generalized information that can be found in books and other media. Tacit knowledge, however, involves the creation of contextualized experiences similar to those authentic learning induces (Hung, Lee, and Lim 2012, 1073). In order for productive learning to occur, the opportunity for students to create explicit artifacts must be provided (Hung, Lee, and Lim 2012, 1076). An *artifact* is an object created by a learner that represents an experience (Hung, Lee, and Lim 2012, 1076, 1082). Artifacts can be created during or after learning experiences, and are meant to act as evidence that learning has occurred (Wiggins and McTighe 2005, 2-3). The production of artifacts ensures that an individual acted *within* a discipline, rather than simply knowing *about* the discipline (Hung, Lee, and Lim 2012, 1076). The importance of learning by doing was stated simply: “Knowing transcends explicit knowledge” (Hung, Lee, and Lim 2012, 1074).

Strand 4: Reflect

Thinking about science as a thought process is an example of *metacognition*: thinking about thinking. Over time, individuals who participate in science consistently with informal learning environments may actively engage in metacognition regarding the current understanding of science, often asking the question, “How did we come to know this?” (NRC 2009, 45-46). It is also important that individuals understand that science is a continually growing and changing body of knowledge and that only by continuous engagement and learning about new discoveries can one truly understand a scientific process (NRC 2009, 45-46).

Strand 5: Practice

Scientific practice requires specific tools, language, and social interactions, and each branch of science requires its own set of tools, language, and social interactions (NRC 2009, 46). Informal learning environments encourage individuals to refine their use and mastery of those three aspects of practice, and help to dispel the pervasive and "inaccurate stereotype of the lone scientist working in isolation in a laboratory" (NRC 2009, 46). It may also encourage appreciation of the skills a scientist must develop in order to work, speak, and interact with others their field in order to achieve more thorough understanding of a phenomenon or problem (NRC 2009, 46).

Even those who are not or not yet scientists can use these principles to engage in *citizen science* projects to gather information about the natural world that one or a group of scientists could not achieve alone (Fenichel and Schweingruber 2010, 30). For example, the Cornell Lab of Ornithology in Ithaca, New York has provided research kits for more than 20 years for Project FeederWatch in which citizen participants make observations and collect data about bird habits during the winter (Fenichel and Schweingruber 2010, 22-24). Typical participants of Project FeederWatch were over 50 years old and considered themselves to be intermediate birders—not scientists, but citizens engaging in valuable scientific research (Fenichel and Schweingruber 2010, 23).

Strand 6: Identify

Transfer skills or *transferability* is the most important characteristic that can be developed from informal learning: the ability to not only retain information, but also apply knowledge from one situation to another that requires comprehension and application (Evans et al. 2014, 625; Mayer 2002, 226; Sasson and Cohen 2013, 721; Wiggins and McTighe 2005, 352). These skills may also be applicable in the workforce, regardless whether the career is in a scientific field (Yates, Drewery, and Murdoch-Eaton 2002). Critical thinking skills are applicable and important in all areas of knowledge. Table 2 provides an example of how transfer skills can be applied to a situation.

Table 2. Example of how transfer skills can be applied

Subject	Retention	Transferability
Osmosis and Membrane Permeability	Remembering definitions, knowing the parts of a cell, types of solutions	Examining a mock case study in which a nurse mistakenly provided intravenous drugs to a patient via a drip of pure water instead of saline. Describing why pure water is not an appropriate solution for intravenous medication and what would happen to a patient in the event that mistake were made.

Many educators emphasize that the ultimate objective of informal science learning is development of students' *science identities* (Fenichel and Schweingruber 2010; Hung, Lee and Lim 2012; NRC 2009; NSTA 2003). A science identity can be described as the relationship a person has with science; knowing that he or she learns science, knows about science, and has the capability to contribute to science (NRC 2009, 46-47). With sustained engagement with informal science learning, individuals may gradually experience *enculturation* into science as a way of thinking and knowing, going beyond what can be learned from books and other media to engage in scientific thought, actions, and dialogue (Hung, Lee, and Lim 2012, 1073, NRC 2009, 46-47). The development of a science identity leads to scientific literacy: having a solid foundation of knowledge and concepts upon which further insight can be built and the ability to make informed, conscientious decisions "regarding the stewardship of the planet" and its inhabitants (NSTA 2003). Making science more visible and accessible to the general public through informal learning venues can help individuals make scientifically-sound decisions and improve how the non-scientific community views science (Yoon et al. 2012).

Benefits of Informal Learning Experiences

The Six Strands of Informal Learning describe the ideal outcomes of informal learning experiences, but more specific examples of how informal learning can benefit young people have been described by other authors. A concise summary of informal learning was stated by Yoon et al. (2012, 521): "Learning in informal spaces is fluid, sporadic, social, and participant-driven." Informal learning settings can provide opportunities for learners to explore, create, demonstrate aptitudes or talents, fill gaps in understanding by observation and experimentation, make mistakes, and gain feedback without fear of scholastic retribution (Harlow 2012, 202; Hung, Lee, and Lim 2012, Yoon et al. 2012). Learning through informal learning environments also provides "real-world" experiences in which individuals can investigate scientific phenomena (Bartley 2009, 93; Evans et al. 2014, 625; Mohr-Schroeder et al. 2014, 293; Yoon et al. 2012, 520), and "help them to assume responsibility for their own future learning" (Eshach 2006, 171).

Not only do students benefit from their experiences with designed informal learning settings, but teachers and parents can as well. Teachers may gain curriculum support and satisfaction due to supplemental information and instruction (NRC 2009). Parents and guardians have a particularly important role in students' involvement with science. Regardless of racial or ethnic background, socioeconomic status, or the parents' own level of education, children whose parents who actively encourage and participate in learning science are more engaged, confident, scientifically literate and show increased comprehension in reading and mathematics (NSTA 2009, Shoults and Shoults 2012). Families visit informal learning venues for shared experiences while learning, often for the children's benefit in particular. Parents are very likely to significantly influence what children learn and how they interact with in the environment. When parents with higher reasoning skills and/or more prior knowledge talk with their children about exhibits and interpretations of exhibits, they promote more effective science learning and transfer conceptual knowledge to their children (Nadelson 2013, 478-479). These interactions encourage higher attendance rates in school, which may result in students taking more challenging, higher-level courses that help them to learn and value science and may better ready them for today's workforce (NSTA 2009, Shoults and Shoults 2012).

Challenges of Informal Learning

One of the most difficult challenges to overcome in the sciences is dispelling misconceptions and preconceived notions about controversial subjects (Schreiber et al. 2013, 463). Previously-held beliefs can be stronger and more strongly accepted than new information, despite the quality of the new information. Most people prefer to have their views reinforced rather than challenged or changed (Schreiber et al. 2013, 463). Change can occur if a person's current understanding is unsatisfactory (Schreiber et al. 2013, 463), but old knowledge and ideas can be deeply entrenched in a person's identity, which will result in resistance to acceptance of new information (Franke and Bogner 2011, 165). Individuals in informal learning venues may simply pass over exhibits that do not align with their current understanding of a phenomenon. Even those who are motivated and willing to have their views challenged may not be able to experience a *paradigm shift* in viewpoint due to time constraints, distractions, or novelty (Colburn 2003, 13-14; Holmes 2011, 275; Schreiber et al. 2013, 463; Swan, Hofer, and Swan 2011, 115; Taylor 2008, 81).

The novelty effect can be a great asset to informal learning venues in that it increases situational interest, but it can also be a challenge to overcome because of the very nature of a new atmosphere. Novelty is not necessarily a drawback, but a venue must be “not so familiar as to be boring, but yet not so unfamiliar as to be threatening” (Holmes 2011, 275). The novelty of an informal learning situation can lead to *cognitive overload*. Cognitive overload can occur simply because of the mass of new sensory input or by the sheer volumes of information presented at each individual exhibit. When students are overwhelmed with information, little to no genuine learning occurs and can skew results for assessment and evaluation (Franke and Bogner 2011, 160; Holmes 2011). To combat the effects of cognitive overload, extraneous information can be limited, a small amount of instruction can be offered for activities and direction, and the information can be broken into smaller pieces that can be grasped more readily (Franke and Bogner 2011, 160; Gutwill and Allen 2010, 716). Limiting information also may invite participants to ask their own questions and seek answers accordingly.

Another challenge of informal learning with respect to field trips is that without preparation before and/or reinforcement after a field trip, it may have little meaning beyond the venue itself. In order for the students to gain the highest possible level of learning during a visit to an informal learning setting, advanced preparation must be facilitated by teachers. Pre-preparation provides a framework for what they should pay attention to and how to interpret what they observe and do (NRC 2009, 132-133). This preparation also decreases the novelty effect that can lead to students becoming overwhelmed. Teachers can also host a post-trip discussion or reinforcement to discuss concepts and learning goals that associates field trips with positive educational experiences (NRC 2009, 134-135). Correlating a field trip with curriculum content "allows students to not only remember what they did, but why they did it" (Kisiel 2006, 48). Without post-visit activities, no lasting impacts were made and the concepts explored during the trip were not perceived as important according to a meta-analysis conducted by Storksdeick in 2001 (NRC 2009, 134-135). This situation represents a challenge that may cause some researchers to doubt the efficacy of informal learning excursions.

Exhibits and activities can be both educational and entertaining—one might argue that that is the purpose of informal learning—but it is possible for an exhibit to be more entertaining than informative. The combination of fun and learning is termed *edutainment* (Eshach 2007, 172; Nadelson 2013, 479). When an exhibit or experience is "entertaining but unfulfilling," no authentic learning occurs. It is also possible that an exhibit or activity has too much or too little structure. The term *scaffolding* in education refers to brief "cognitive supports" that are used to provide enough information upon which an individual can build knowledge (Colburn 2003, 63; Gutwill 2009, 715-716). In informal learning environments, scaffolding can be a benefit or drawback; too much scaffolding and the experience seems contrived and akin to a cookbook recipe; too little and the message may be completely obscured or absent (Hung, Lee, and Lim 2013, Yoon et al. 2012). Those who create informal science learning exhibits or activities must be cognizant that a fine line exists between providing enough content to be educational without being overwhelming. They must also consider what type of instruction or interactions are most appropriate for the subject material, the effects of scaffolding, how many individuals can interact with an exhibit at once, how much time it will take for individuals to receive the full experience, and to what demographics it will appeal. These factors make creating informal learning exhibits and activities a challenge in themselves. Exhibits and programs must be "brief, memorable, useful, and appealing" (Gutwill 2009, 712).

Science Standards

A national core science curriculum for the United States was published in 1996 titled the National Science Education Standards (NSES). An updated version, the Next Generation Science Standards (NGSS), are being adopted gradually. The NGSS, instead of specifying explicit pieces of information like its predecessor did, outlines a series of overarching "disciplinary core ideas" in each subject (NSTA 2013b). Each of the concepts is reiterated every few years in more detail, so students gain a deep understanding of important scientific concepts such as genetics and biological evolution, earth and space, and energy and matter (NSTA 2013a, 2013b). As of October 15, 2015, fifteen states have adopted the NGSS (Heintin 2015; Siegler 2015).

Texas, however, developed its own science core curriculum that is similar to the NSES: the Texas Essential Knowledge and Skills (TEKS). According to the Texas Education Agency (2015b), TEKS are “the state standards for what students should know and be able to do”. TEKS are curriculum standards used in all Texas public schools, describe what must be taught in each grade or course, and what will subsequently be assessed in the State of Texas Assessments of Academic Readiness (STAAR), Texas’ standardized test program. Because of the continual expansion of scientific knowledge, it is important to select specific topics that will prepare students with enough core knowledge so they can later seek additional information on their own (Eshach 2006, 171; NRC 2012).

Laboratory and Field Investigations

The Texas Education Agency recommends or requires that a percentage of each grade level or course is spent doing “laboratory and field investigations” in which students interact directly with natural phenomena and collect qualitative or quantitative data to draw conclusions about their observations (NSTA 2007; TEA 2010d). It is important that laboratory investigations not be rote “recipes” as if from a cookbook, but focus on the processes of science to convey content and enable students to learn how to safely and effectively work in a laboratory environment (NSTA 2007). Students in kindergarten through fifth grade are recommended to spend between 50% and 80% of instructional time dedicated to lab and field investigations, while middle and high school are required to spend only 40% of instruction time on laboratory and field investigations (Figure 1, Pickhardt 2015; TEA 2010a, 2010b, 2010c, 2010d).

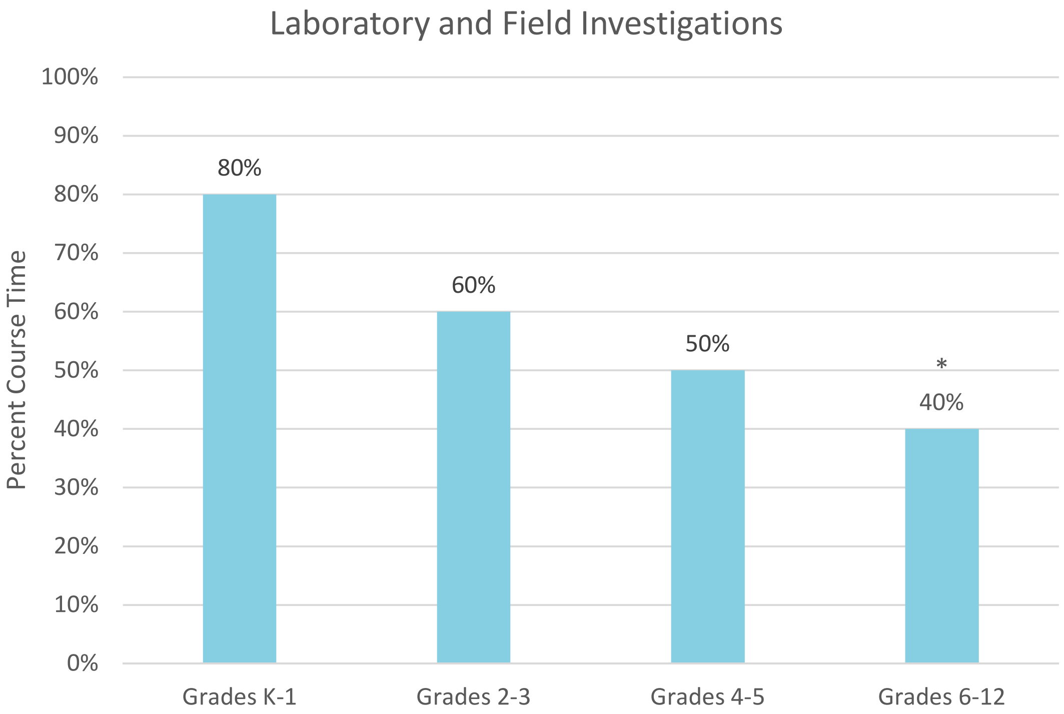


Figure 1. Percent of Texas science classes spent on laboratory and field investigations.
Sources: adapted from TEA 2010a, 2010b, and 2010c.
* denotes required, not recommended percentage class time.

High school students are among those who attend the fewest educational field trips according a survey published by the New Jersey School Boards Association (2012). The survey results stated that approximately 49% of high school students attend field trips, compared to 78% of middle and 92% of elementary students (Figure 2, NJSBA

2012). No data could be found for the percentage of Texas or United States students of each grade level that attend field trips.

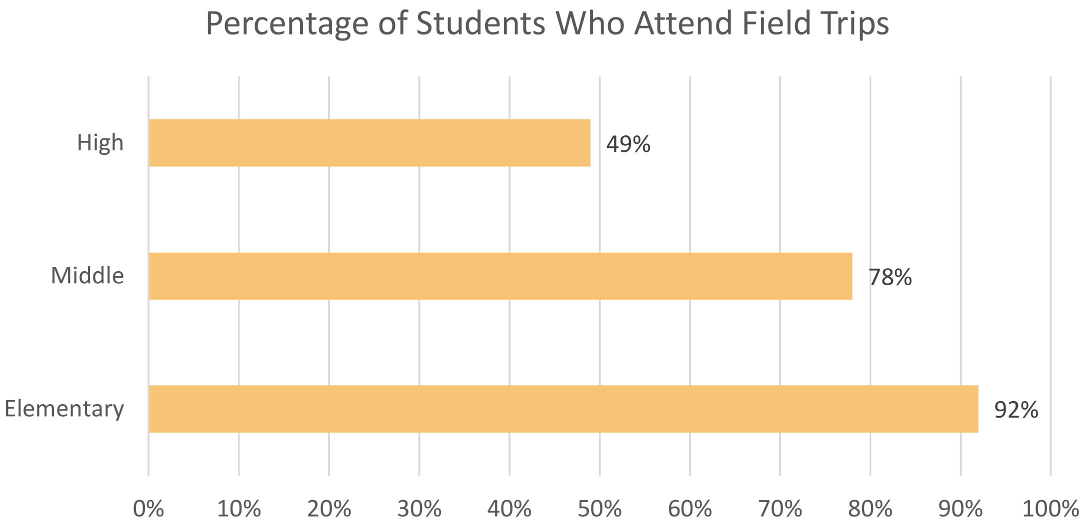


Figure 2. Percent of New Jersey students who attended field trips in 2012. *Source*: NJSBA 2012.

Assessment

In order to determine whether student learning outcomes have been reached, teachers, facilitators, and researchers must employ some form of assessment. Assessment is the gathering and critical analysis of information (Colburn 2003, 37). The information collected from assessments is used to provide feedback to students to determine what they do and do not understand, whether learning goals have been met, and to help teachers make informed decisions regarding their teaching materials and methods (Colburn 2003 37, NRC 2009, 55; Wiggins and McTighe 2005, 6).

Standardized Assessment

Standardized assessment has been increasingly emphasized throughout the last few decades. Students are faced with “large incentives and threatening punishments” determined by the results of their high-stakes tests (Nichols 2006, 4). There is much pressure for students to perform well on these examinations, which often leaves teachers very little room in which to deviate from curriculum-driven lesson plans, a method Wiggins and McTighe call, “Teach, test, and hope for the best” (2005, 3). An informal learning experience can serve to break the monotony of teacher-led lectures within the classroom and allow for more authentic interactions with objects and phenomena that result in deeper understanding of covered concepts, and subsequently better performance on standardized tests (Hung, Lee, and Lim 2012, 1076).

Each state administers its own standardized grade or subject tests. Texas’ version is the STAAR program. The STAAR was initiated in 2012 and was validated through a three-phase peer review process by education state officials and educational assessment experts as described by the House Bill 3 Transition Plan (Eighty-First Texas Legislature 2009). Elementary and middle school STAAR subject examinations are administered at the conclusion of prescribed grade levels (Table 3). In high schools, five end-of-course examinations are administered: English I, English II, Algebra I, Biology, and U.S. History (TEA 2015a).

Table 3. Grades and subjects in which Texas students take the STAAR

	Mathematics	Reading	Writing	Science	Social Studies
Grade 3	✓	✓			
Grade 4	✓	✓	✓		
Grade 5	✓	✓		✓	
Grade 6	✓	✓			
Grade 7	✓	✓	✓		
Grade 8	✓	✓		✓	✓

Source: Adapted from State of Texas Assessments of Academic Readiness (STAAR) Frequently Asked Questions (FAQs) (TEA 2015a).

Previously, Texas high school students were required to pass all five end-of-course STAARs to graduate, but that is no longer true. On May 11, 2015 Texas Senate Bill 149 was signed into effect by Texas governor Greg Abbott (Eighty-Fourth Texas Legislature 2015; Green 2015). This bill provides alternative graduation options for students who do not pass all five examinations. Students can now pass a minimum of three examinations and still graduate from high school with additional provisions described in the bill, such as recommendations from a committee of teachers or other standardized test scores (Eighty-Fourth Texas Legislature 2015; Green 2015). This bill was created to allow exceptions for certain individuals who did not perform well on the tests but may otherwise be qualified to complete high school (Green 2015).

Assessing Informal Learning

Informal learning experiences are particularly difficult to assess because no one method of assessment may be adequate to determine whether learning has occurred. The multiple-choice test standard, though useful, is at odds with the nature of activities and learning in informal environments (NRC 2009, 56). There are, however, many methods for measuring learning in informal learning environments that are regularly employed. Many procedures can be employed at once, and the decision of which method or methods of assessment are appropriate for a researcher's needs lies with the researcher herself.

The most popular method of assessment observed in the articles cited in this work is self-reported student response surveys using a *Likert scale* or similar metric. A Likert scale assesses to what extent an individual agrees with a statement (Colburn 2003, 69). The scale is often a 1 (strongly disagree) to 5 (strongly agree) scale with 3 being a neutral response. Participants may be forced to be more decisive if a scale with an even number of choice is used: this eliminates the possibility of a "neutral" option (Colburn 2003, 69). There are benefits to collecting this type of data, but it can be unreliable due to students providing answers they think the testers want to see instead of their own (Westmoreland 2014). Franke and Bogner (2011) examined mental effort using a modified Likert scale ranging from 1 (very easy) to 9 (very difficult) with 5 being a neutral response. Sasson and Cohen (2013) also employed a Likert scale to measure seven separate parameters including interest level, learning atmosphere, and exposure to new topics not available in school when assessing gender differences among science subject preferences. There are many ways to modify this assessment method to suit the tester's needs.

Another popular method of assessment is a *conceptual survey*. This type of survey is not opinion-based, but measures learning by asking specific questions about exhibits or experiments. This method is somewhat more reliable than self-reported surveys, though it has its own drawbacks. For example, a phenomenon called the *retest effect* can occur when the same questionnaire is used to assess students multiple times: students memorize previous answers for identical questionnaires, which could skew data due to memorization rather than report content learning (Sasson and Cohen 2013, 721). To combat this issue, it is advised to use *parallel questionnaires* that contain similar, but not identical, questions (Sasson and Cohen 2013, 721).

There are also many questions within science that do not have a purely “right” or “wrong” answer, therefore multiple choice questions can pose a problem if only one absolute answer will award points, but an incomplete or semi-correct answer would receive none (Franke and Bogner 2011). Special care, therefore, must be taken in formulating multiple choice questions to ensure that there are no intermediate answer choices available, or to ensure that partial credit is given to any intermediate choices. Another issue that may arise is that if groups are not guided through specific exhibits, it is possible that some may not have seen particular displays and therefore would not be able to answer questions about them.

A less-frequently used method of assessment by measuring *degrees of reflection* in written work was established in 2008 (Kember et al.). Four stringent criteria were defined that would describe a student's level of thought on their experience (Kember et al. 2008). Another study used a similar method of assessment to the degrees of reflection that assessed level of higher-order thinking (Swan, Hofer, and Swan 2011, 118). The method used by Swan, Hofer, and Swan (2011) involved three degrees of reflection that were specific to social studies, and all involved higher order thinking, unlike the criteria defined by Kember et al. (2008).

Table 4. Degrees of reflection

1	Habitual Action	Answer without trying to reach comprehension of a concept or theory that reinforces the topic.
2	Understanding	Concepts understood as theory, but no relationship to personal experiences or applications; no practicality.
3	Reflection	Comprehension with personal meaning attached, application of theory.
4	Critical Reflection	Change previous notions or assumptions, conceptual change.

Source: Adapted from Kember et al. 2008, 372-375.

Demonstration of skill is an effective method of measurement, as it requires immediate critical thought. One study facilitated by Monzack and Petersen (2011) used a demonstrative assessment method in which individuals would carry a "blood bag" (corn syrup and red food coloring) to the "next location" from a specified one within a human circulatory system diagram to confirm comprehension of blood flow through the circulatory system. However, two problems may arise from this method: first, a student may become nervous in front of his peers when asked to demonstrate his skills, and second, a tester must be present to immediately collect the data, or videotaping must be approved in order to record the results. In order for this method of assessment to be effective, the students must feel comfortable enough in the situation to take risks, make mistakes, then learn from them.

Several other methods can be used: interviews, observational notes, and video footage are three examples (Yoon et al. 2012). These data can be either self-reported (interviews) or objective (observational notes and video footage). In the case of observational notes, as the author of this work discovered when she observed the field trip proceedings, the note-taker must take care not to allow bias to skew the observations.

An additional question regarding assessment is, “When to assess?” Many studies employ pretests and posttests immediately before and after an experience to measure learning comprehension, but the question still remains: when should the assessments be implemented? Some studies supply the students with assessments at the beginning and end of an activity, and some are given weeks or even months before or after completion of the activity to measure long-term retention of information. Again, the decision must be made by the experimenter.

Purpose, Significance, and Validity

The purpose of this study was to create and implement three new TEKS-aligned field trip modules at the Trinity River Audubon Center and measure the effect of the modules on participants' content knowledge and attitudes toward learning in an informal science environment.

Much research has been published documenting students' academic performance and attitudes in response to their experiences in an informal learning environment, but few university-partnered studies have been conducted to determine the effect of informal learning during science field trips (Kisiel 2006; Pasquier and Narguizian 2006; Verma, Dickerson, and McKinney 2011). This was a pioneering pilot study that established a collaborative relationship with an informal learning venue, facilitated honing of core-aligned curriculum development skills, and will serve as a model for future researchers who choose to exercise their skills of curriculum design in informal learning settings.

The informal learning venue partnered for this study was the Trinity River Audubon Center (TRAC) located at 3500 Great Forest Way Dallas, Texas 75217. TRAC is an affiliate of the National Audubon Society that hosts a variety of activities for children, youth, and adults such as school field trips, outdoor activities and trips, and birding classes. The center previously hosted TEKS-aligned field trips for students from pre-kindergarten to 8th grade, but no similar opportunities were available specific to high school students. It is precisely for that reason that a collaboration was formed between Texas Woman's University and TRAC in early 2014 with the intention of creating a new, high-school level Eco-Investigation field trip that could be permanently incorporated into the repertoire of activities for students visiting TRAC. The Eco-Investigation created for this thesis was later expanded to allow students in fifth, seventh, and eighth to participate in the field trip.

The modules described in this project were created specifically for the Trinity River Audubon Center based upon an observed pattern of field trip execution: each current TRAC field trip is divided into three distinct TEKS-aligned, structured, and interchangeable segments: a nature walk, a laboratory investigation, and a museum exploration. The field trip model TRAC currently uses was implemented in the creation of the modules in this project. Promoting field trips that have science curriculum standards as their foundation ensures that teachers and students alike will benefit from their experiences, as the material covered in the trip reinforces and enhances concepts that have been or will be addressed within the classroom (TEEAC 2010).

To ensure the validity of this study, all modules and Assessment questions were based upon Texas curriculum standards (TEKS) and the Texas standardized examinations (STAAR), both of which have been validated and reliability-tested. To guarantee the validity of the instruction students received at the Trinity River Audubon Center, all field trips conducted for this study were led by permanent staff members of the Trinity River Audubon Center, not volunteer guides, which guaranteed that all docents received adequate and equal training.

Hypotheses

The hypotheses proposed for this research study were: (1) three new learning modules at the Trinity River Audubon Center would enhance participants' content knowledge about the subjects addressed in the modules and (2) participants would show a more positive attitude toward nature and learning in an informal science environment.

CHAPTER II

MATERIALS AND METHODS

Participants recruited for this study engaged in three new structured inquiry learning modules at the Trinity River Audubon Center: a guided nature walk (Module 1: Bird Biodiversity), a laboratory investigation (Module 2: Classified Information), and a museum exhibition (Module 3: Organism Interactions). Implementation of the modules and collection of subsequent data was approved by the Texas Woman's University Institutional Review Board (IRB, Appendices A, B, and C).

Project Design

A curriculum design technique called *backward design* was utilized to create the modules. Backward design emphasizes beginning a lesson plan with the desired results fully formulated, and only then continuing on to creating assessments, then activities that will help lead students to achieve the desired outcome (Wiggins and McTighe 2005). A succinct description of backward design was stated by Stephen Covey (1989): "Begin with the end in mind." The process of backward design is counterintuitive to what many teachers practice: activities that promote learning often lack specific focus on ideas and evidence of learning, especially with regard to the learner. The learners are often led to think that they are learning by doing the activity itself rather than considering the meaning of the activity. Teachers often commit the error of concentrating more on the teaching than the learning: teachers focus on what they will do, what materials they will need, and what they may ask of students rather than what the learner him or herself will need in order to accomplish the learning objectives (Wiggins and McTighe 2005, 16). Westmoreland described traditional lesson design as starting with an activity in mind and trying to fit learning objectives and assessments into the activity idea, rather than beginning with any specific objectives (2014). In a similar vein, Wiggins and McTighe describe traditional lesson design as a being "hands-on without being minds-on" in which insight and achievement happen only accidentally, though the activity may be fun and engaging (Wiggins and McTighe 2005, 16). Figure 3 shows a basic schematic of how backward design can be used to create a lesson or activity.

Initially, the project was only designed for high school biology students. Due to an inability to recruit participants of that demographic, the project was scaled to include students in fifth, seventh, and eighth grades.

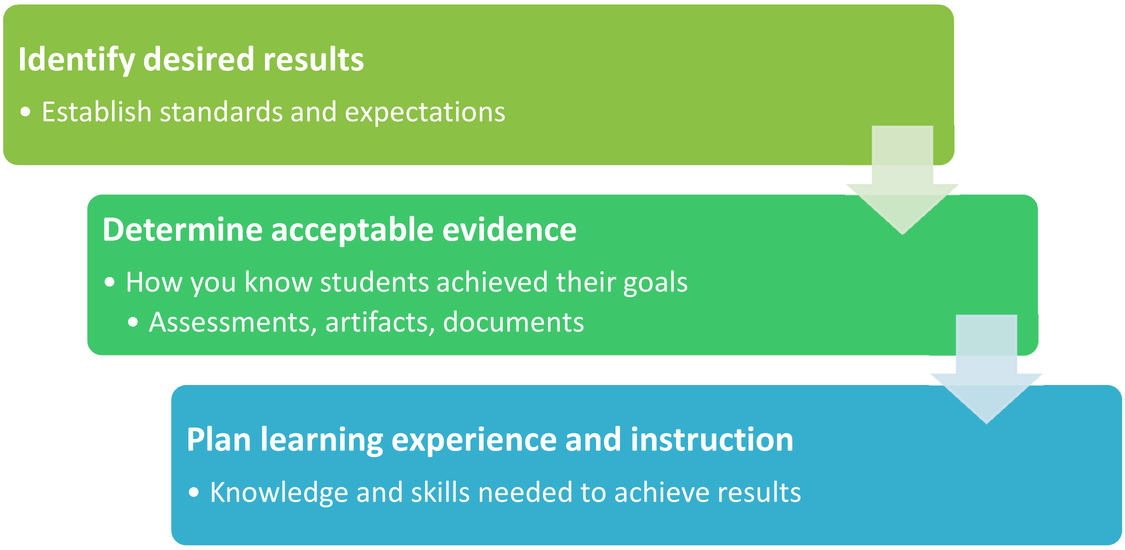


Figure 3. Schematic diagram for the process of backward design. *Source*: Adapted from Wiggins and McTighe 2005, 18.

Learning Objectives

In congruence to the process of backward design, the science Texas Essential Knowledge and Skills (TEKS) requirements for fifth-grade, seventh-grade, eighth-grade, and high school biology students were first consulted in order to establish specific learning objectives to ensure that teachers and students would find their field trip a valuable use of time. The following TEKS were chosen as a framework for the assessments and learning modules described in this thesis:

Grade 5 Science (TEA 2010a)

(b) Knowledge and skills.

(2) Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

    - (A) describe, plan, and implement simple experimental investigations testing one variable;
    - (B) ask well-defined questions, formulate testable hypotheses, and select and use appropriate equipment and technology;
    - (C) collect information by detailed observations and accurate measuring;
    - (D) analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence;
    - (F) communicate valid conclusions in both written and verbal forms.
- (9) Organisms and environments. The student knows that there are relationships, systems, and cycles within environments. The student is expected to:
    - (A) observe the way organisms live and survive in their ecosystem by interacting with the living and non-living elements;
    - (B) describe how the flow of energy derived from the Sun, used by producers to create their own food, is transferred through a food chain and food web to consumers and decomposers.
- (10) Organisms and environments. The student knows that organisms undergo similar life processes and have structures that help them survive within their environments. The student is expected to:
    - (A) compare the structures and functions of different species that help them live and survive such as hooves on prairie animals or webbed feet in aquatic animals.

Grade 7 Science (TEA 2010b)

- (b) Knowledge and skills.
    - (3) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:
        - (A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology;
        - (B) design and implement experimental investigations by making observations, asking well-defined questions,

formulating testable hypotheses, and using appropriate equipment and technology;

(C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing and graphic organizers;

(E) analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

(8) Earth and space. The student knows that natural events and human activity can impact Earth systems. The student is expected to:

(A) predict and describe how different types of catastrophic events impact ecosystems such as floods, hurricanes, or tornadoes.

(10) Organisms and environments. The student knows that there is a relationship between organisms and the environment. The student is expected to:

(A) observe and describe how different environments, including microhabitats in schoolyards and biomes, support different varieties of organisms;

(B) describe how biodiversity contributes to the sustainability of an ecosystem.

(11) Organisms and environments. The student knows that populations and species demonstrate variation and inherit many of their unique traits through gradual processes over many generations. The student is expected to:

(A) examine organisms or their structures such as insects or leaves and use dichotomous keys for identification.

Grade 8 Science (TEA 2010b)

(c) Knowledge and skills.

(2) Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

(A) plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology;

- (B) design and implement comparative and experimental investigations by making observations, asking well-defined questions, formulating testable hypotheses, and using appropriate equipment and technology;
- (C) collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers;
- (E) analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

(11) Organisms and environments. The student knows that interdependence occurs among living systems and the environment and that human activities can affect these systems. The student is expected to:

- (A) describe producer/consumer, predator/prey, and parasite/host relationships as they occur in food webs within marine, freshwater, and terrestrial ecosystems;
- (B) explore how short- and long-term environmental changes affect organisms and traits in subsequent populations.

High School Biology (TEA 2010c)

(c) Knowledge and skills.

(8) Science concepts. The student knows that taxonomy is a branching classification based on the shared characteristics of organisms and can change as new discoveries are made. The student is expected to:

- (B) categorize organisms using a hierarchical classification system based on similarities and differences shared among groups.

(11) Science concepts. The student knows that biological systems work to achieve and maintain balance. The student is expected to:

- (B) investigate and analyze how organisms, populations, and communities respond to external factors.

(12) Science concepts. The student knows that interdependence and interactions occur within an environmental system. The student is expected to:

- (B) compare variations and adaptations of organisms in different ecosystems;

(C) analyze the flow of matter and energy through trophic levels using various models, including food chains, food webs, and ecological pyramids;

(F) describe how environmental change can impact ecosystem stability.

Many of the selected TEKS above were considered experiential learning objectives because there were no corresponding STAAR or assessment questions, though they were experienced by the participants during their field trip to TRAC. Table 5 provides abbreviated descriptions of each of the experiential learning objectives. No experiential objectives were selected for high school biology.

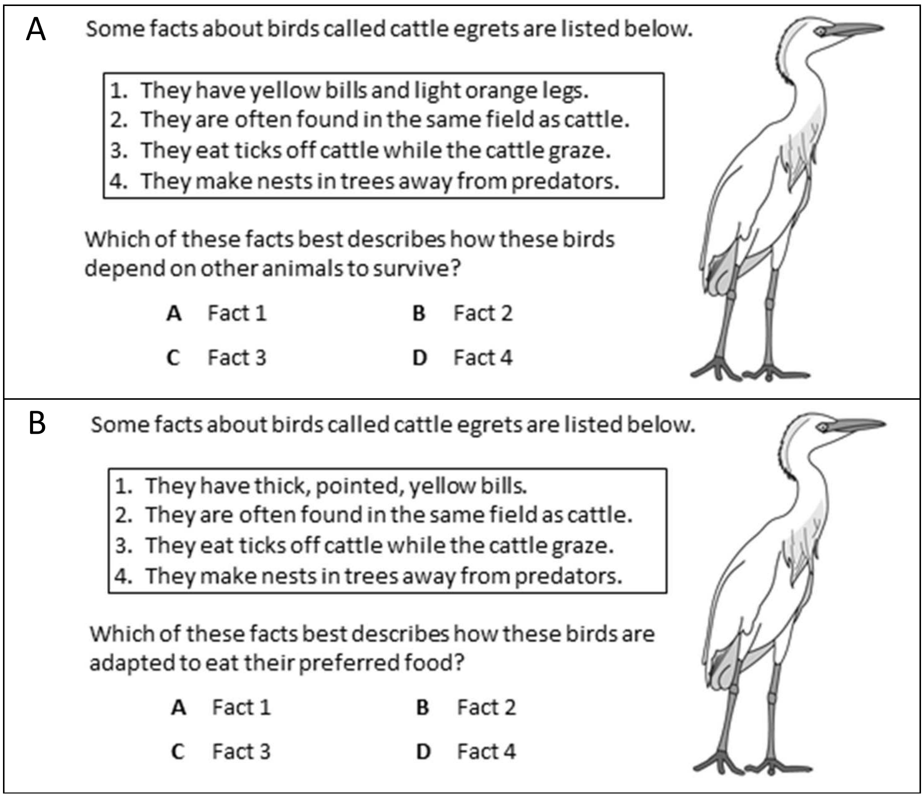
Table 5. Experiential learning objectives (TEKS) targeted by the three learning modules created in this work

Grade	TEKS	Subject
5	2.A	Describe, plan, and implement simple experiments testing one variable
	2.B	Ask questions, formulate hypotheses, select appropriate equipment
	2.C	Collect information by observation and measurement
	2.D	Analyze and interpret information and construct explanations
	2.F	Communicate valid conclusions
7	2.A	Plan and implement investigations by making observations, asking questions, using appropriate equipment
	2.B	Make observations, ask questions, formulate testable hypotheses
	2.C	Collect and record data using SI units and by qualitative means
	2.E	Analyze data, formulate explanations and conclusions, predict trends
	10.A	Different environments support different organisms
	10.B	Biodiversity contributes to ecosystem sustainability
8	2.A	Plan and implement investigations by making observations, asking questions, using appropriate equipment
	2.B	Make observations, ask questions, formulate testable hypotheses
	2.C	Collect and record data using SI units and by qualitative means
	2.E	Analyze data, formulate explanations and conclusions, predict trends

Source: Adapted from TEA 2010a, 2010b, and 2010c.

Assessment Methodologies

This project required the creation of multiple learning tools that were used at the Trinity River Audubon Center. Again, reflecting the backward design scheme, the first tools generated were the Pretest and Posttest. The Texas Education Agency published previously-used STAAR questions and answer keys which provided an invaluable source of multiple-choice questions (TEA 2011a-2011c, 2013a-2013f, 2014a-2014f). All STAAR answer keys detailed the TEKS from which each question was derived, ensuring that the questions chosen for the Pretest and Posttest used for this project had a core curriculum foundation. Parallel Posttest questions were devised to prevent the retest effect. An example of parallel questions written for the assessments can be viewed in Figure 4.



A

Some facts about birds called cattle egrets are listed below.

1. They have yellow bills and light orange legs.
2. They are often found in the same field as cattle.
3. They eat ticks off cattle while the cattle graze.
4. They make nests in trees away from predators.

Which of these facts best describes how these birds depend on other animals to survive?

A	Fact 1	**B**	Fact 2
C	Fact 3	**D**	Fact 4

B

Some facts about birds called cattle egrets are listed below.

1. They have thick, pointed, yellow bills.
2. They are often found in the same field as cattle.
3. They eat ticks off cattle while the cattle graze.
4. They make nests in trees away from predators.

Which of these facts best describes how these birds are adapted to eat their preferred food?

A	Fact 1	**B**	Fact 2
C	Fact 3	**D**	Fact 4

Figure 4. Example parallel Pretest (Figure 4A) and Posttest (Figure 4B) questions from the fifth-grade assessments.

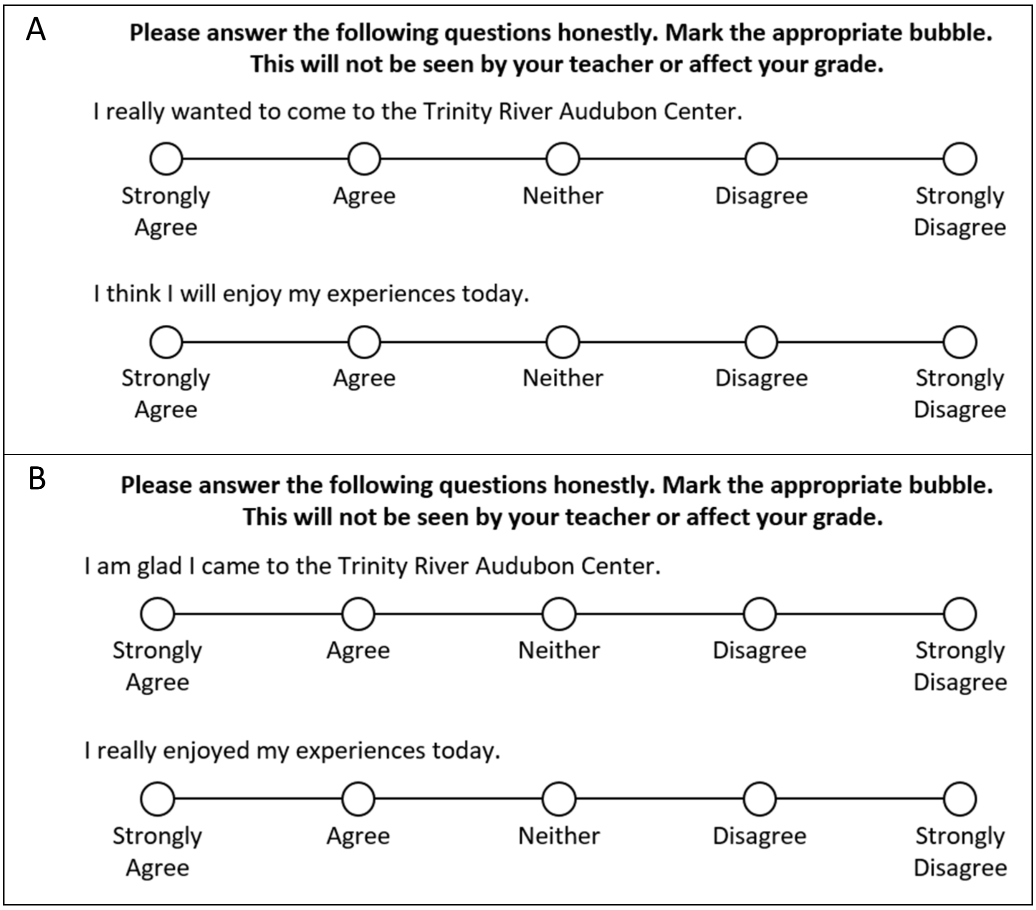
On both Pretest and Posttest, participants answered five questions of similar format to those they will answer during the fifth-grade, eighth-grade, or end-of-course biology STAAR. Because of the grades in which science STAARs are given, three assessments were written: fifth grade (Appendix D), seventh and eighth combined (Appendix E), and high school biology (Appendix F). At least one question on each assessment contained drawings that were created by the researcher using Adobe Illustrator (see example in Figure 4). Question 2 on the high school assessments did not have a corresponding TEKS objective, but indicated whether the participant learned about biodiversity during their field trip. Table 6 details the *assessed learning objectives* and to which assessment questions they correspond.

Table 6. Learning objectives (TEKS) assessed by the three learning modules created in this work

Grade	TEKS	Subject	Question
5	9.A	Organisms interacting with environments	5
	9.B	Flow of energy through the food chain and food web	2, 3, 4
	10.A	Compare structures and functions for survival	1, 5
7	8.A	Catastrophic events impact ecosystems	4
	10.A	Different environments support different organisms	1
	11.A	Use dichotomous keys	5
8	11.A	Feeding relationships in food webs	2, 3
	11.B	Environmental changes affect organisms	4
HS Bio	8.B	Hierarchal classification	5
	11.B	Organisms respond to external factors	3, 4
	12.B	Compare variations and adaptations in different ecosystems	1
	12.C	Flow of matter and energy through food chains and webs	3
	12.F	Environmental changes impact ecosystem stability	4

Source: Adapted from TEA 2010a, 2010b, and 2010c.

In addition to the content assessment questions, several subjective questions were answered to measure students' attitudes toward their experiences at TRAC. For those questions, a Likert scale was employed. The scale used for the subjective questions included the choices "strongly disagree", "disagree", "neutral", "agree", and "strongly agree". Participants were also asked about their time spent outdoors on the Pretest and the likelihood of spending more time outdoors on the Posttest. They were also asked if they would like to return to TRAC or visit other similar nature centers. Figure 5 provides two of the Pretest and Posttest attitude assessment questions that were used for statistical analysis.



A

Please answer the following questions honestly. Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I really wanted to come to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I think I will enjoy my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

B

Please answer the following questions honestly. Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I am glad I came to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I really enjoyed my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Figure 5. Pretest and Posttest attitude assessment questions.

Learning Tools

Five learning tools were created specifically for this project with the financial support of the Texas Woman's University Quality Enhancement Plan Experiential Scholar Program. The learning tools were provided to participants in every grade level during their TRAC field trip experiences. Table 7 briefly describes each of the learning tools created.

Table 7. Original learning tools

Learning Tool	Description	Module	Appendix
Eco-Investigation Science Journal	Journal provided to each student that contains outlines and thought-provoking questions for each of the three modules. Students will record data throughout the day and will be allowed to keep the Journal as an artifact.	all	G
TRAC Bird Identification Guide	Laminated 8.5"x11" card containing pictures, silhouettes, and common names of birds that can be found year-round at TRAC.	1	H
Example Dichotomous Key	Laminated 8.5"x11" card that illustrates how a dichotomous key might be made using popular Nabisco® brand cookies.	2	I
Bird Classification Cards	Five 5"x7" laminated cards each containing information for a different bird. Photographs and a QR code students can scan to hear the call are included.	2	J
Food Web Demonstration	Microsoft Power Point slideshow in which a food web is displayed. As the presentation is advanced, the effects of fire, flood, and drought are shown.	3	K

Five original learning tools created by the researcher for this project, their descriptions, and to which module and appendix they correspond. Module 1 is the Bird Biodiversity nature walk, Module 2 is the Classified Information laboratory investigation, and Module 3 is the Organism Interactions museum exhibition.

Eco-Investigation Science Journal

The Trinity River Audubon Center provided an Eco-Investigation Science Journal to every participant attending an Eco-Investigation field trip. It was used throughout the entire trip as an activity and learning guide, and participants were encouraged take it home with them as an artifact of their learning and experience at TRAC. This journal served as a source of activity prompts, critical-thinking questions, and provided spaces in which participants recorded data from their field trip activities. The original Eco-

Investigation Science Journal used during TRAC's field trips was offered by as an example upon which the researcher could model a new Journal (Appendix G). Jenna Hanson very generously shared the Microsoft Publisher file in which the original Science Journal was created to be used as a rough template.

The front cover of the original Journal provided a box in which participants were asked to draw their idea of "home" to engage the students and focus their attention on the theme of the field trip: "Our Amazing Home." A similar strategy was used by the researcher to engage participants. The new Journal provided a space on the front cover in which students could write their own nature-themed hashtags (Figure 6). A hashtag, according to the Oxford Advanced Learner's Dictionary, is a word or short phrase preceded by the pound sign (#) that acts as a searchable tag on social media sites such as Facebook, Instagram, Tumblr, and Twitter. In this modern world of ever-increasing technology use, many young people may not experience nature in the way that older generations did. Allowing participants to create their own nature-themed hashtags would provide a bridge between technology and nature while allowing them creative license.

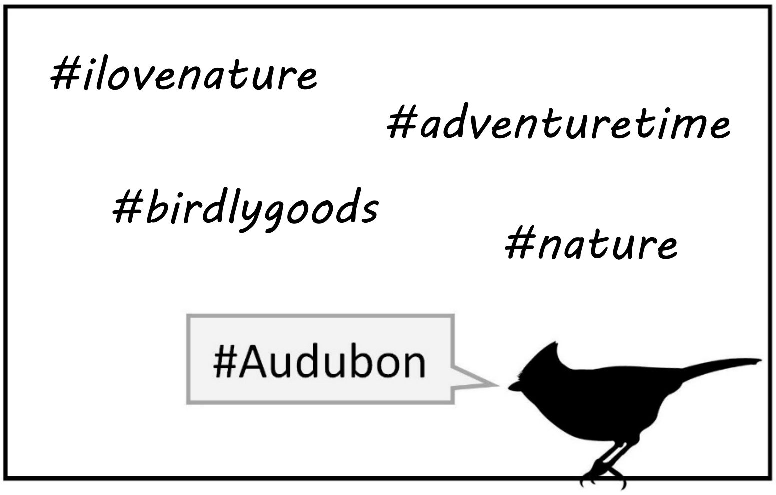
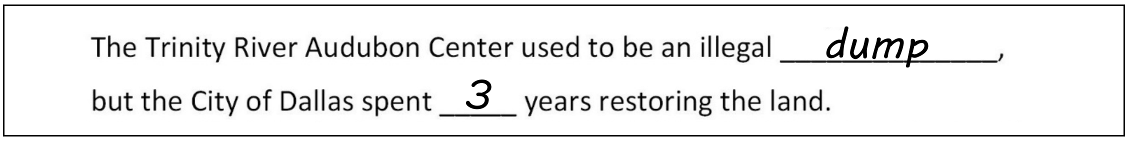


Figure 6. The box on the cover of the New Eco-Investigation Science Journal in which participants could write their own nature hashtags. In script are a few of the hashtags participants contrived by participants during the field trip observed by the researcher.

The first inside spread of the new Journal, pages 2 and 3, contained the same information as the original Journal. Minor changes to grammar and punctuation were made to suit the researcher's style preferences. This information described the migratory bird pathway in which TRAC resides and general information about the three distinct ecosystems that were explored while at TRAC, which were relevant to every visitor.

Pages 4 and 5 of the new Journal described Module 1 of the field trip: "Bird Biodiversity." Participants attended a nature walk in which they visited the three ecosystems that were found at TRAC: the Trinity River Watershed, the Blackland Prairie, and the Great Trinity Forest. The first statement of the guided nature walk module of the original Journal was reused for the New Journal (Figure 7). This statement demonstrates the power of nature to restore itself after a major disturbance, and was meant to engage students in their natural surroundings during the walk.



The Trinity River Audubon Center used to be an illegal __dump__,
but the City of Dallas spent __3__ years restoring the land.

Figure 7. First statement on page 4 of the new Eco-Investigation Science Journal.

The Bird Biodiversity module guided participants through the scientific method. First they were asked to formulate a hypothesis as to which of the three ecosystems will contain the greatest bird biodiversity based upon what they already thought or knew. They then collected data by observing birds and signs of activity and marking their results on page 5 of the Journal. Finally, they analyzed their results and formulated a conclusion as to which ecosystem actually demonstrated the greatest bird biodiversity and why that was. This process reflected all of the experiential TEKS described in Table 5.

Module 2: Classified Information was located on Pages 6 and 7 of the new Journal. Participants were provided with the Example Dichotomous Key (Appendix I), Bird Classification Cards (Appendix J), a dry-erase board, and a plastic box containing dry-erase markers in six colors and a dry-erase marker eraser. In their Journal they wrote similarities and differences among five species of birds found on the cards and attempted to create their own dichotomous key to organize the birds. The new Journal also prompted participants to consider how taxonomic classification of organisms is done and the difficulties that could arise. Having created their own dichotomous keys in the lab, they had a ready-made example: upon what criteria are organisms classified?

This module was designed to have infinitely many correct answers. The laboratory investigation in the original Journal guided participants in identifying organisms found in a pond to determine water quality. Each time a group of participants calculated the water quality based upon the presence of particular organisms the water quality was deemed to be “healthy,” regardless of the group of students, time of year, or precise organisms identified. The researcher and her mentor wanted to provide the same type of structured inquiry activity in which participants are provided with materials and methods to answer a hands-on problem without knowing the expected outcome. This type of activity allowed students to discover relationships and make generalizations from the data they collected and observed (Colburn 2003, 20).

Pages 8 and 9 of the new Journal detailed the proceedings of Module 3: Organism Interactions. There were spaces on page 8 in which participants could document organisms they found in the exhibition hall of TRAC and their characteristics related to feeding habits, thus emphasizing organismal structure-function relationships. They then constructed their own food chain using the organisms they described. Feeding relationships and flow of energy are important subjects for science STAARs taken in fifth grade, eighth grade, and high school biology (Table 6).

Participants then viewed a Microsoft Power Point slideshow created by the researcher that demonstrated feeding relationships, the complexity of food webs of an ecosystem, and how natural disasters (e.g. fire, flood, and drought) can harm the organisms and affect the food web. The final four questions on Page 9 of the new Journal addressed the food web demonstration. The activity was then concluded with an open-ended question asking participants how they may be able to protect the wildlife around their home.

Boldface terms throughout the new Journal indicated key terms that could be found on page 10 of the Journal (*Biology Online*). Below the key terms section was a list of how individuals could make their homes bird-friendly. These were copied from the original Journal, as they were relevant to all field trip participants, especially because the major focus of the field trip described in this thesis was birds. Page 11 showed a map of TRAC and a mention of the collaboration between the author of this work at Texas Woman's University and the Trinity River Audubon Center.

The back cover of the new Journal contained much the same information as the Original Journal: a map of the TRAC location in Dallas, an invitation to connect with TRAC via social media, and a free pass for up to ten people with a previous participant of an Eco-Investigation field trip. Information that was added to the new Journal at the recommendation of TRAC staff member Jenna Hanson were volunteer and internship opportunities at TRAC.

Trinity River Audubon Center Bird Identification Guide

The Trinity River Audubon Center Bird Identification Guide (Appendix H) was created to be a quick reference guide for individuals on the TRAC nature trails. Twenty-one species of birds commonly found at TRAC selected by Jenna Hanson were included on the Identification Guide (Table 8). Most of these birds can be found year-round at TRAC. All photographs of birds were selected from the Audubon Society website. The researcher used Adobe Photoshop to remove the background from each image so a clear and precise image could be seen (Figure 8A and Figure 8B). For a few of the species that have distinctive silhouettes (e.g. vultures, hawks, swifts, gulls, herons, egrets, and swallows), the researcher used Adobe Illustrator to draw them (Figure 8C).

Table 8. Selected bird species used for the Identification Guide

American Crow	Great Blue Heron	Red-bellied Woodpecker
Barn Swallow	Great Egret	Red-shouldered Hawk
Black Vulture	Killdeer	Red-tailed Hawk
Blue Jay	Little Blue Heron	Ring-billed Gull
Carolina Chickadee	Mourning Dove	Snowy Egret
Cedar Waxwing	Northern Cardinal	Tufted Titmouse
Chimney Swift	Northern Mockingbird	Turkey Vulture

The images were then assembled in an organized fashion using Microsoft Power Point, and shadows were added to all images for depth. Only the common names of the birds were included; the scientific names were not important for the identification activity so were not included. A few of the photographs showed arrows pointing to particular features of certain birds. The purpose of these arrows was to indicate a unique feature that would aid in identification, such as the yellow bill of a Great Egret or the mask-like markings on a Cedar Waxwing's face. The Guides were professionally printed and laminated to be a double-sided reference.

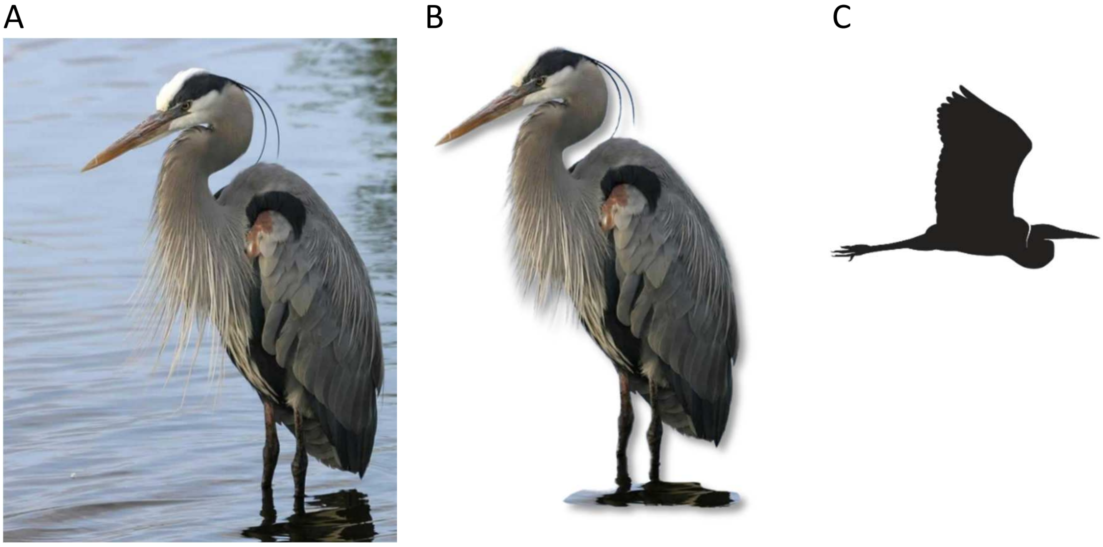
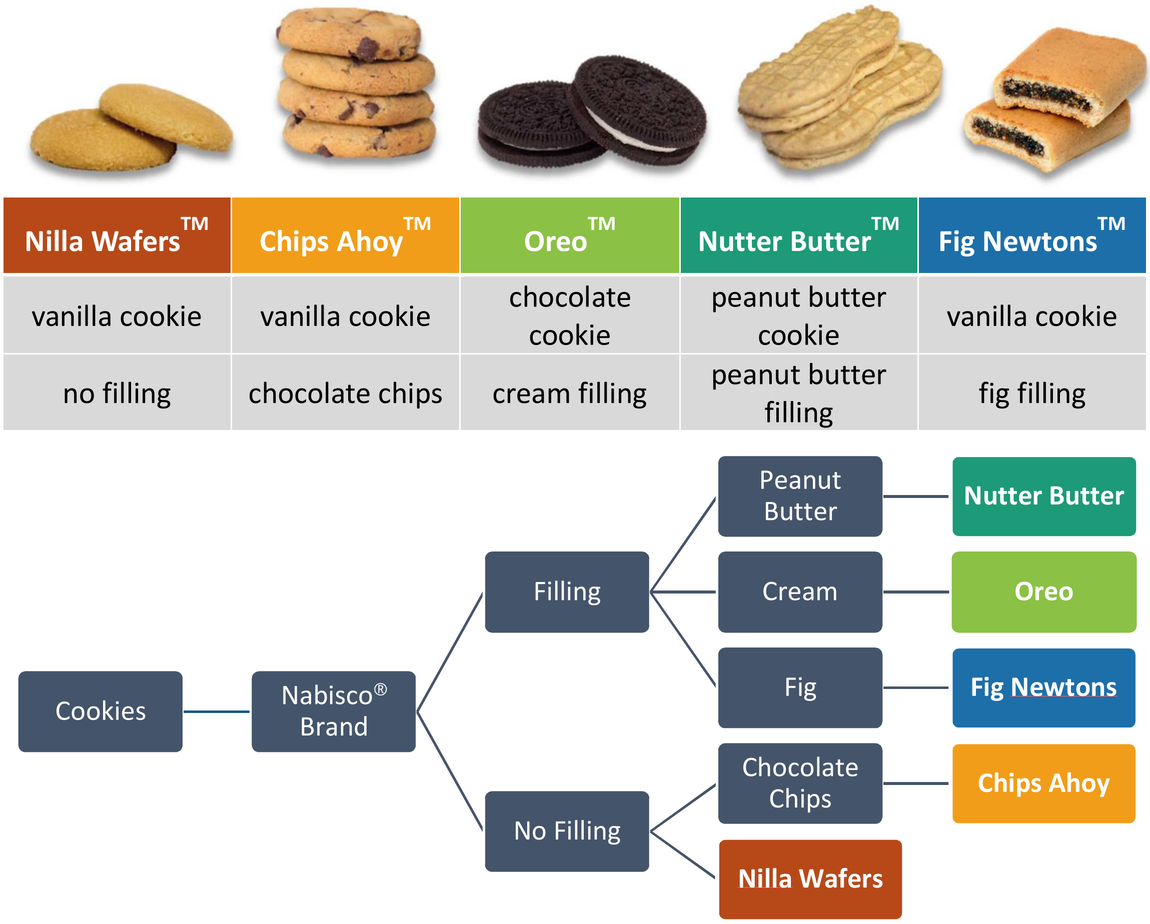


Figure 8. Example of how images were processed for the Identification Guide. Figure 8A shows the original image of a Great Blue Heron, Figure 8B shows the image after background erasure and addition of a shadow, and Figure 8C shows the silhouette created to represent the herons and egrets. *Image source*: Claude Nadeau.

Example Dichotomous Key

When the idea for Module 2: Classified Information was conceived, the researcher and her mentor had some misgivings about participants' abilities to understand what a dichotomous key should look like—much less create one—without seeing an example. For the example dichotomous key that could be used with all groups of participants, cookies were chosen for the subject due to their ubiquitous nature. Candy varieties were a secondary option.

The Example Key was entitled, “What is a dichotomous key?” Beneath the title was a brief description of what “dichotomous” means and how a key can be used. The Example Key emphasized that items could be sorted and organized by similarities and differences. Five cookies of the same brand were selected to be represented on the Example Key. The Key provided three criteria on which the selected cookies could be sorted: flavor of cookie, filling/additive, and shape. The example dichotomous key used only cookie flavor and filling/additive to organize them (Figure 9). The example Keys were laminated for protection and durability.



Nilla Wafers™	Chips Ahoy™	Oreo™	Nutter Butter™	Fig Newtons™
vanilla cookie	vanilla cookie	chocolate cookie	peanut butter cookie	vanilla cookie
no filling	chocolate chips	cream filling	peanut butter filling	fig filling

Figure 9. Example dichotomous key using cookies.

Bird Classification Cards

Five species of birds were chosen for the Bird Classification Cards (Appendix J) by Jenna Hanson for Module 2: Classified Information to be organized into dichotomous keys. The species were selected because they are common, recognizable, and from different taxonomic orders. Each card contained the following information: common name, scientific name, taxonomic order, habitats, habits, active time of day, preferred food, predators, a QR ("quick response") code to hear the bird's call, and at least two photographs obtained with permission from the National Audubon Society website (audubon.com). The cards were printed professionally to be 5 inches by 7 inches and double-sided. The cards were laminated for durability, holes were punched in an upper corner of each card, and were bound with a loose leaf ring. Figure 10 displays the card containing information about the Ruby-throated Hummingbird.

Ruby-Throated Hummingbird
Archilochus colubris
Taxonomic Order: Apodiformes ("without feet")

Size	3-3.5 in (7-9 cm)
Habitats	Forest edges, meadows, grasslands, parks, gardens, backyards
Habits	Precision flyers: can hover, stop, or dart in any direction in an instant
Activity	Diurnal (daytime)
Food	Nectar, tree sap, mosquitoes, gnats, fruit flies, small bees, spiders, caterpillars, aphids
Predators	Domestic and feral cats, hawks

To hear the bird's call, scan the QR code below.

Male

Female feeding chick

Images © National Audubon Society

Figure 10. Ruby-throated Hummingbird Bird Classification Card. *Image sources*: male: Paula Cannon; female feeding chick: Fred Truslow.

The researcher felt it was important to include a wide variety of information on the classification cards because many different factors can be considered when taxonomically organizing organisms; she did not wish to limit options for participants by not including behavioral traits in addition to physical traits. The QR code was an addition to the card that aimed to again bridge the gap between experiences with nature and technology. A mobile device application could be downloaded and the code opened a sound file of the bird's call. These calls were found at the Cornell Lab of Ornithology's website, allaboutbirds.org.

Food Web Demonstration

The final learning tool used during the field trip was the Food Web Demonstration during Module 3: Organism Interactions. The Demonstration was created in Microsoft Power Point and shows what food chains look like, how they interact, and how they are affected by drought, flood, and fire. Each trophic level was represented by a different color: producers were green, primary consumers were orange, secondary consumers were blue, and tertiary consumers were purple. The color was not necessarily important, as each trophic level was distinctly visible on its own axis.

The presentation began with the building of a simple food chain containing flowers and grasses, insects, birds, and hawks and owls. It then built a second food chain beside it containing trees and shrubs, large mammals, and foxes and coyotes (Figure 11A). The next frame showed what it looked like when those food chains interacted with one another to create a food web (Figure 11B). More primary consumers were added (Figure 11C), then more secondary consumers (Figure 11D) to create a complete forest food web.

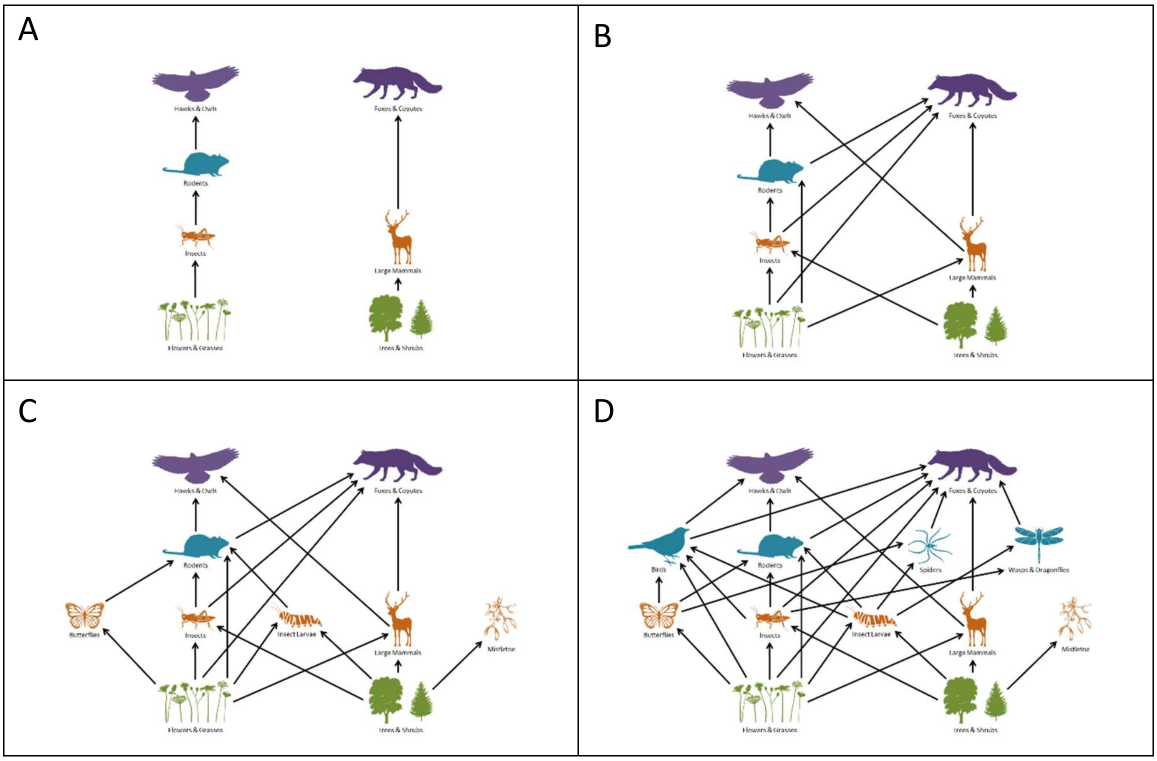


Figure 11. Food web demonstration. Figure 11A shows the first two sample food chains, and Figure 11B shows what the chains looked like when the feeding relationships were expanded to include both chains. Figure 11C added a more primary consumers, and Figure 11D added more secondary consumers.

The final food web was then subjected to three natural disasters: drought, flood, and fire, which are all possible disasters in the North Texas area. The full web was shown in its entirety, and as the slideshow was advanced, it was as if time was advancing as well. The first effects of the three disasters were demonstrated by changing affected objects' colors to grey to indicate they were no longer usable (Figure 12A). Organisms that used the now-grey objects as a food source were then changed to gray, until no more organisms were viable. On the last frame of each disaster segment, however, the first organisms to reappear after the disaster would return to their colored appearance (Figure 12B). The purpose of this demonstration was to illustrate how one ecological change can affect the entire ecosystem.

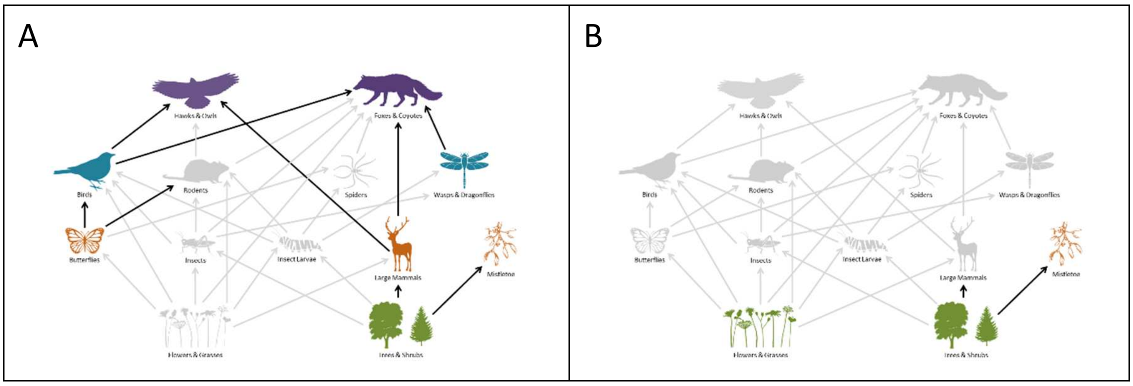


Figure 12. Food web demonstration showing some of the devastation caused by a flood. Figure 12A shows what organisms are first harmed after a major flood and Figure 12B shows the first organisms to reemerge after the flood.

Advertisement

Melissa Malone of TRAC requested that an advertisement for the new Eco-Investigation field trip described in this thesis be created to distribute to school administrators and teachers (Appendix L). The advertisement emphasized TEKS and STAAR alignment and described the field trip activities thus:

> … Students will embark upon a three-part field trip in which they will
> - Explore three unique ecosystems: Blackland Prairie, Great Trinity Forest, and Trinity River Watershed.
> - Use a key to identify various bird species seen in each ecosystem.
> - Use the Scientific Method to make predictions, gather information, and formulate conclusions.
> - Work with their peers to create their own dichotomous identification key for a selection of bird species.
> - Consider eating adaptations of various organisms found within the exhibit hall.
> - Construct a food chain using the organisms they find.
>   Observe the consequences of natural disasters on a food web.

The advertisement also invited students to participate in this research study and included contact information for the researcher, Sarah Wehner.

Project Creation

The creation of the field trip modules described in this work commenced in early 2014. The initial idea for the collaboration between TWU and TRAC was to create a series of scanning electron microscope (SEM) image installations that would engage visitors of all ages. The idea was to "take a closer look at our amazing home" by zooming in on common items found in nature to examine their physical structure more closely. Lifting the micrograph would reveal an example of the actual object magnified in order to spark visitors' interest in the natural world. That idea was discussed when the author of this work began to pursue research under Sandra Westmoreland in December 2013.

After a conference call with Jenna Hanson on January 24, 2014, however, the idea evolved into creating field trip modules, and the creation of the modules described in this work began. The first idea proposed was a poster showing micrographs of objects and their macroscopic counterparts that could be displayed in the Exhibit Hall at TRAC. Another idea was to invent a game in which birds were sorted into their taxonomic orders based upon physical and behavioral similarities and differences. That idea eventually evolved into Module 2: Classified Information.

The process of seeking IRB approval was a particular challenge because little was understood about the requirements for recruiting minors as participants. The first draft of the IRB document was submitted in August 2014 after working on it for several months. The document was returned in September with a long and detailed list of items to add or modify that took until December 2014 to complete. Among those items were obtaining agency approval from TRAC, ensuring that both the researcher and mentor had completed the appropriate human subject research training certificates, creating a detailed consent form that abided by the guidelines established by the IRB, detailing the proceedings of each lesson module and its related learning tools, and defining potential risks and how they could be avoided. In short, the project must be complete in every aspect before the IRB would approve its implementation.

The IRB approved the project on December 11, 2014 (Appendix A). In January 2015, professional prints of the learning tools were requested, and prints were received in early February. The prints were assembled and laminated by the author for delivery to TRAC. All items required were delivered to TRAC before summer, but unfortunately, field trips were not able to be scheduled that late in the school year. After encountering some difficulties in recruiting high school students, an amendment to the IRB approval document was requested to include fifth-, seventh-, and eighth-grade participants in June 2015. The modifications were approved on July 1, allowing much more freedom in recruiting participants for data collection (Appendix B). The original expiration date for the IRB protocol was September 9, 2015, so an extension was filed and approved on July 10, 2015 (Appendix C).

Three important documents were delivered to teachers for recruitment of their students: a Letter to Teachers (Appendix L), a Research Recruitment Script (Appendix M), and the Consent to Participate in Research Form (Appendix N). The script must be read and/or provided to all participants wishing to participate in any IRB-approved research study. For this reason, the letter to teachers was devised. The Letter is not usually a part of the IRB approval process, but was essential as the recruiting was not done by the author. The Letter contained information about the author, the project, a request read the Script aloud and to provide all students with a copy of the Script and Consent Form, the researcher's and advisor's contact information, and the TEKS specified for each grade level.

CHAPTER III

RESULTS

Field Trip Learning Module Observation

The field trip observed by the researcher on October 16, 2015 was populated by Dr. Westmoreland's Science in the Secondary Classroom students and Mrs. Garcia's Science in the Elementary Classroom students, both containing pre-service teachers. Unfortunately, no field trips populated with study participants could be observed due to time constraints.

Immediately after arriving at TRAC, field trip participants were greeted by intern Michael Trevino who led the day's proceedings. Field trip consent forms were given to a TRAC staff member, and each participant was provided with a clipboard and a pencil. Participants then completed the High School level Pretest and turned it in to Michael. Upon collection of the Pretests, participants received an Eco-Investigation Science Journal (Appendix C) a Trinity River Audubon Center Bird Identification Guide (Appendix H), and a pair of binoculars. Because the group was small (fewer than 30 participants), the participants were not broken into groups of approximately equal size as the docents would do with a large group. The three modules were designed to be non-sequential so that TRAC staff may lead their groups in any order, but Michael led the group in the order in which they occurred in the Journal.

Module 1: Bird Biodiversity

This module was a guided nature walk that lasted approximately 1 hour. After a brief tutorial on how to use their binoculars and instructions to not leave the trail, the participants were led out a back door into the Blackland Prairie. The group stopped along a trail in the open prairie behind TRAC. Michael asked the group to turn the Journal to page 4 and began speaking about the history of the Trinity River Audubon Center and how it had been an illegal dump. He spoke about the ability of nature to recover from such a manmade disaster and the importance of biodiversity. The group was the asked to make a hypothesis as to which ecosystem would have the most bird biodiversity, and then stayed in that area of the trail for at least 10 minutes after hypotheses were made.

A Great Egret, TRAC's mascot, could be seen at the edge of Great Blue Heron Pond. Several more birds were sighted including a Red-tailed Hawk, Turkey Vulture, Northern Mockingbird, Northern Cardinal, Killdeer, Mourning Dove, and Wood Duck. As they were sighted, Michael instructed the group to write the names of the birds on page 5 of the Journal and check the column or columns to indicate in which ecosystem the birds were sighted. Many of the birds were spotted by participants using their binoculars. The group was then led around Great Blue Heron Pond on a trail between Raccoon Pond and Spider Web Pond to see if any more prairie birds could be spotted.

After a few minutes, the group was then led down a trail through the Great Trinity Forest. Michael mentioned spots of lichen on the trees and talked about their mutualistic components, algae and fungi, and their role as pioneer species—the ability to make a home on bare rock that, in time, would break down to create topsoil. Only a few birds could be seen or heard along the forest trail: Northern Mockingbird, Northern Cardinal, and American Crow.

The group moved through the forest toward the Trinity River where they stopped at a picnic area. Michael mentioned that the Trinity River is unique to Texas: it begins and ends in Texas. He also explained that more than 40% of Texans receive their drinking water from the Trinity River. A small group of participants spotted a Great Blue Heron on the far side of the Trinity and added it to their list. After observing the river for a few more minutes, the group moved back along the trail toward the Center, diverting to another path along a bridge across Trailhead Pond. A few Mockingbirds and Cardinals were flitting back and forth across the pond.

Michael asked the group to count the number of bird species seen in each ecosystem. The consensus was that the Blackland Prairie showed the greatest biodiversity. He then explained that the greatest biodiversity was almost always seen in the Prairie because visibility is better, and that birds have excellent eyesight and could spot prey much easier in the open. The Module guided the participants through the scientific process of hypothesis formation, experimentation, data collection, and data analysis. The group was then led inside the facility, and the Identification Guides and binoculars were collected. Participants were instructed to leave their clipboards against the wall in the Great Hall during lunch.

Module 2: Classified Information

After lunch, the group gathered in the Great Hall and walked to the Laboratory where five tables were each laid with the Bird Classification Cards (Appendix J), a dry-erase board, dry-erase markers, and an eraser. Michael talked about a few of the morphological features of birds: feathers and their types, bone structure, and eggs. He passed around a small case containing the skeleton of a pigeon and held up an ostrich egg (the largest bird egg) and a white Tic Tac candy that was approximately the size of a hummingbird egg. He mentioned some similarities: feathers, scaly legs, and they lay eggs, then instructed the group to find similarities and differences among the bird species on the cards and document them on page 6 of the Journal. He walked around observing and showed around a preserved female Ruby-throated Hummingbird.

Michael called the group to order and started an example dichotomous key on the large white board at the front of the classroom (Figure 13). He began to guide the participants in creating their own dichotomous key using the similarities and differences they had defined. He gave the group a few more minutes to complete their key.

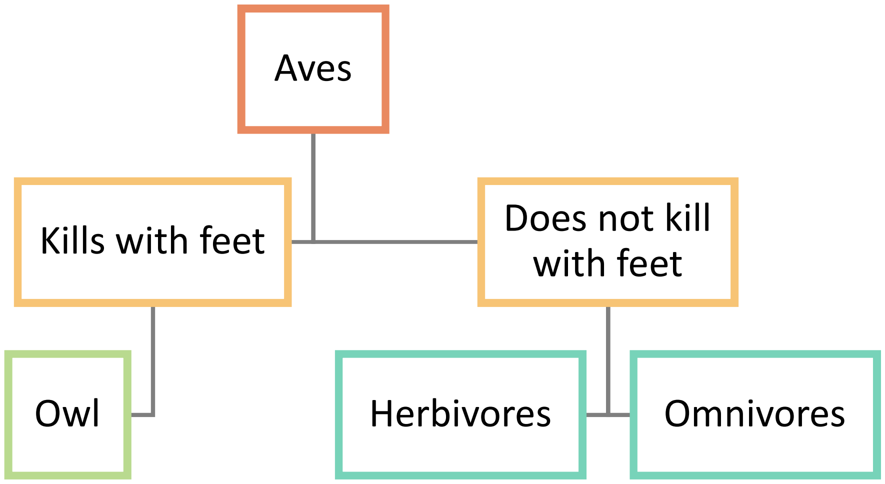


Figure 13. Starter example dichotomous key Michael drew on the white board.

A group volunteered to write their key on the large white board and Michael explained how it was organized. The volunteer group further classified omnivores into "sexually dimorphic" and "non-dimorphic", then by size. Michael discussed what sexual dimorphism means and that the male sex is generally flashier in order to attract a mate. Another group's white board was held up for the rest of the participants to see, and he noted that they chose a different way of organizing the birds. The group was then called to order and asked to go into the Theater Room for the final module.

Module 3: Organism Interactions

The group gathered in the Theater Room in the main building and sat while Michael explained the next activity on page 8 of the Journal: walk around the Exhibit Hall and observe the different organisms or evidence of organisms available and complete the table. He then asked them to use any of the organisms around the Exhibit Hall to construct a food chain, but recommended to use "grasses" or "plants" in the

Producers box and an insect in the Primary Consumers box, since those organisms were not necessarily readily available to observe in the exhibit hall. Participants roamed around the Exhibit Hall for about 15 minutes listening to recorded bird calls, observing the reptiles and amphibians (Speckled Kingsnake, Bullfrog, Rough Green Snake, and Red-eared Slider turtles), and exploring the other objects such as horns, antlers, and nests of birds and insects.

When the participants were asked to reenter the Theater Room, Michael asked which trophic level was missing from the food web (decomposers). He began the Food Web Demonstration and described that producers' source of energy is the sun, primary consumers eat producers, secondary consumers eat primary consumers, and tertiary consumers, or apex predators, have no natural predators other than humans. He also described that an ecosystem was not complete unless abiotic factors (e.g. soil, water, oxygen, and sunlight) were also included with the biotic factors. He described a food web as containing only living things, while an ecosystem contains all factors, living and nonliving.

When moving through the Food Web Demonstration, Michael described the "domino effect" of harm to organisms during drought, flood, and fire. He specifically mentioned that Texas trees are adapted for both flood and drought because that alternation of wet and dry is part of North Texas weather. He also mentioned that fire is not necessarily a bad thing because it can make room for new plants and make the soil richer. He recapitulated the demonstration by asking what events can harm ecosystems, what organisms are most immediately affected by those events, and what the participants could do to help the ecosystem. The participants were invited back to the Trinity River Audubon Center and invited to bring up to 10 people using the coupon on the back of their Journal. The participants took the High School Posttest and returned their clipboards to a box in the Theater Room as they prepared to leave the facility.

Data Analysis

Data for this project were collected in 2015 from four grade levels on five separate field trips on September 1, 2, 3, 4, and 18. High-school level assessments completed by pre-service teachers from the observed field trip were not collected because the IRB document submitted by the researcher did not include participants in grades other than fifth, seventh, eighth, or high school. Consent forms were individually checked for completion to ensure all participants were given permission to participate in this study from their parent or guardian. Names of participants with accepted consent forms were entered into a Microsoft Excel spreadsheet and assigned a code number. Codes were assigned thus: 500X for fifth grade, 700X for seventh grade, 800X for eighth grade, and 900X for ninth grade, where X values were positive integers. Names on the Consent Forms were matched with the corresponding Pretest and Posttest and given their assigned code number. Code numbers were written at the top right-hand corner of the consent form and assessments. Assessments were grouped by grade level: fifth, seventh, eighth, and ninth. The grade level of several middle school participants could not be determined, so they were grouped with eighth grade.

Pretests and Posttest content assessment questions were graded for correctness. Correctly-answered questions on Pretests and Posttests were awarded one point, and incorrect answers were awarded zero. Questions that were left blank were also awarded zero points. Assessments that contained more than one unanswered question were discarded. Attitude assessment questions were graded on a scale from 1-5: a score of five points constituted the most positive answer (“Strongly Agree” or “Very Likely”) and a score of one point constituted the most negative (“Strongly Disagree” or “Very Unlikely”). Assessments were discarded if the attitude assessment questions were not complete.

Power Calculation

Power calculations were performed to determine whether the sample sizes of each group were sufficient to confidently reject the null hypotheses proposed by the researcher. The researcher used a tool provided by the Stats To Do website (statstodo.com) to calculate power based upon the mean paired difference of the total content assessment scores for each grade level. The confidence interval for all groups was 95% (α = 0.05) and the power value of 0.2 was selected (1 – β). The power value of the calculation must have been > 0.8 to have statistical power. Power calculation analyses revealed that none of the groups assessed contained a large enough sample size to reliably reject the null hypotheses proposed and to avoid Type II statistical errors (Table 9).

Table 9. Power calculation results

	Sample Size	Mean Paired Difference	Standard Deviation of Paired Difference	Power (1 – β)
Fifth Grade	24	-0.5417	1.1788	0.5790
Seventh Grade	32	-0.0313	1.7503	0.0313
Eighth Grade	49	-0.0408	1.2903	0.0407
Ninth Grade	12	0.1667	1.2673	0.0615

Item Analysis

One of the analyses performed was termed *item analysis* in which each question from the Pretest was compared to its counterpart on the Posttest to determine which learning objectives were satisfied by the field trip. It was hypothesized that a significant increase in item score would be detected when comparing Posttest to Pretest. The mean point values for each question were calculated; the maximum number of points that could be received for each correct answer was 1, so all mean values are between 0 and 1. The mean difference was calculated by subtracting the mean Pretest score from the mean Posttest score. The means were then graphed as a percentage of the group who answered the questions correctly. One-tailed Mann-Whitney U-tests were performed to determine if statistically significant differences could be detected between Pretest and Posttest scores (α = 0.05). The null hypothesis proposed for all groups was that the distribution of Pretest and Posttest scores was identical.

Fifth-Grade Item Analysis

Answers to questions 1, 2, 3, and 5 on the fifth-grade Posttest showed no significant change in score as compared to corresponding questions on the Pretest. A significant decrease in score was seen for question 4 ($p < 0.0005$) because it was a flawed question (Figure 15). There were two correct answers to the Posttest question. The correct answer the researcher intended was answer choice "D," but another correct option was answer choice "B" (Figure 15). No significant increase in score was detected by the Mann-Whitney U-tests between any fifth-grade Pretest and Posttest question, but the sample size was not sufficient to confidently reject or accept the null hypothesis.

Table 10. Fifth-grade mean item analysis scores, score change, and significance ($n = 24$)

	Question 1	Question 2	Question 3	Question 4	Question 5
Mean Pretest	0.67	0.29	0.67	0.67	0.54
Mean Posttest	0.75	0.33	0.83	0.04	0.33
Mean Difference	0.08	0.04	0.16	-0.63	-0.21
P-value	0.316	0.405	0.164	0.0001	0.109

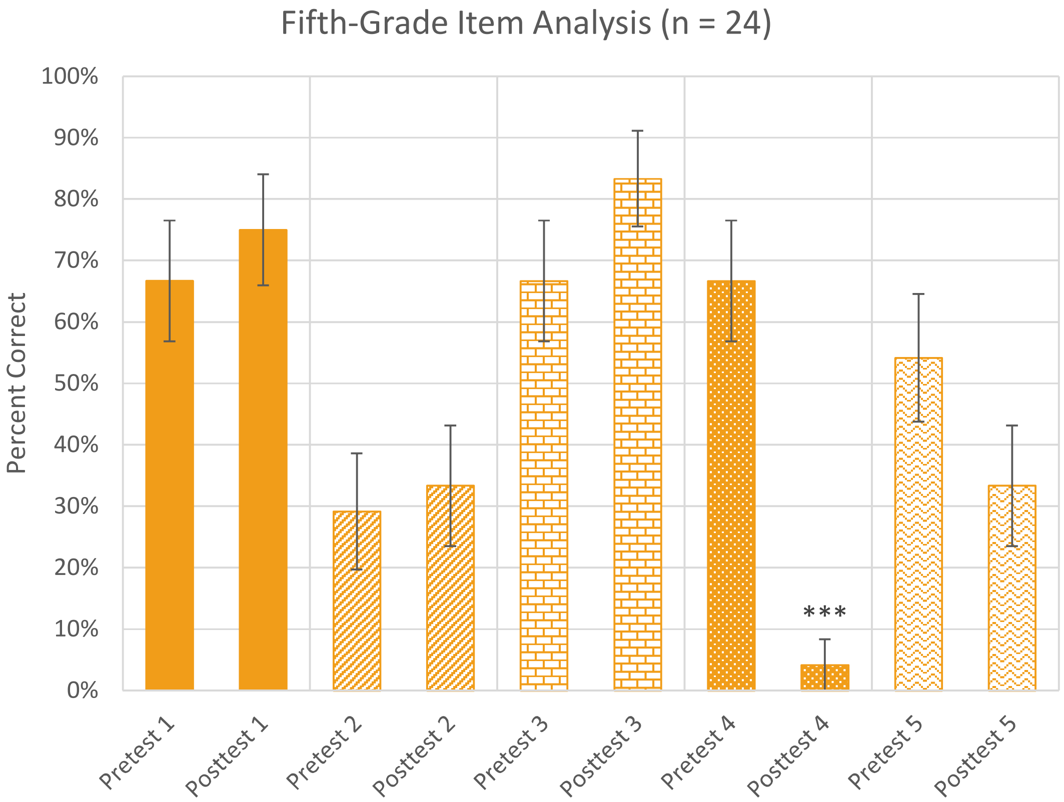


Figure 14. Percent of fifth-grade group who answered correctly on each content assessment question on the assessments. Error bars indicate ± 1 standard error. *** denotes $p < 0.0005$

Using the food web below, answer the following two questions.

A What change would most likely occur if all the producers in this ecosystem were removed?

A The mouse population would increase.
[✓ **B**] All the animals would either die or move away.
C All the animal populations would increase.
D The beetles would become the new producers.

B What change would most likely occur if all the predators in this ecosystem were removed?

A The snake population would increase.
[✓ **B**] The snake population would decrease.
C All the animals would either die or move away.
[✓ **D**] The pine tree population would decrease.

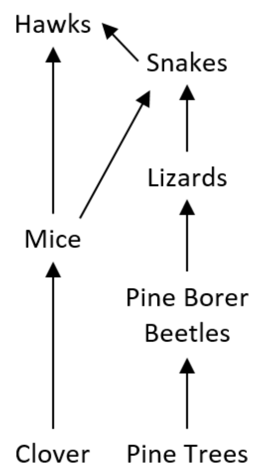


Figure 15. Fifth-grade content assessment question 4. Figure 15A displays the Pretest question, and Figure 15B displays the Posttest question. Correct answer choices are circled in red.

Table 11. Frequency of fifth-grade Pretest and Posttest question 4 answers

	Pretest Answer Choice			
	A	B	C	D
Number	5	16	2	1
Percent of Group	21%	67%	8%	4%
	Posttest Answer Choice			
	A	B	C	D
Number	12	5	6	1
Percent of Group	50%	21%	25%	4%

Seventh- and Eighth-Grade Item Analyses

Seventh- and eighth-grade groups were analyzed separately, but were combined in this section of the work because the participants in both groups completed identical assessments and showed similar trends in their answers. Mann-Whitney U-test analyses revealed a significant decrease in score on question 2 for both seventh- and eighth-grade groups ($p < 0.05$ and $p < 0.005$, respectively), and a significant increase in score on question 5 for both seventh- and eighth-grade groups ($p < 0.05$ and $p < 0.005$, respectively, Figure 16 and Figure 17). The sample sizes of the seventh- and eighth-grade participants were not sufficient to confidently reject or accept the null hypothesis.

Table 12. Seventh-grade mean item analysis scores, score change, and significance (*n* = 32)

	Question 1	Question 2	Question 3	Question 4	Question 5
Mean Pretest	0.59	0.91	0.75	0.41	0.16
Mean Posttest	0.41	0.59	0.72	0.63	044
Mean Difference	-0.19	-0.31	-0.03	0.22	0.28
P-value	0.100	0.016	0.417	0.067	0.027

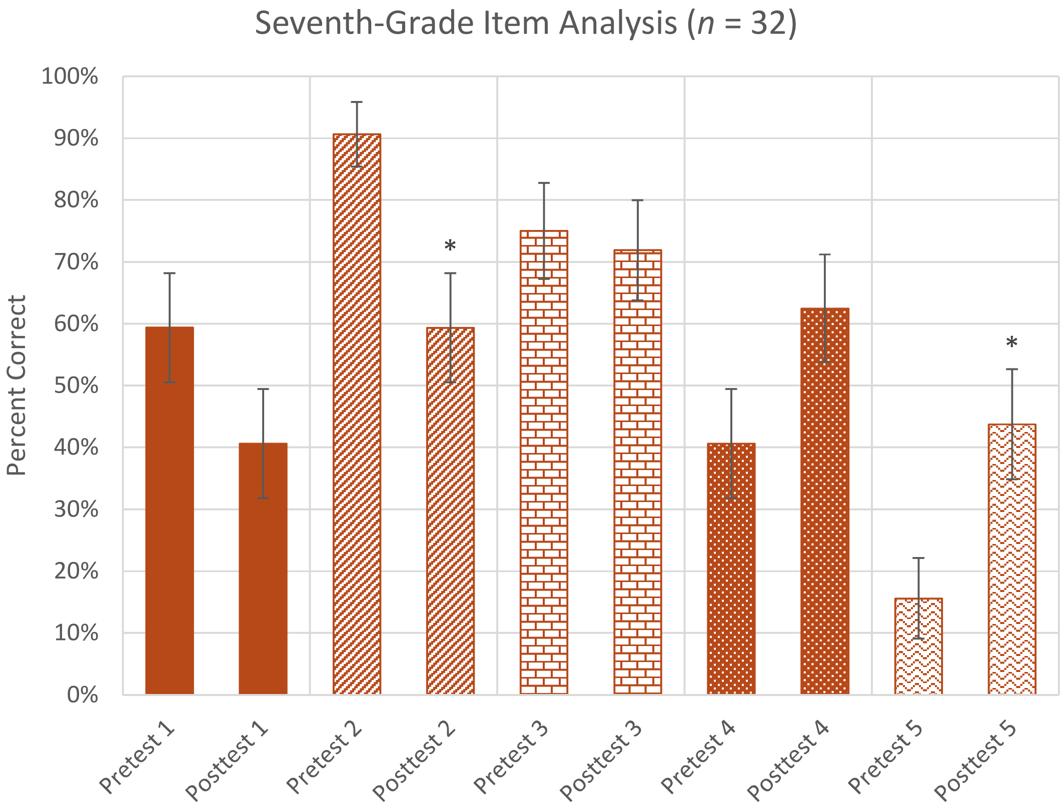


Figure 16. Percent of seventh-grade group who answered correctly on each content assessment question on the assessments. Error bars indicate ± 1 standard error. * denotes $p < 0.05$

Table 13. Eighth-grade mean item analysis scores, score change, and significance (*n* = 49)

	Question 1	Question 2	Question 3	Question 4	Question 5
Mean Pretest	0.67	0.88	0.78	0.49	0.20
Mean Posttest	0.63	0.59	0.71	0.55	0.49
Mean Difference	-0.04	-0.29	-0.06	0.06	0.29
P-value	0.364	0.008	0.302	0.302	0.008

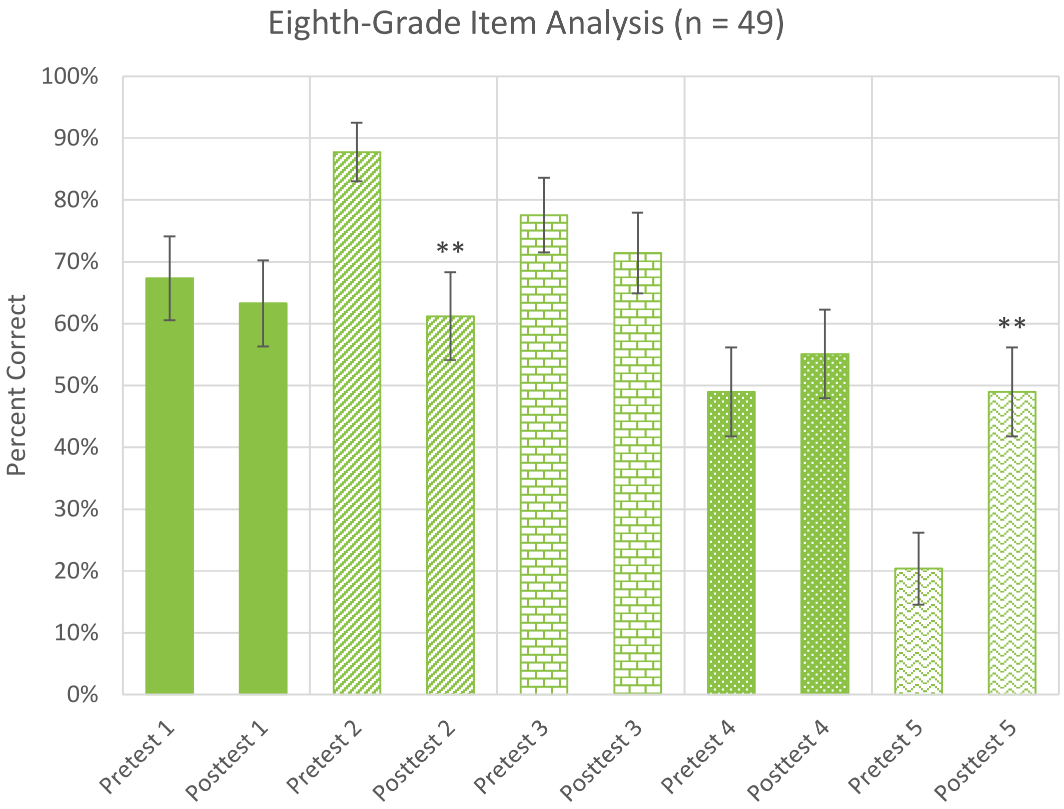


Figure 17. Percent of eighth-grade group who answered correctly on each content assessment question on the assessments. Error bars indicate ± 1 standard error. ** denotes $p < 0.005$

Using the food web below, answer the following three questions.

A Which statement most appropriately reflects a feeding relationship in the food web below?

[✓ **A**] Hawks are predators and mice are prey.
B Beetles are producers and lizards are consumers.
C Clover are parasites and mice are hosts.
D Beetles are parasites and lizards are hosts.

B Which statement most appropriately reflects a feeding relationship in the food web below?

A Mice are predators and clover are prey.
[✓ **B**] Pine trees are producers and beetles are consumers.
C Clover are parasites and mice are hosts.
D Beetles are parasites and lizards are hosts.

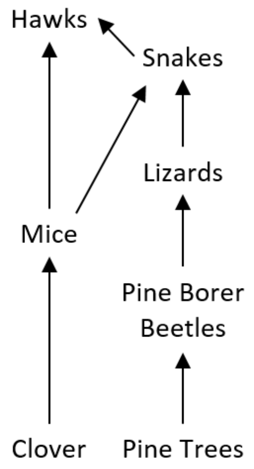


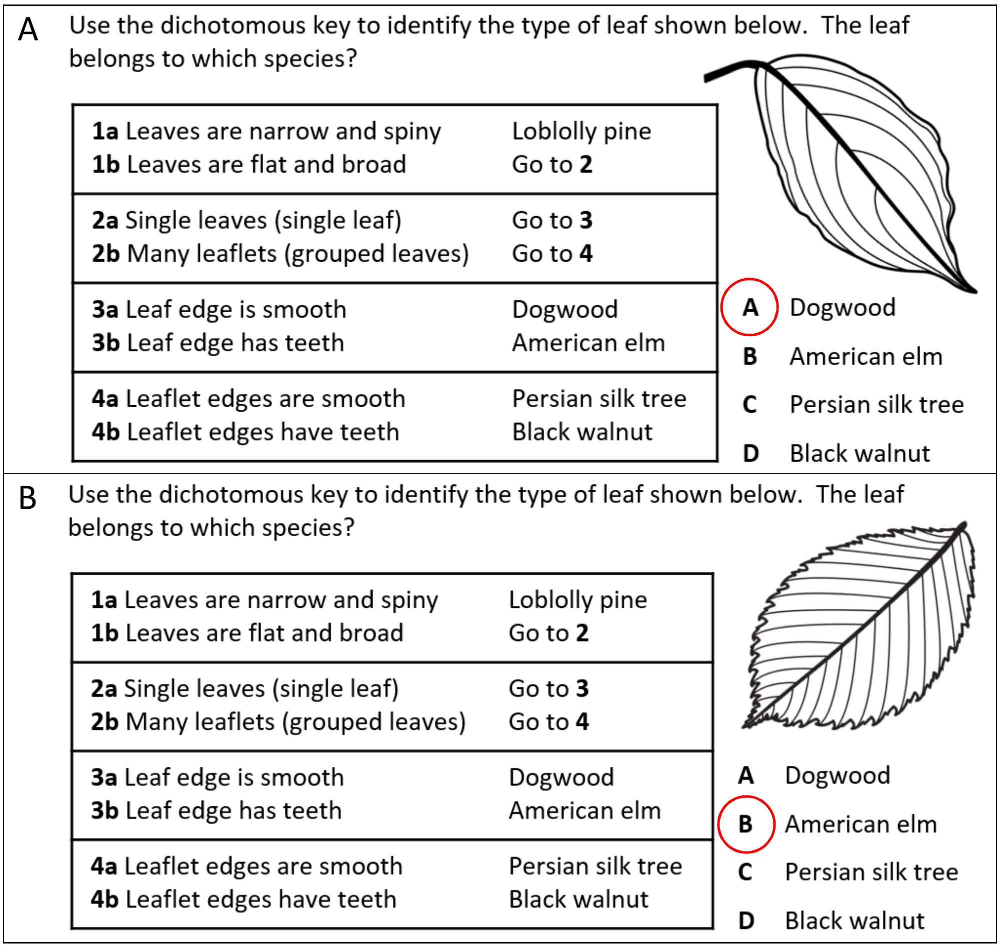
Figure 18. Seventh- and eighth-grade content assessment question 2. Figure 18A displays the Pretest question, and Figure 18B displays the Posttest question. Correct answer choices are circled in red.

Table 14. Frequency of seventh-grade Pretest and Posttest question 2 answers

	Pretest Answer Choice			
	A	B	C	D
Number	29	1	1	1
Percent of Group	91%	3%	3%	3%
	Posttest Answer Choice			
	A	B	C	D
Number	6	19	3	4
Percent of Group	19%	59%	9%	13%

Table 15. Frequency of eighth-grade Pretest and Posttest question 2 answers

	Pretest Answer Choice			
	A	B	C	D
Number	43	1	3	2
Percent of Group	88%	2%	6%	4%
	Posttest Answer Choice			
	A	B	C	D
Number	10	30	3	6
Percent of Group	20%	61%	6%	12%



A Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are narrow and spiny	Loblolly pine
1b Leaves are flat and broad	Go to **2**
2a Single leaves (single leaf)	Go to **3**
2b Many leaflets (grouped leaves)	Go to **4**
3a Leaf edge is smooth	Dogwood
3b Leaf edge has teeth	American elm
4a Leaflet edges are smooth	Persian silk tree
4b Leaflet edges have teeth	Black walnut

[✓ **A**] Dogwood

B American elm

C Persian silk tree

D Black walnut

B Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are narrow and spiny	Loblolly pine
1b Leaves are flat and broad	Go to **2**
2a Single leaves (single leaf)	Go to **3**
2b Many leaflets (grouped leaves)	Go to **4**
3a Leaf edge is smooth	Dogwood
3b Leaf edge has teeth	American elm
4a Leaflet edges are smooth	Persian silk tree
4b Leaflet edges have teeth	Black walnut

A Dogwood

[✓ **B**] American elm

C Persian silk tree

D Black walnut

Figure 19. Seventh-grade content assessment question 5. Figure 19A displays the Pretest question, and Figure 19B displays the Posttest question. Correct answer choices are circled in red.

Table 16. Frequency of seventh-grade Pretest and Posttest question 5 answers

	Pretest Answer Choice			
	A	B	C	D
Number	5	10	8	7
Percent of Group	16%	31%	25%	22%
	Posttest Answer Choice			
	A	B	C	D
Number	4	14	8	3
Percent of Group	13%	44%	25%	9%

Table 17. Frequency of eighth-grade Pretest and Posttest question 5 answers

	Pretest Answer Choice			
	A	B	C	D
Number	10	20	14	5
Percent of Group	20%	41%	29%	10%
	Posttest Answer Choice			
	A	B	C	D
Number	9	23	6	10
Percent of Group	18%	47%	12%	20%

Ninth-Grade Item Analysis

Table 18. Ninth-grade mean item analysis scores, score change, and significance (*n* = 12)

	Question 1	Question 2	Question 3	Question 4	Question 5
Mean Pretest	0.75	0.58	0.33	0.58	0.33
Mean Posttest	0.5	0.5	0.5	0.66	0.58
Mean Difference	-0.25	-0.8	-0.17	0.08	0.25
P-value	0.156	0.374	0.255	0.374	0.156

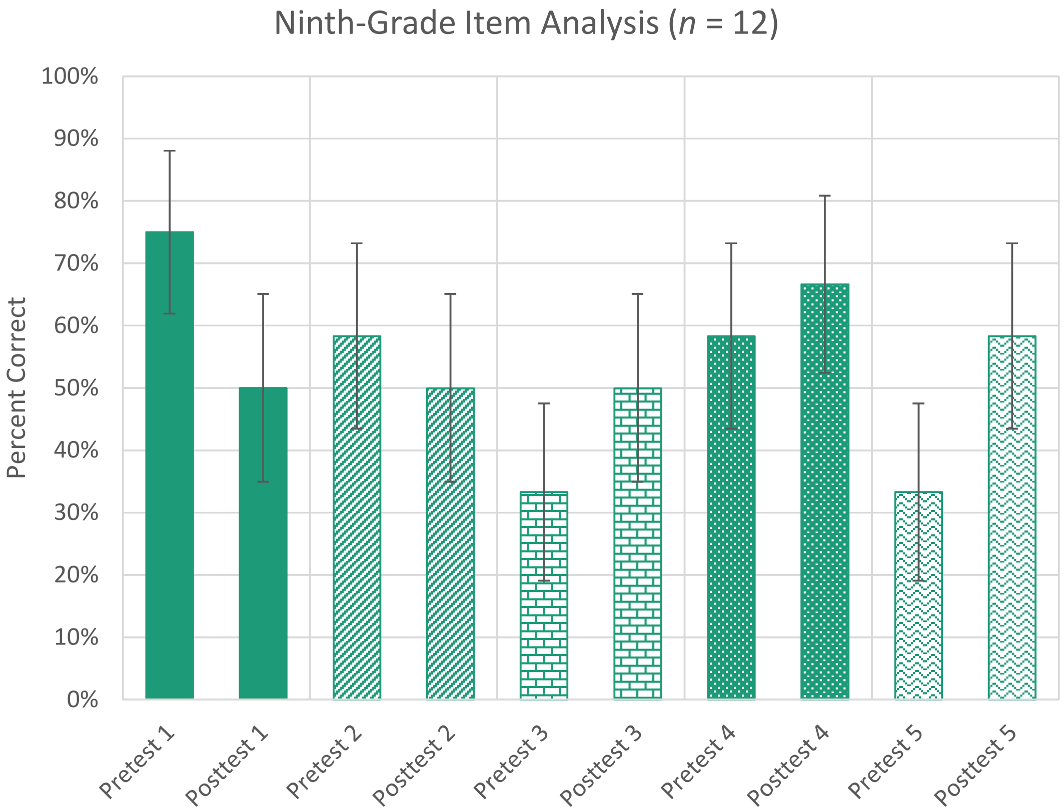


Figure 20. Percent of ninth-grade group who answered correctly on each content assessment question on the assessments. Error bars indicate ± 1 standard error.

No content assessment question in the ninth-grade group showed any statistically significant improvement or decline. The sample size was not sufficient to confidently reject or accept the null hypothesis.

Total Content Assessment Score

Total content assessment scores were determined by adding the point values for each participant's assessment questions together for a minimum value of 0 and a maximum value of 5 on each the Pretest and Posttest. All totaled results for each assessment were then subjected to a paired one-tailed *t*-test to obtain the mean and *p*-value to indicate statistical significance ($\alpha = 0.05$). The seventh-, eighth-, and ninth-grade groups showed no significant change in total content assessment score. Before omitting the flawed question 4 from the fifth-grade assessment, the fifth-grade group showed a significant decrease in total content assessment score ($p < 0.05$). After omission of question 4 and calculating the percent score by dividing scores by 4 points instead of 5, no statistically significant difference in score was detected. Larger data sets would have allowed rejection or acceptance of the null hypothesis.

Table 19. Content score mean percentages, standard error and paired *t*-test results

	Assessment	Mean Percent	Standard Error	*P*-Value
Fifth Grade	Pretest	56%	0.206	0.470
	Posttest	56%	0.201	
Seventh Grade	Pretest	56%	0.208	0.460
	Posttest	56%	0.290	
Eighth Grade	Pretest	60%	0.166	0.413
	Posttest	60%	0.219	
Ninth Grade	Pretest	52%	0.336	0.329
	Posttest	56%	0.329	

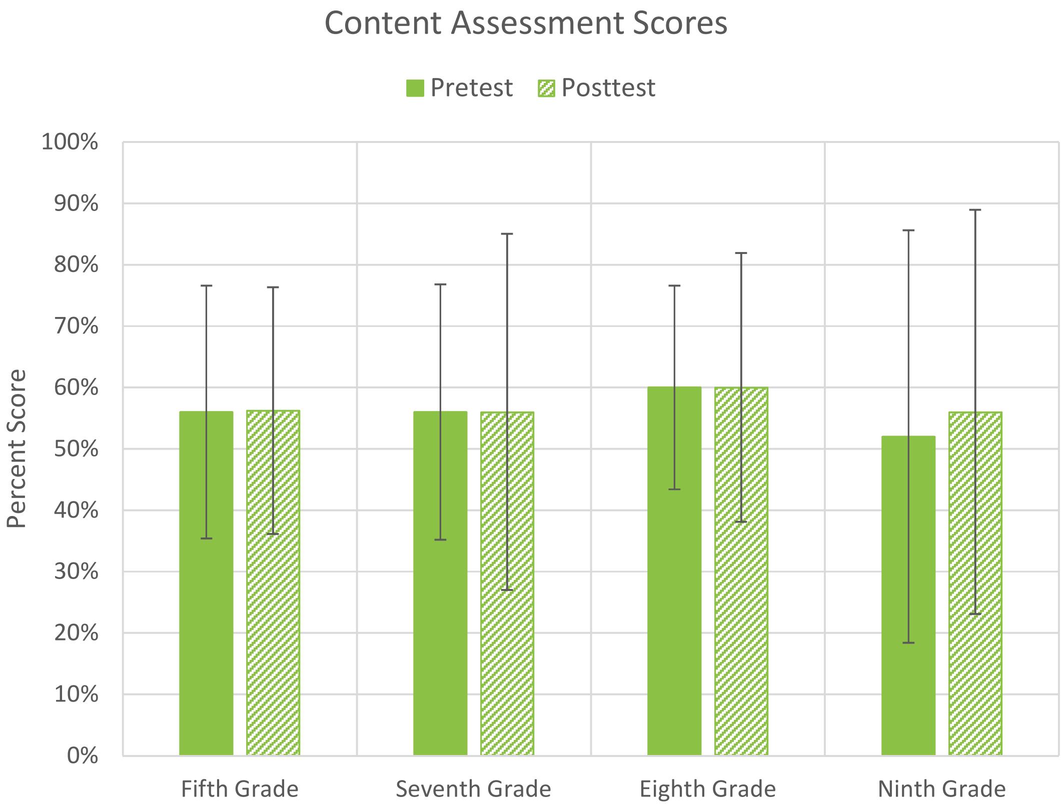


Figure 21. Content assessment scores for each grade level. Error bars indicate ± 1 standard error.

Change in Total Content Assessment Score

Total content assessment score change was calculated by subtracting each participant's Pretest score from their Posttest score. It was possible for participants to decrease or increase their score by 5 points; the lowest possible score participants could receive was 0 and the highest possible was 5. The number of participants in each group who scored above, the same as, and below their original score was tallied. The percent of the group *n* was calculated. Table 20 describes the percent of participants in each group who showed an increase, decrease, or no change in content score. *P*-values are those from Table 19.

Table 20. Change in percent participant content score

	Decreased Score	No Change	Increased Score	*P*-Value
Fifth Grade	38%	46%	17%	0.470
Seventh Grade	44%	16%	41%	0.460
Eighth Grade	33%	27%	41%	0.413
Ninth Grade	25%	17%	58%	0.329

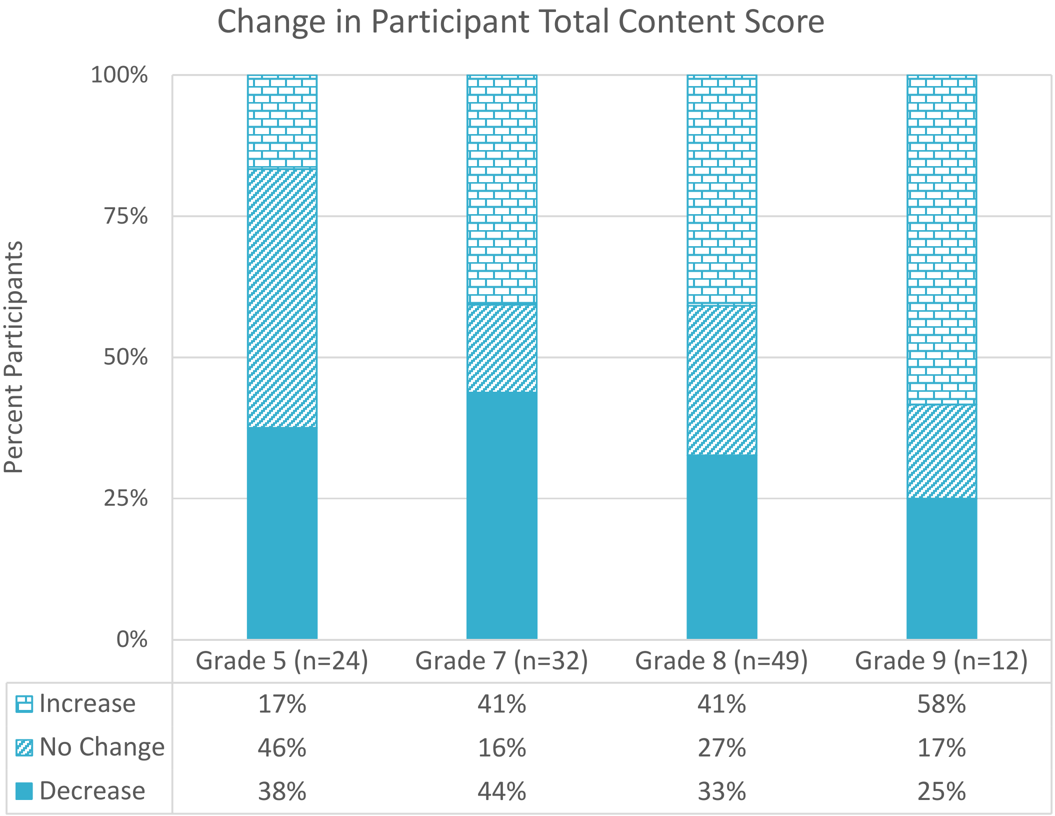


Figure 22. Percent participant content assessment score change.

The score change was calculated for the fifth-grade group including and omitting the flawed question 4. Paired *t*-test showed no significant difference was detected in score change ($p > 0.05$), so question 4 was included in this data set. No group showed a statistically significant change in total assessment paired one-tailed *t*-test. The data set was not sufficient to confidently reject or accept the null hypothesis.

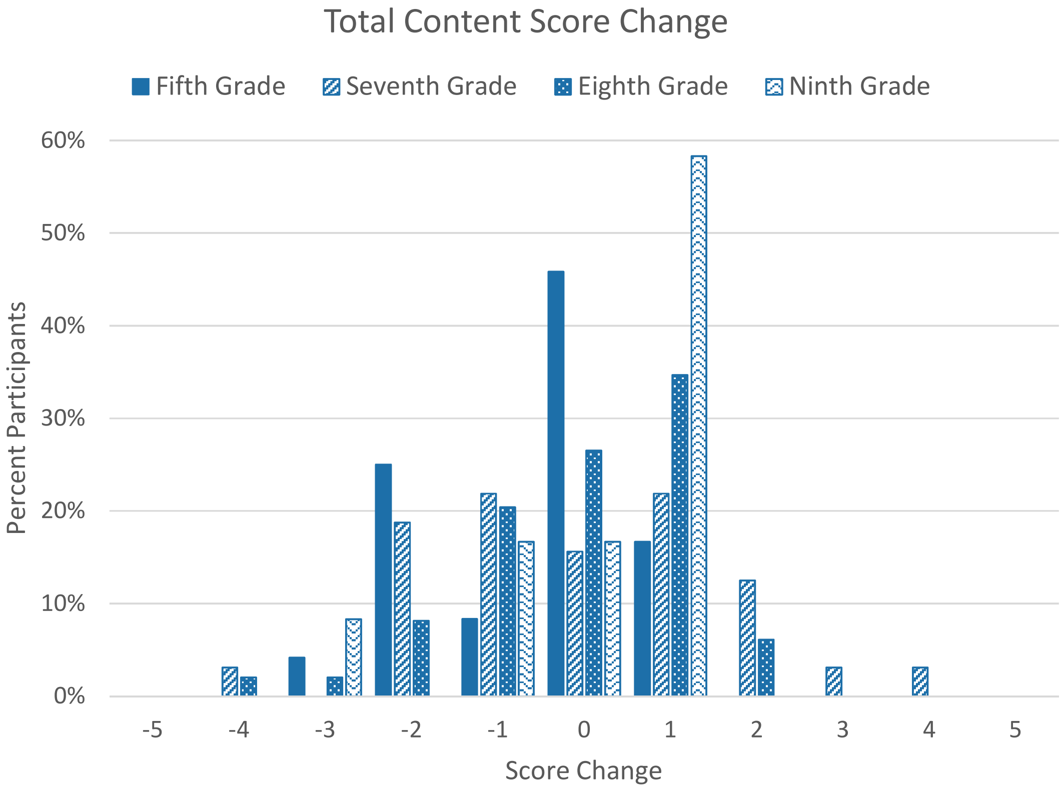


Figure 23. Distribution of score changes among all participant groups.

Figure 23 shows the distribution of score changes among all assessment groups. The graph shows a fairly normal distribution of score changes: the majority of participants' scores increased or decreased by only one or two points, and many showed no score change at all. Of the total 117 participants in this study 87, or 74%, showed a decrease by one point, no change, or an increase by one point.

The first hypothesis stated that three new learning modules at the Trinity River Audubon Center would enhance participants' content knowledge about the subjects addressed in the modules. The alternative hypothesis proposed for paired one-tailed *t*-tests stated that significant increases in content comprehension would be detected. Statistical analyses confirmed that no statistically significant differences were found for any of the three academic levels assessed. No significant increase in overall score was detected for any grade level, but the sample sizes were not sufficient to confidently reject or accept the null hypothesis.

Attitude Change

The second hypothesis proposed by the researcher stated that participants will show a more positive attitude toward learning in an informal science environment. Several sets of data were used to analyze attitude. First, participants were categorized by what type of activity they would most likely pursue if outdoors. The choices provided were, "Play soccer," "Go on a hike," "Walk around downtown," "Ride a bicycle," and "I would not go outside" (Figure 24). Participants were also categorized by how much time they spend outside. The available choices were, "0-1 hour," "2-3 hours," "4-5 hours," "6-7 hours," and "More than 7 hours". Over 50% of all seventh-, eighth-, and ninth-grade participants said they spent 3 or fewer hours outdoors per week (Figure 25).

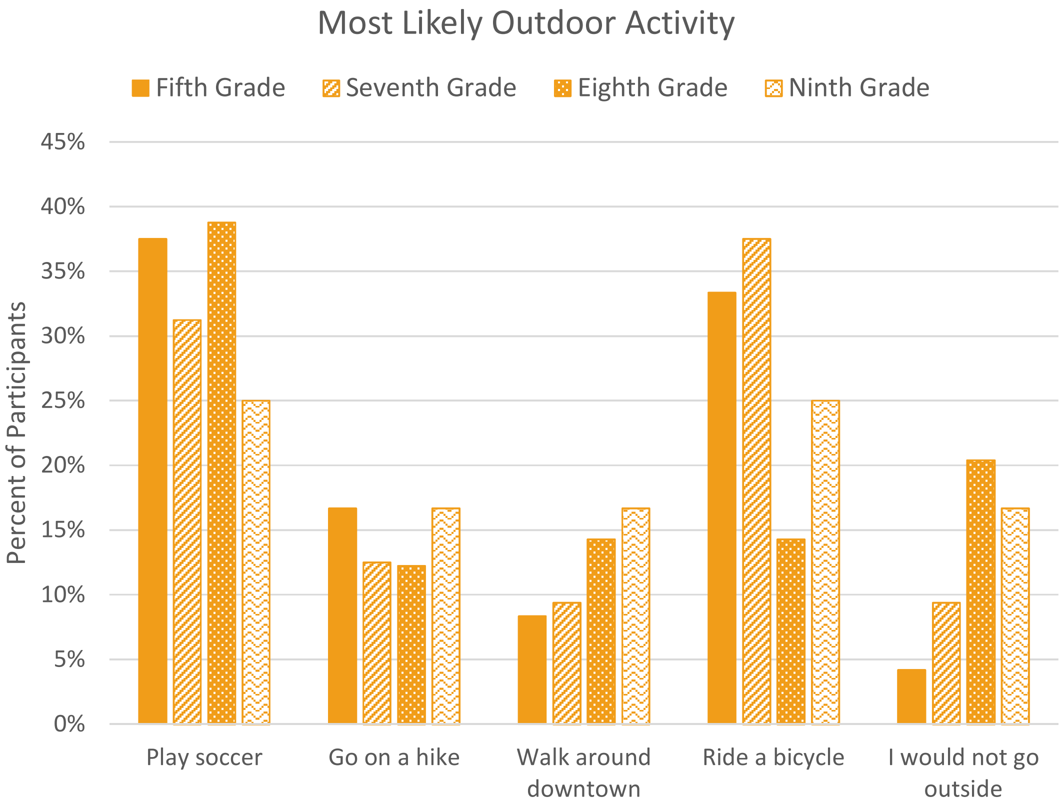
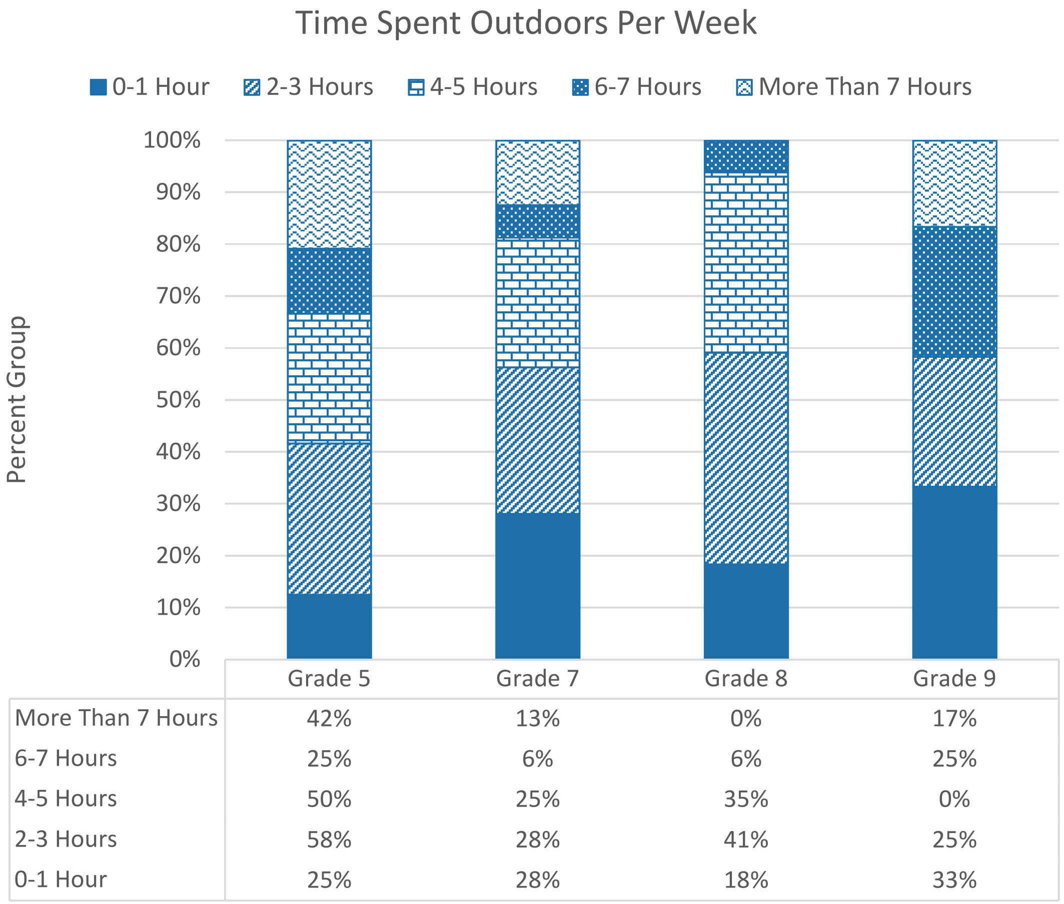


Figure 24 Participants selected which of five activities they would most likely do outdoors.



	Grade 5	Grade 7	Grade 8	Grade 9
More Than 7 Hours	42%	13%	0%	17%
6-7 Hours	25%	6%	6%	25%
4-5 Hours	50%	25%	35%	0%
2-3 Hours	58%	28%	41%	25%
0-1 Hour	25%	28%	18%	33%

Figure 25. Average number of hours each group spent outdoors per week.

Attitude Score Change

Mean attitude scores were calculated for each group and subjected to paired one-tailed *t*-tests (α = 0.05). Attitude assessment question 1 on the Pretest stated, “I really wanted to come to the Trinity River Audubon Center,” and its counterpart on the Posttest, “I’m really glad I came to the Trinity River Audubon Center.” Both fifth-grade and eighth-grade group answers showed statistically significant increases on the posttest (*p* < 0.05 and *p* < 0.005, respectively), but seventh- and ninth-grade participants did not show statistically significant increases in attitude score. Sample sizes were not sufficient to confidently reject or accept the null hypothesis.

Attitude Question 1 Scores

Table 21. Means and *p*-values for attitude assessment question 1

	Pretest Mean	Posttest Mean	*p*-value
Fifth Grade	4.00	4.33	0.009
Seventh Grade	3.81	3.94	0.211
Eighth Grade	3.20	3.51	0.003
Ninth Grade	3.50	3.83	0.052

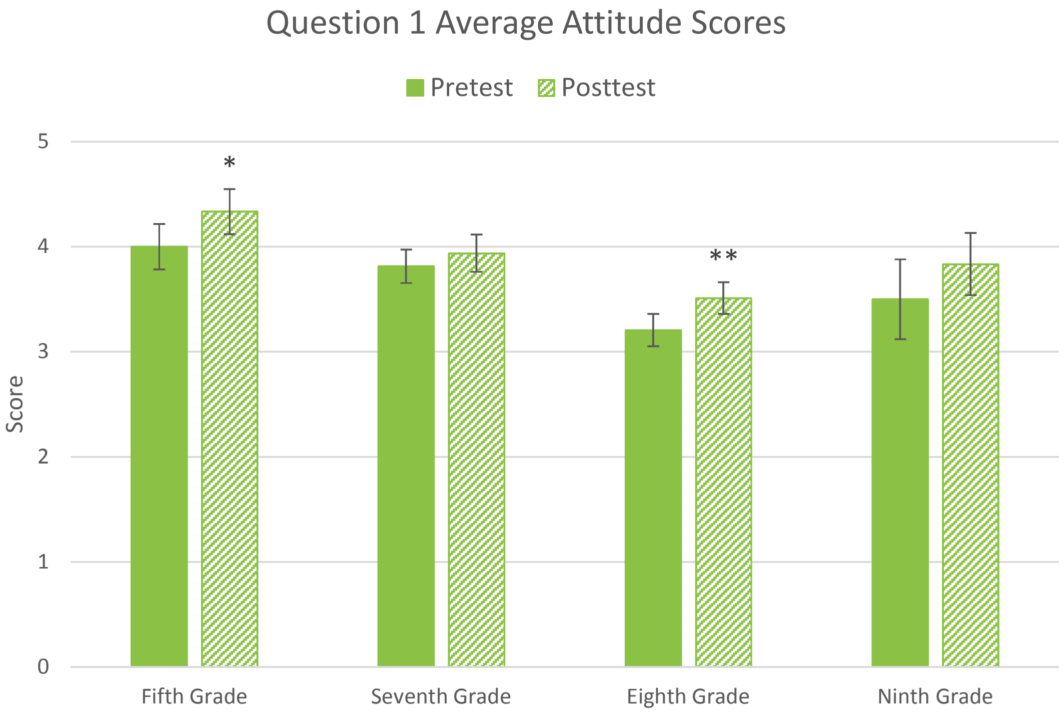


Figure 26. Average participant responses to attitude assessment question 1. Error bars indicate ± 1 standard error.
* denotes *p* < 0.05
** denotes *p* < 0.005

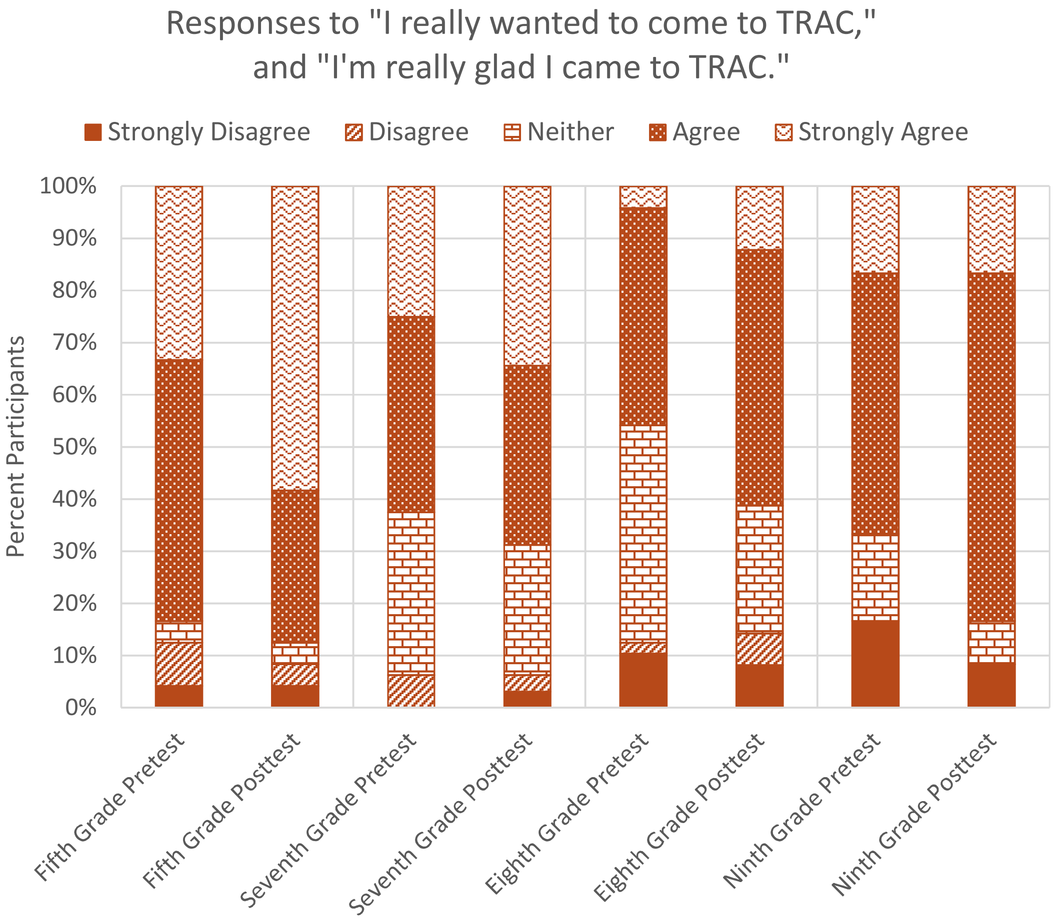


Figure 27. Percent response values for attitude assessment question 1.

Attitude Question 2 Scores

Attitude assessment question 2 on the Pretest stated, “I think I will enjoy my experiences today,” and its counterpart on the Posttest, “I really enjoyed my experiences today.” No group showed statistically significant increase in score, though the sample size was not sufficient to confidently reject or accept the null hypothesis.

Table 22. Means and *p*-values for attitude assessment question 2

	Pretest Mean	Posttest Mean	*p*-value
Fifth Grade	4.38	4.33	0.407
Seventh Grade	3.97	4.06	0.250
Eighth Grade	3.69	3.65	0.355
Ninth Grade	4.00	4.00	0.5

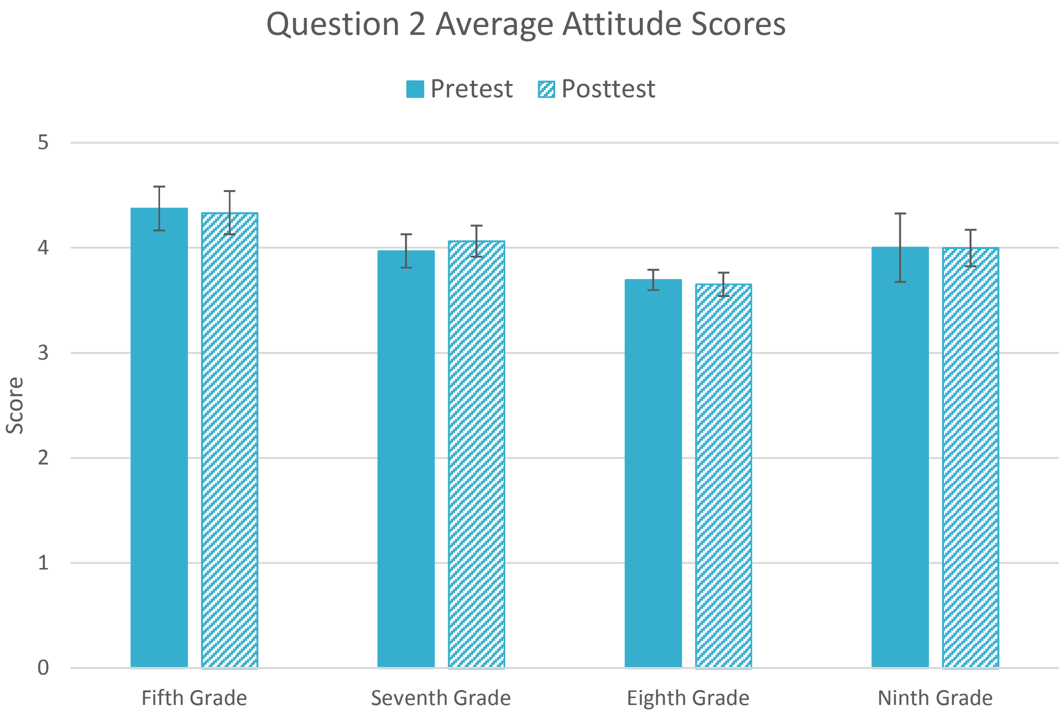


Figure 28. Average participant responses to attitude assessment question 2. Error bars indicate ± 1 standard error.

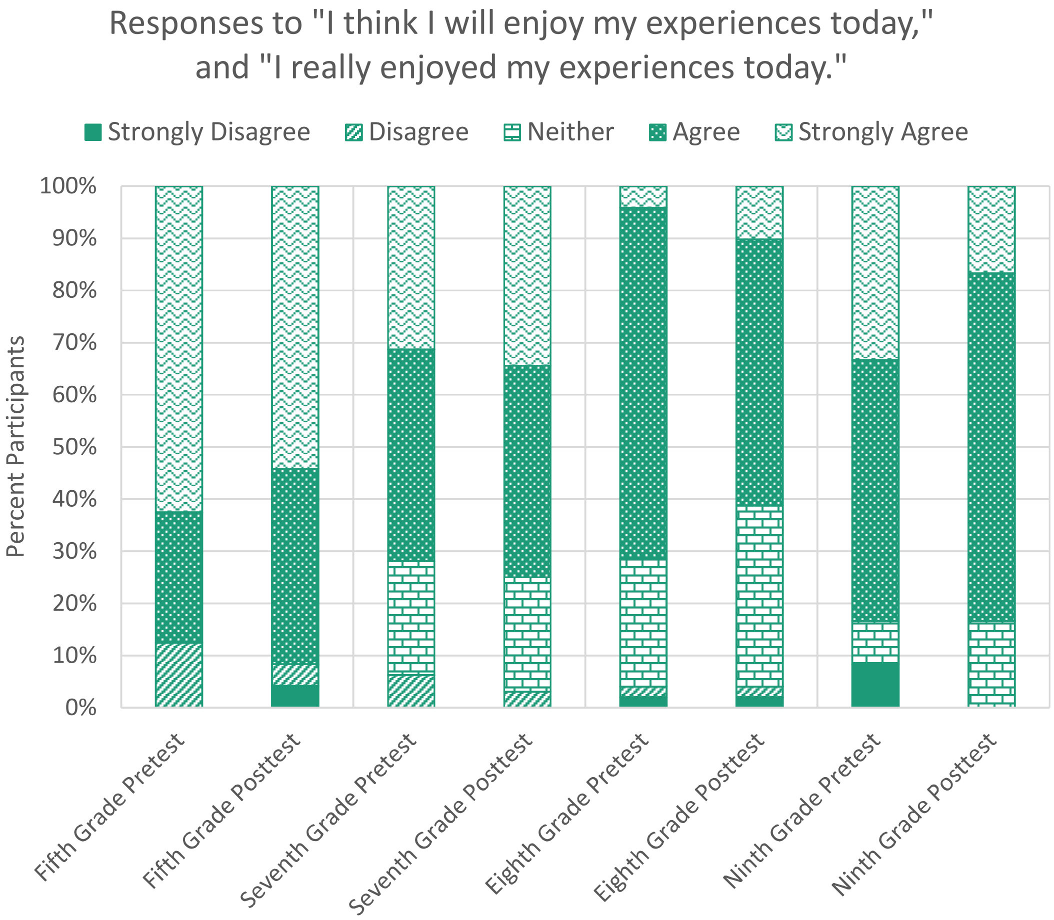


Figure 29. Percent response values for attitude assessment question 2.

Average Attitude Score Changes

No group showed statistically significant increase in overall attitude score, though the sample sizes were not sufficient to confidently reject or accept the null hypothesis.

Table 23. Means and *p*-values for average attitude assessment scores

	Pretest Mean	Posttest Mean	*p*-value
Fifth Grade	4.19	4.33	0.098
Seventh Grade	3.89	4	0.145
Eighth Grade	3.45	3.58	0.045
Ninth Grade	3.75	3.92	0.128

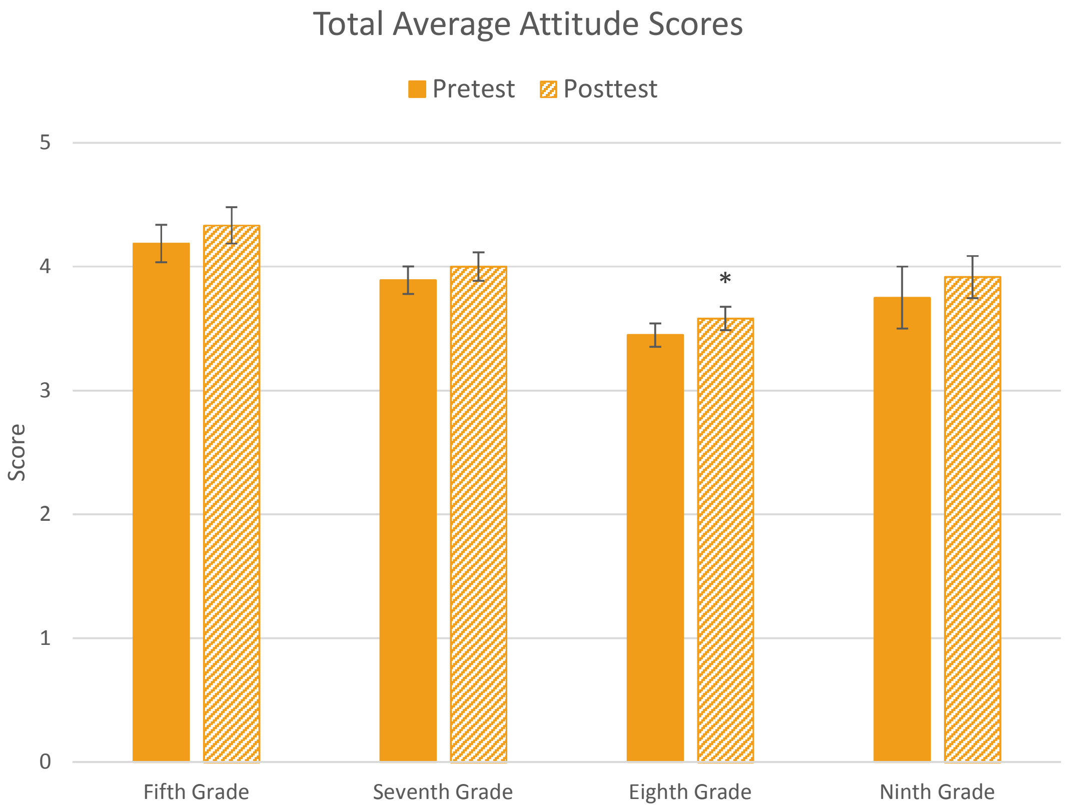


Figure 30. Average total attitude score. Error bars indicate ± 1 standard error.
* denotes $p < 0.05$

Attitude Toward Learning in Informal Science Environments

Three items that appeared exclusively on the Posttests were used to assess attitudes toward learning in informal learning environments: “Based upon my experiences today I am likely to spend more time outdoors," "I would like to visit the Trinity River Audubon Center again," and "I would like to visit other nature centers like the Trinity River Audubon Center." The average score for each question was calculated (Figure 31). The total number of each response value was calculated and graphed as a percent of participants who responded to the statement for each question (Figure 32, Figure 33, and Figure 34).

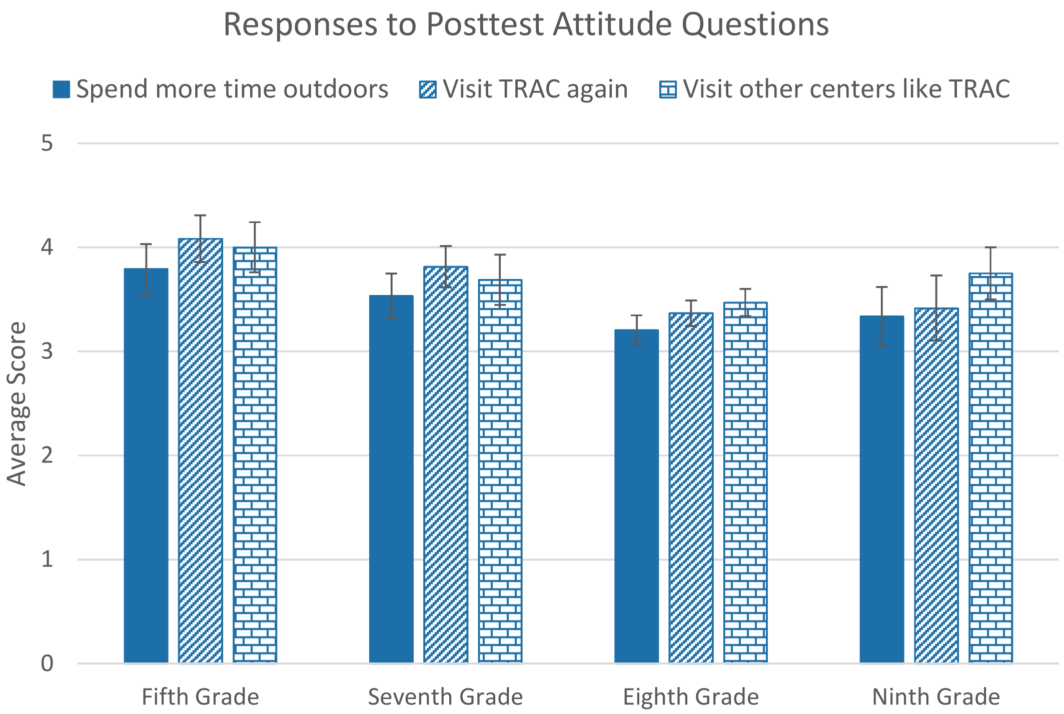


Figure 31. Average responses to attitude questions regarding learning in informal science environments. Error bars indicate ± 1 standard error.

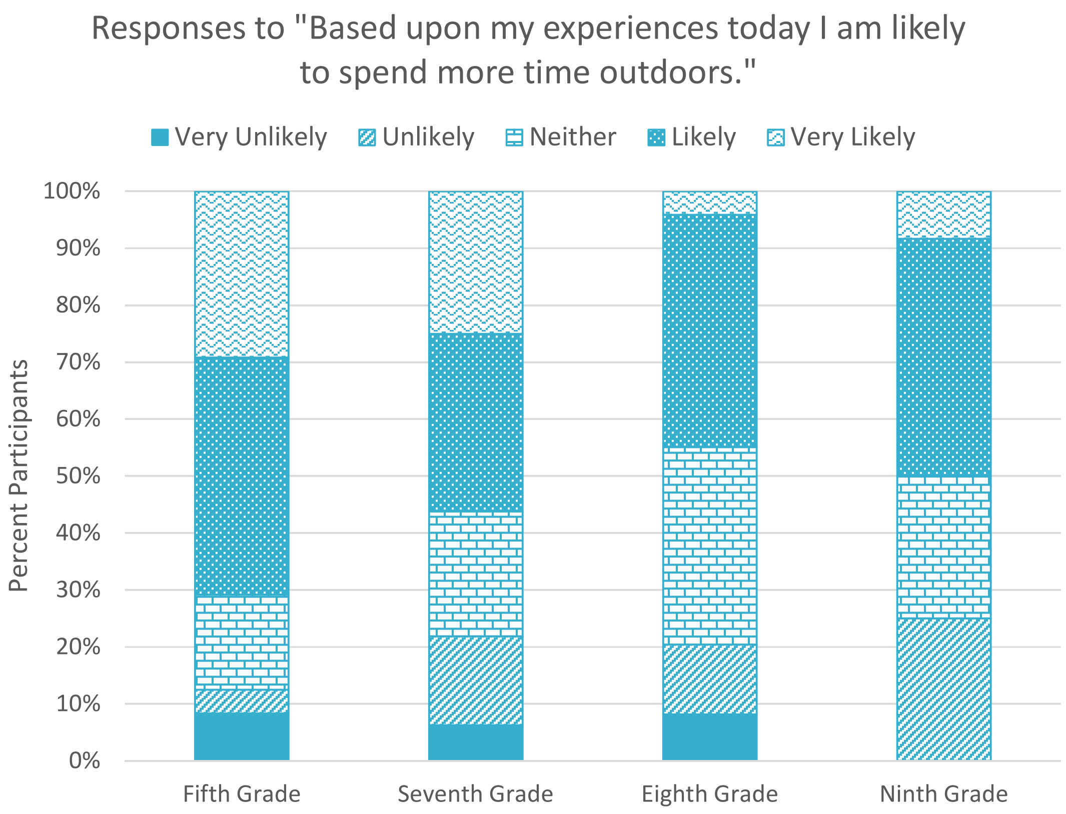


Figure 32 Responses to Posttest statement, “Based upon my experiences today I am likely to spend more time outdoors.”

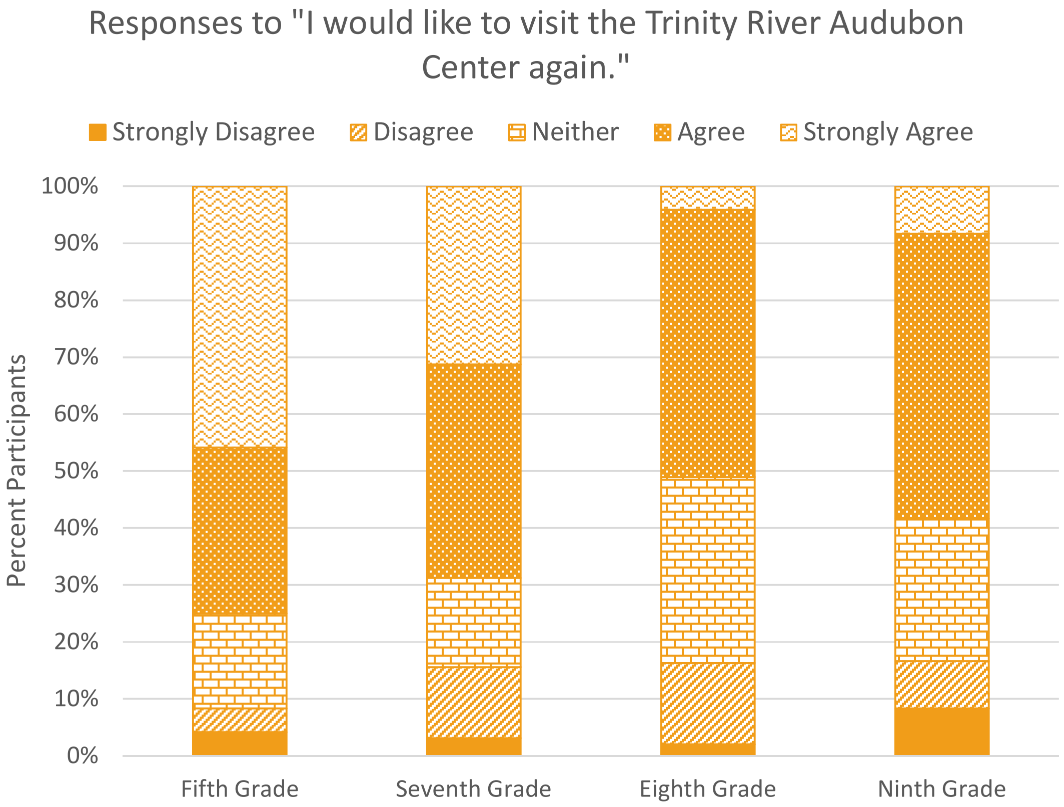


Figure 33. Responses to Posttest statement, “I would like to visit the Trinity River Audubon Center Again.”

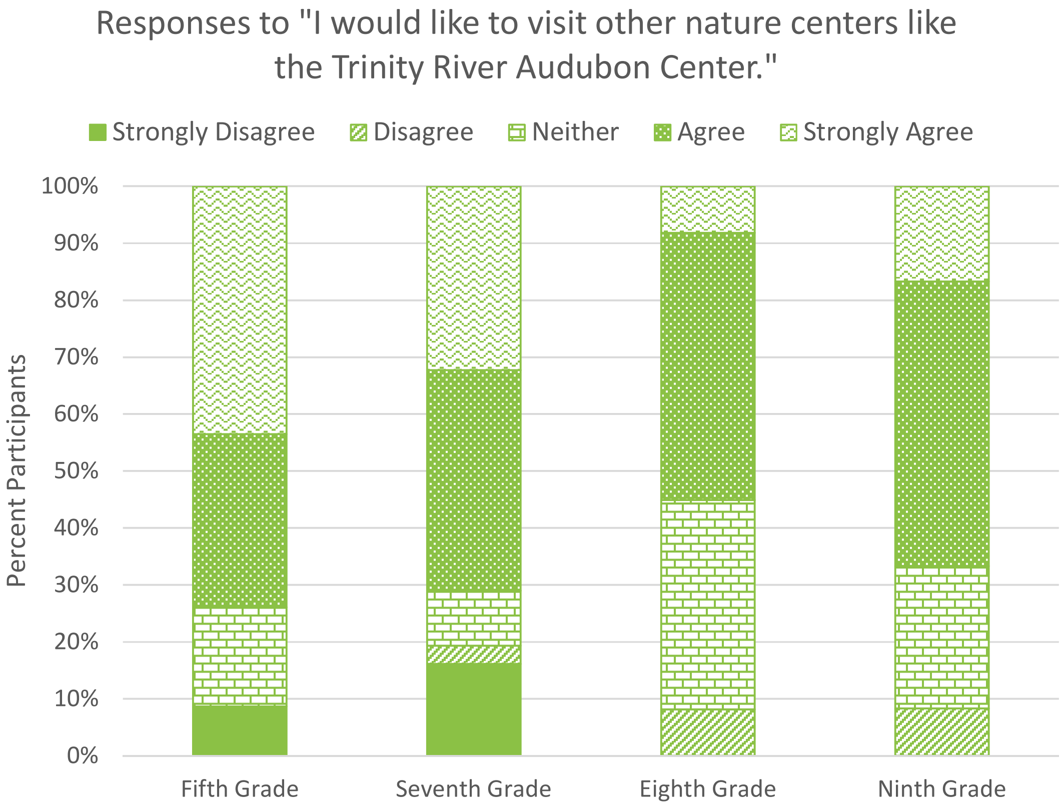


Figure 34. Responses to Posttest statement, “I would like to visit other nature centers like the Trinity River Audubon Center.”

Attitude and Content Change Correlation

It is understood by many researchers that interest and enthusiasm correlate directly with authentic learning (Dierks, Höffler, and Parchmann 2014; Fenichel and Schweingruber 2010; Hidi and Reinniger 2006; Holmes 2011; NRC 2009; Uitto et al. 2009; Yoon et al. 2012). In alignment with that understanding, the correlation between initial attitude score and content comprehension score change was calculated by Pearson’s correlation analysis. It was hypothesized that a positive correlation between attitude score and content score change would exist. The correlation coefficients were calculated for all sets of data. The null hypotheses could not confidently be rejected nor accepted due to insufficient sample sizes.

Table 24. Correlation between initial attitude score and content score change

	Coefficient	Correlation	Direction
Fifth Grade	-0.433	medium	negative
Seventh Grade	-0.275	low	negative
Eighth Grade	-0.013	low	negative
Ninth Grade	0.396	medium	positive

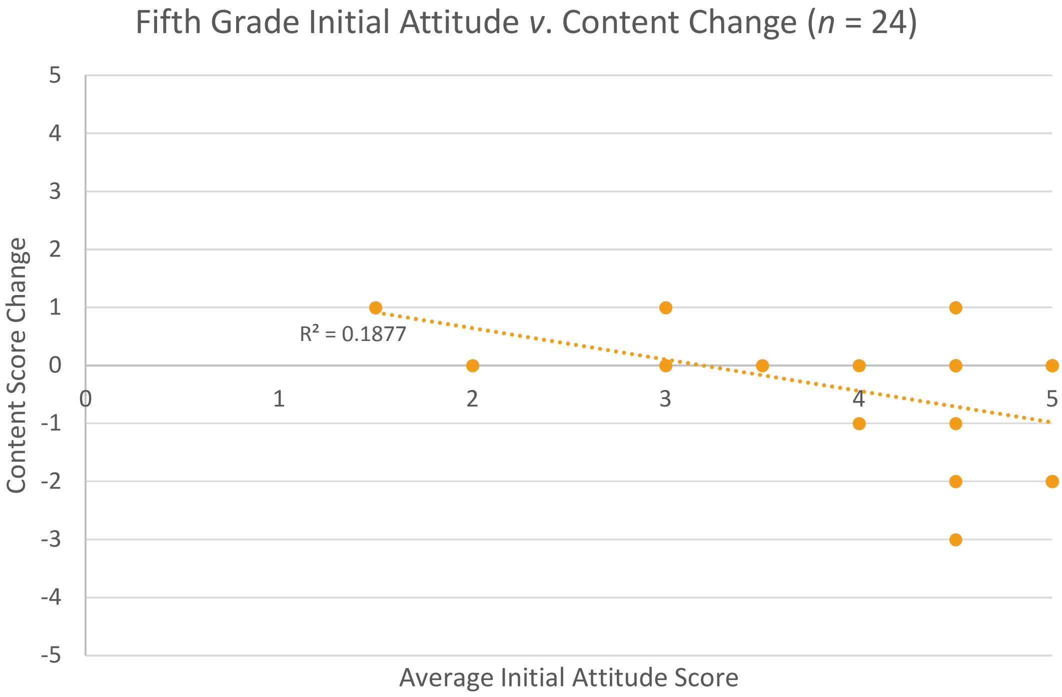


Figure 35. Fifth-grade initial attitude score versus content change score. Superimposed is a linear trendline displaying the coefficient of determination (R^2).

The correlation between initial attitude score for fifth-grade participants was a medium negative correlation (-0.433), and the coefficient of determination (0.1877) shows that the distribution of data is fairly random and the regression line does not fit the data well.

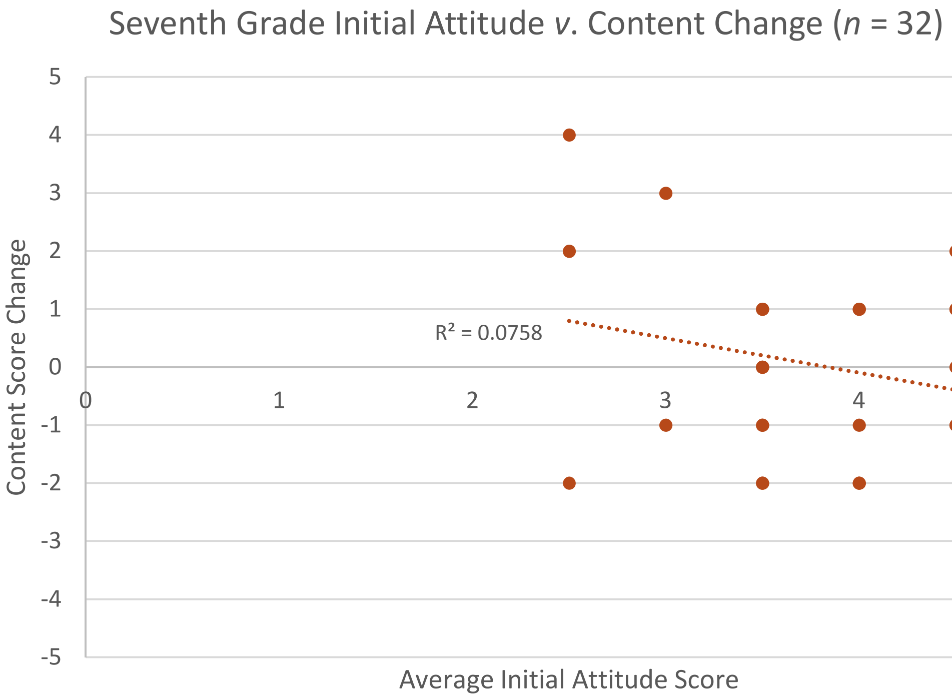


Figure 36. Seventh-grade initial attitude score versus content change score. Superimposed is a linear trendline displaying the coefficient of determination (R^2).

The correlation between initial attitude score for seventh-grade participants was a low negative correlation (-0.275), and the coefficient of determination (0.0758) shows that the distribution of data is fairly random and the regression line does not fit the data well.

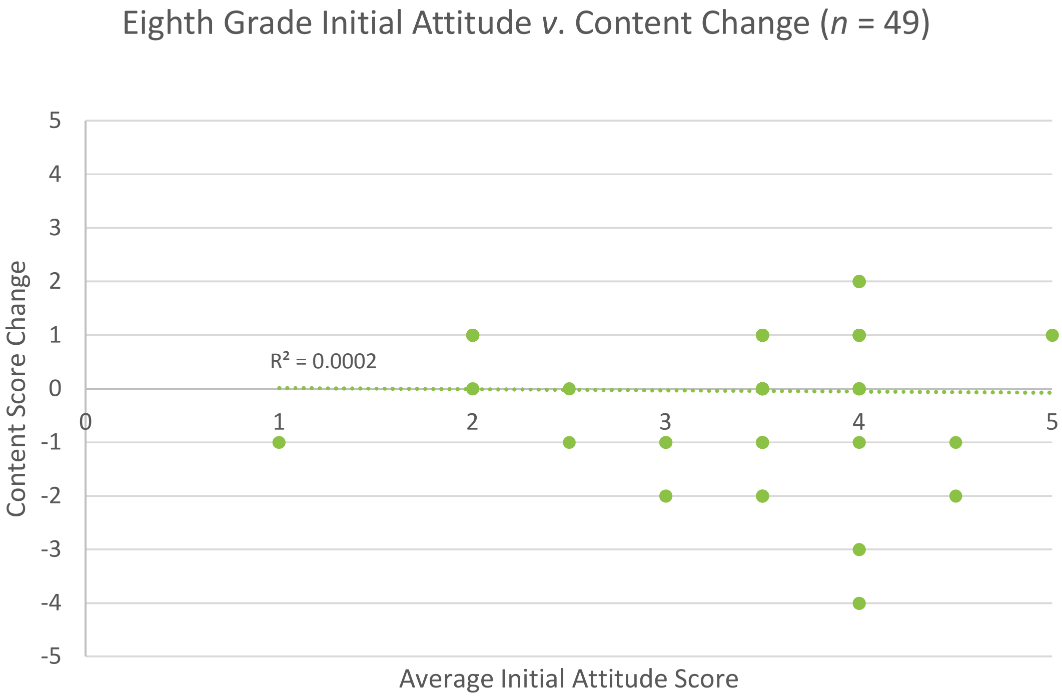


Figure 37. Eighth-grade initial attitude score versus content change score. Superimposed is a linear trendline displaying the coefficient of determination (R^2).

The correlation between initial attitude score for seventh-grade participants was a very low negative correlation (-0.013), and the coefficient of determination (0.0002) shows that the distribution of data is fairly random and the regression line does not fit the data.

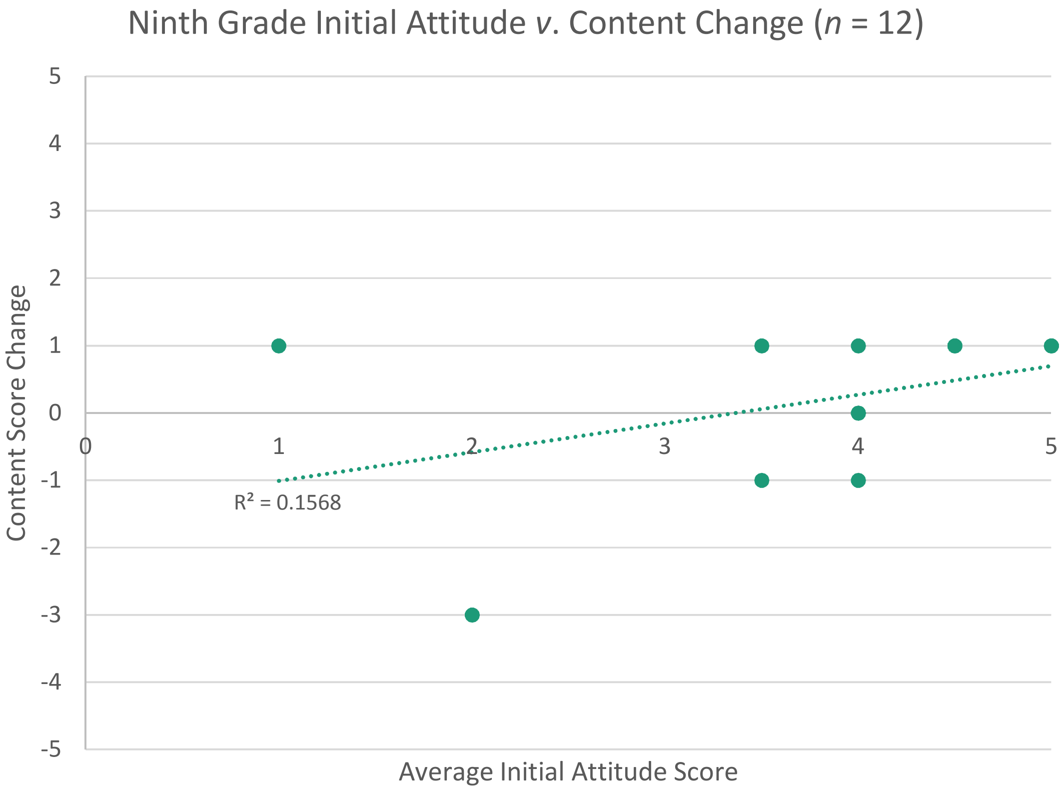


Figure 38. Ninth-grade initial attitude score versus content change score. Superimposed is a linear trendline displaying the coefficient of determination (R^2).

The correlation between initial attitude score for ninth-grade participants was a medium positive correlation (0.396). A positive correlation was observed for the ninth-grade group, but low coefficient of determination value (0.1568) indicates that the regression line does not fit the data well.

CHAPTER IV

DISCUSSION AND CONCLUSION

Scalability

Due to the initial inability to recruit any students in high school, it was recommended during a meeting with the Trinity River Audubon Center staff in May 2015 that the project be scaled to cater to students in fifth, seventh, and eighth grades as students of those grades visited TRAC more often than others. This was beneficial to the researcher because it demonstrated the scalability of the project to any learning level without changing the learning tools themselves. It was also beneficial to TRAC because it expanded the scope of the field trip to include many more students. Modifying the project for multiple other grades involved revisiting the TEKS and selecting those that correspond with the learning objectives initially selected for high school biology. Such versatility is beneficial in informal learning settings because it enables people with a wider range of ages, knowledge, and skills to participate in the learning experiences (NSTA 2012; Yoon et al. 2012, 520).

Shortcomings

One of the prominent issues with data collection was that many of the Consent Forms were incorrectly completed by participants or their guardians. A large number were incomplete: many lacked participant initials at the bottom of each page and many others lacked the participant's signature. Others were incorrectly completed: some guardians wrote their names and signatures on the participant spaces. The Institutional Review Board provided special permission to use consent forms that were missing only initials at the bottom of the pages (Byford 2015). Any other incomplete or incorrect Consent Form was discarded and its participant's data was omitted from this study. The researcher could not be present to oversee completion of the consent forms due to the nature of the project: teachers gave the forms to their students to take home to complete with their guardians. It was also not possible to contact the participants in order to obtain complete consent forms. This greatly reduced the number of eligible participants, particularly those in fifth grade (Table 25). Some of the Pretests and Posttests were also incomplete: many lacked a full name, multiple content assessment questions, or attitude assessment questions. Those, too, were discarded, resulting in a smaller sample size.

Table 25. Number of consent forms collected, discarded, and eligible

	Consent Forms		
	Total Collected	Discarded	Eligible (*n*)
Fifth Grade	67	43	24
Seventh Grade	38	6	32
Eighth Grade	57	8	49
Ninth Grade	17	5	12

Power calculation analyses revealed that no group contained a sufficient number of participants to reliably reject or accept any hypotheses proposed by the researcher and neither initial hypothesis proposed by the researcher could be accepted nor rejected: (1) three new learning modules at the Trinity River Audubon Center would enhance participants' content knowledge about the subjects addressed in the modules and (2) participants would show a more positive attitude toward nature and learning in an informal science environment.

Both Holmes (2011) and Yoon et al. (2012) found that if activities are too unstructured then they may fall under the category of "hands-on without being minds-on" (Wiggins and McTighe 2005, 16-17) and be more entertaining than educational, and thus unproductive (Colburn 2003, 13-14; Eshach 2007, 172; Nadelson 2013, 479). However, if activities are too structured, they may be perceived as too "formal" and little authentic content learning may occur (Yoon et al. 2012, 538). This project may have fallen into the "too structured" category due to its guided nature, though no evidence of authentic learning was detected in this study because the assessments were not designed to measure authentic learning. The updated assessments created (Appendices P, Q, and R) will be able to measure authentic learning because participants must directly apply their knowledge to answer open-ended questions.

Participants may or may not have experienced authentic learning during the field trip modules, though it is not possible to draw valid conclusions regarding authentic learning from the data collected for this work due to small sample sizes. If the assumption is made that authentic learning did not occur even within a sufficient sample size, a new assessment method that better suits the style of informal learning could be devised. It has been noted that standardized testing is not the most effective form of assessment for many pupils because many do not learn or test in the same manner, and because tacit knowledge is generally much more difficult to assess (Green 2015; Hung, Lee, and Lim 2013; Nichols 2006; NRC 2009; Wiggins and McTighe 2005). The researcher was very focused on providing STAAR preparation and did not consider that a different assessment method may provide a more accurate description of learning that occurred. If, however, the assumption that authentic learning did occur but could not be accurately described because of small sample sizes, the solution is to continue to collect data in order to obtain sufficient sample sizes to confidently accept or reject hypotheses.

It was initially thought that another possible reason participants may have received lower scores than predicted could have been because the parallel Pretest and Posttest questions were not the same level of difficulty, especially on the fifth-grade assessment, question 4. After analysis by three inter-raters, however, this was not the case. The level of difficulty for Pretest and Posttest questions were the same level of Bloom’s Taxonomy, but the problem was that more than one correct answer existed.

The researcher made a mistake foreseen by Franke and Bogner (2011): multiple correct answers on a multiple-choice test could skew data.

The flawed question 4 on the fifth-grade Posttest did produce some illuminating results, however. Half of the fifth-grade students answered the question incorrectly in such a way that it indicated an incomplete or incorrect understanding of the term “predator” (Figure 15, Table 11) Using a food web, the participants answered the question, “What change would most likely occur if all the predators in this ecosystem were removed?” The possible correct answer choices were “B” and “D”, but many answered “A, the snake population would increase.” Looking at the food web, one would notice that snakes eat mice and lizards, meaning they are also predators. The definition seems to have been understood by half the group that a predator can only be an *apex* predator at the top of the food chain. This discrepancy in understanding may be rectified by including the definitions of “predator” and “prey” on page 10 of the Eco-Investigation Science Journal and by clarification on those definitions and relationships from field trip docents.

One portion of the results, however, did reveal that a significant improvement in content learning occurred: seventh-, eighth-, and ninth-grade participants all showed increases in score on the Posttest questions involving interpreting a dichotomous key. The ninth-grade participants’ scores were not statistically significant, unlike those of the seventh- and eighth-grade groups, which could have been because of the small sample size of the ninth-grade group (*n* = 12). Those results suggested that the Classified Information module in which participants created their own dichotomous key was at least somewhat effective in conveying how a dichotomous key works and how to interpret one. Deciphering dichotomous keys is a skill required for all science STAARs (TEA 2011a-2011c, 2013a-2013f, 2014a-2014f). For those reasons the dichotomous key question was reused on the updated assessments. Alternately, participants may have selected the same answer choice for both Pretest and Posttest assessments not realizing that the object to be identified was different between the two assessments. Table 16 and Table 17 show that similar numbers of seventh- and eighth-grade participants chose answer choice "B" for both Pretest and Posttest questions. That answer choice was incorrect for the Pretest question and correct for the Posttest question.

One way in which increased content knowledge may be achieved would be for participants to engage in multiple interactions with the same informal learning venue (Bartley, Mayhew, and Finkelstein 2009; Mayhew and Finkelstein 2009; NRC 2009). Doing so would eliminate the novelty effect and promote sustained interest and engagement. Several studies provided such repeated interactions may also reduce the stress of having "one chance" to experience everything during a field trip (Franke and Bogner 2011; Holmes 2011).

Attitude Responses

Participants' attitudes showed no statistically significant increase toward their experiences at TRAC, though overall attitude responses were positive. One of the reasons there was no significant increase could have been because of the weather, as all data were collected from field trips held in September. Several participants wrote "It was hot," on the attitude assessment portions of their Posttests beside the statement, "I really enjoyed my experiences today." It also may be because they were not engaged in the field trip proceedings because of the modules themselves or the participants had little interest in the field trip in general. Additionally, the attitude scores were generally high—between neutral and positive—therefore improvement on already-high scores may not have been possible.

Examination of the *t*-test results from attitude assessment questions 1 and 2 indicate that participants enjoyed their experience at TRAC approximately as much as they expected to enjoy it—it was not significantly more or less enjoyable than they predicted. The average score of "3" corresponded to "neither agree nor disagree" or "neither likely nor unlikely," and all average responses fell above that value near the "agree" answer choice. It can be concluded that based upon these data the response to the field trip was positive, despite not detecting any statistical *change* in attitude score.

Field Trip Challenges and Shortcomings

One of the particular challenges of this project was that the researcher had no control over the field trip proceedings. Even if feedback was provided, there was no guarantee that it would be implemented by the docents at the Trinity River Audubon Center. Other uncontrolled parameters included differences in instruction style, knowledge, or enthusiasm among docents leading the field trip groups (Holmes 2011, 274-275). The weather is also an uncontrolled parameter that may affect participants' attitudes toward their experiences. The researcher took as many steps as possible to ensure the validity of the study by requesting that only employees (not volunteers) lead the field trips, but variations among individuals may have been unavoidable.

Because the researcher was not able to observe a field trip of participants whose data was used for the study, she was unable to observe exactly how the trip may have proceeded with children and not adults. After the Pretest was taken by the participants at the beginning of the observed field trip, the docent did not acknowledge the front cover of the Eco-Investigation Science Journal upon which participants could create their own social media hashtags (Figure 6). It may have been because of the demographics of the participants in the observed field trip, but the researcher noticed that the engagement piece was missing, having observed two previous field trips that used the Original Journal. The purpose of that piece was to focus the participants' attention on the present moment and the coming activities.

The Example Dichotomous Keys were not used during the Classified Information module because, according to the docent, the example Key using cookies distracted younger participants who were too fixated on food to quickly switch their focus to categorizing birds. The docent told the researcher, after she asked about the missing Keys, that it was a unanimous decision among the field trip guides that they were more of a hindrance than a learning aid. In order to rectify the situation, a new Example Dichotomous Key was created featuring insects rather than cookies (Appendix R).

The researcher observed that the docent spoke in a way that may have been unintentionally condescending to the participants during the Classified Information module. The participants were following the information provided on the Bird Classification Cards about what the birds preferred to eat, but several of the groups' decisions about their own key were contradicted without explaining that they were correct according to the information provided, but new evidence had surfaced that was also correct. The docent also did not emphasize that each dichotomous key created was correct, yet unique, or the implications of that observation for the science community at large: that classifying organisms is a challenging task and requires particular attention to detail. It would have been an effective demonstration of that concept if he had asked a member of each group to stand at the front of the laboratory with their white board to compare and contrast their dichotomous keys.

A general critique of how the docent guided the field trip was that the manner in which information was presented was very reminiscent of traditional education. Employing the Socratic Method of teaching may have been a more effective way to prompt participants to answer their own questions by evoking deeper thinking. It did not seem to leave much room for alternative viewpoints or curiosity. Similarly, the docent focused much more on answering the questions in the Journal than using them as prompts to begin conversations with the participants, though that may have been because the typical age group taught was much younger. It was noted previously, however, that fifth-grade participants respond well to Socratic instruction and effectively engaged participants in thinking critically about their observations.

Future Work

Because this project was focused on how students learn outside the classroom, it would be beneficial for this study to continue using a true control group: a group of participants who do not attend an outdoor field trip, but instead receive only classroom instruction on the same topics discussed previously. Student learning in the control (classroom) and test (field trip) groups would be provided with the same information and measured using the same assessment tools. The control group would be provided with no hands-on experiences in order to determine whether the same quality of learning occurs between those who attend a field trip and those who do not.

The previous assessment method may not have been appropriate for the informal learning experience at TRAC, so for future assessments it would be beneficial to provide questions with open-ended answers so participants could be “graded” on a scale of understanding much like the assessments Kember et al. utilized in 2008 (Table 4). Alerby (2000) and Cainey et al. (2012) used participant drawings to gauge learning comprehension, which surpasses verbal barriers and can be a direct interpretation of thought. The challenge of judging open-ended questions and drawings, however, is that strict scoring criteria must be established (Cainey et al. 2012, 268). Other data collection methods such as video or audio interview responses may also be beneficial, as they provide immediate feedback (Yoon et al. 2012, 527). Another possible option for assessment would be to collect participants’ Eco-Investigation Science Journals and select specific questions on which to gauge how much students comprehend the subject matter. Though using the participants’ artifacts may provide an accurate measure of learning, it would be unfair to take the evidence of their experience away from them on both academic and personal levels.

A new set of assessments was devised that utilizes open-ended questions in order to gain a more accurate measure of participants’ learning (Appendices P, Q, and R). To determine level of thought required for each assessment question (old and new), *Bloom’s Taxonomy* was consulted: a hierarchal classification system that separates levels of thinking and understanding into six discrete tiers (Figure 39, Colburn 2003, 3-5).

The new assessments were created for future research and may better reflect the styles of teaching and learning that occur in informal science learning venues (Table 26).

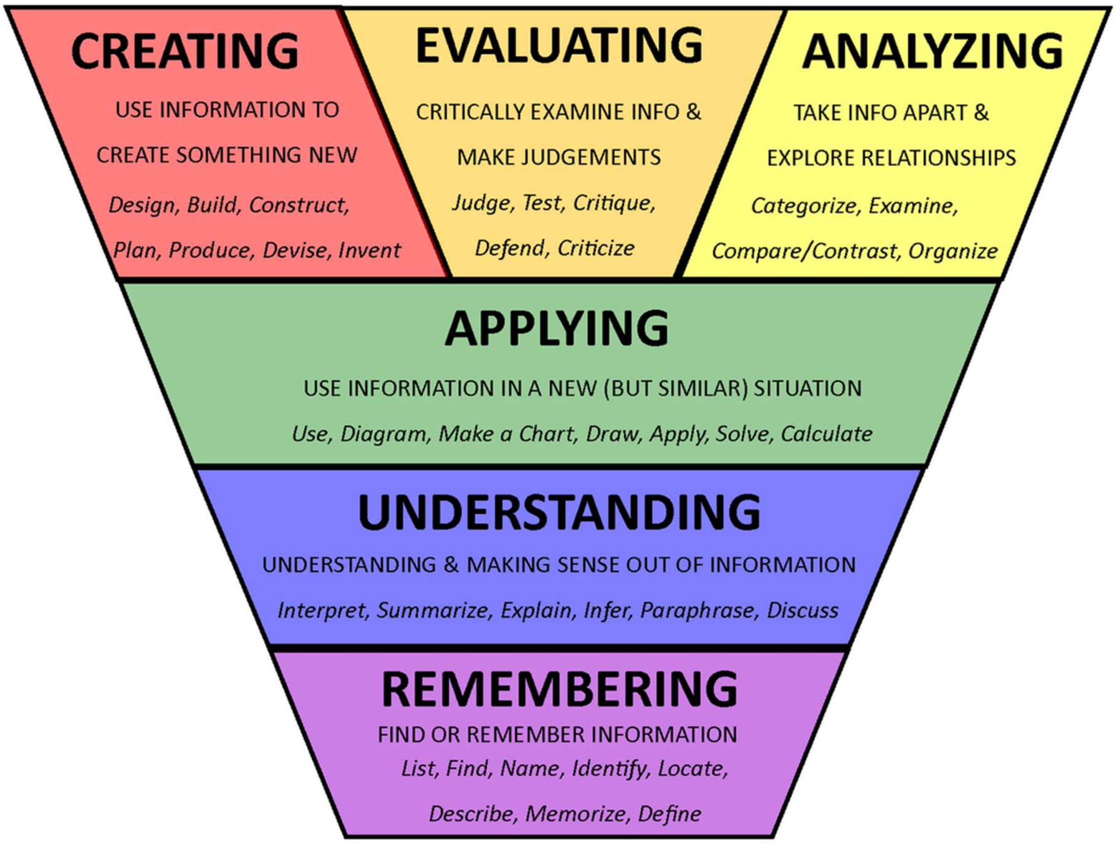


Figure 39. Bloom's Taxonomy diagram including descriptive terms for each level.
Source: Thomas Shields.

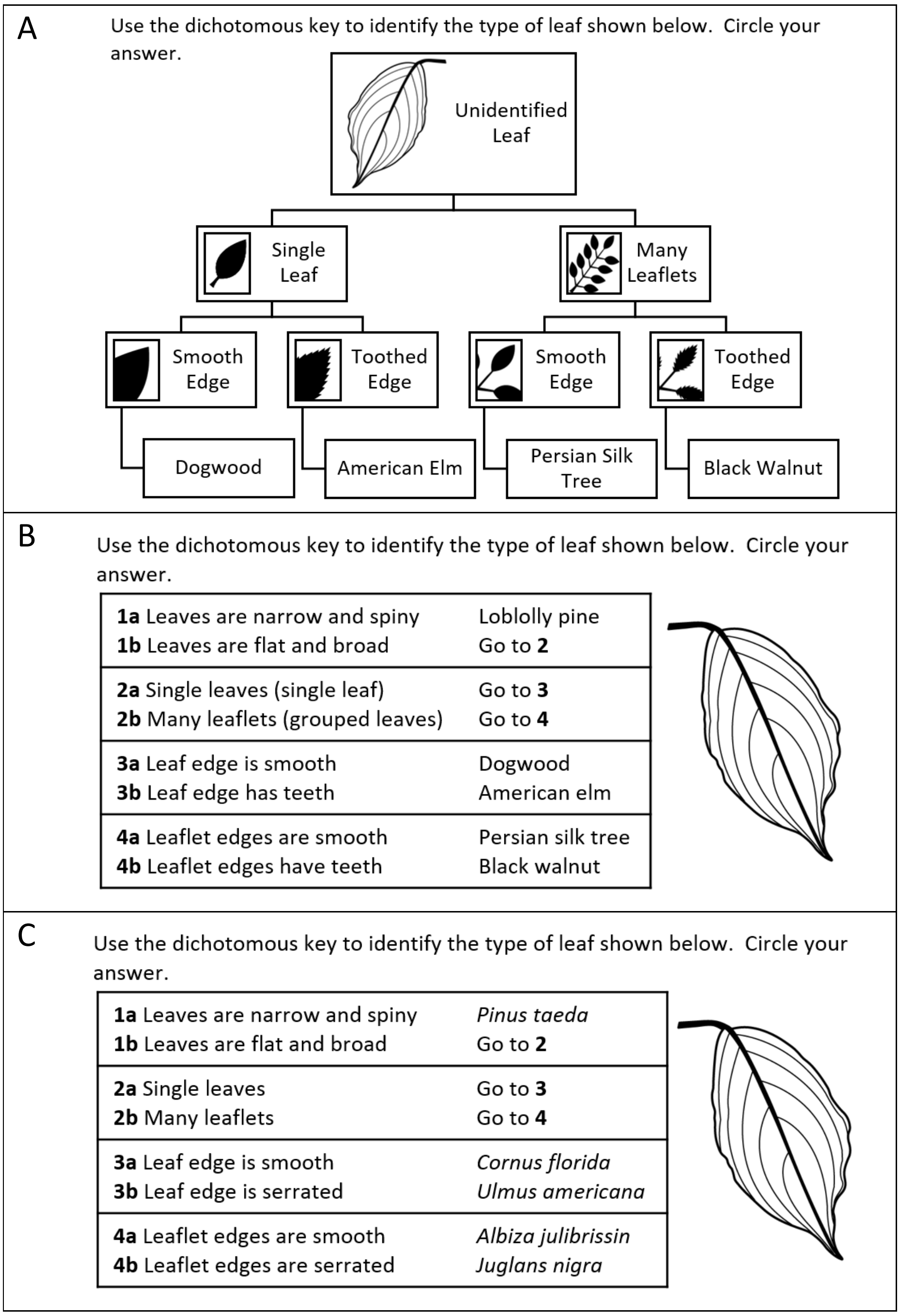
Table 26 Bloom's Taxonomy tier applied to each assessment question

	Fifth Grade	
	Old Assessment	New Assessment
1	understand	apply
2	understand	create
3	apply	apply
4	understand	apply
5	apply	analyze
	Seventh and Eighth Grades	
	Old Assessment	New Assessment
1	understand	apply
2	apply	create
3	understand	apply
4	understand	apply
5	analyze	analyze
	Ninth Grade	
	Old Assessment	New Assessment
1	apply	apply
2	understand	create
3	apply	apply
4	apply	apply
5	analyze	analyze

In order to ensure that bias was limited when rating each assessment question for Bloom's Taxonomy levels, two raters in addition to the researcher contributed their evaluations of the assessment questions. When the responses varied, each was considered by the researcher using the verbs in each category on Figure 39 and a final decision was reached. Four of the new assessment questions are open-ended, and one is a similar dichotomous key question as was on the old assessments. The fifth-grade version is more scaffolded in the new assessment than seventh, eighth, and ninth-grade versions (Figure 40). Because this is the only multiple-choice question, the questions are parallel: different leaves can be found on the Pretest and Posttest.

The general subjects assessed previously were retained in the new assessments: organization using dichotomous keys, food webs and energy flow, response of an ecosystem to a stimulus, animal adaptations, and biodiversity. The Bloom's Taxonomy levels, however, insinuate that the new assessments require higher-order levels of thinking. The food web question is now open-ended: participants will create their own food chain or food web using provided organisms (Figure 41).

Grading the new assessments will undoubtedly be more difficult due to the nature of assessing open-ended questions, but with a strict rubric, an accurate and fair measure may be obtained. The food web example in Figure 41 would be graded on three criteria: (1) the number of correct "connections" made between organisms, (2) correct orientation of arrows to illustrate flow of energy, and (3) distinct and logical trophic levels. An additional challenge would be presented to the staff at TRAC: the docents must specifically teach what they assess in order to determine whether authentic learning has occurred.

 A

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

B

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

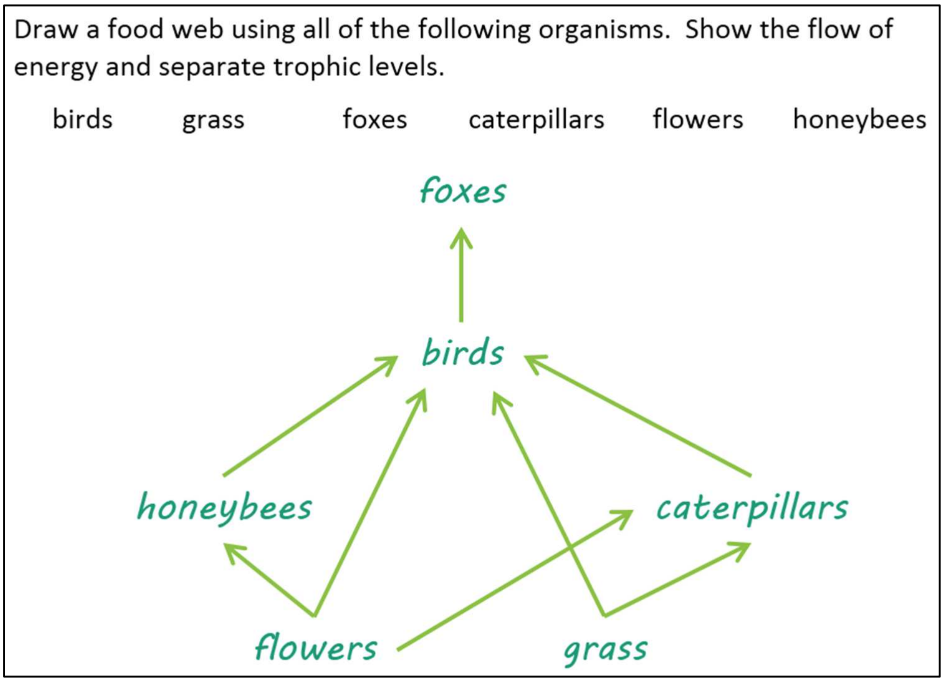
1a Leaves are narrow and spiny	Loblolly pine
1b Leaves are flat and broad	Go to **2**
2a Single leaves (single leaf)	Go to **3**
2b Many leaflets (grouped leaves)	Go to **4**
3a Leaf edge is smooth	Dogwood
3b Leaf edge has teeth	American elm
4a Leaflet edges are smooth	Persian silk tree
4b Leaflet edges have teeth	Black walnut

C

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

1a Leaves are narrow and spiny	*Pinus taeda*
1b Leaves are flat and broad	Go to **2**
2a Single leaves	Go to **3**
2b Many leaflets	Go to **4**
3a Leaf edge is smooth	*Cornus florida*
3b Leaf edge is serrated	*Ulmus americana*
4a Leaflet edges are smooth	*Albiza julibrissin*
4b Leaflet edges are serrated	*Juglans nigra*

Figure 40. Dichotomous key questions from the new assessments. Figure 40A shows the fifth-grade question, Figure 40B shows the seventh- and eighth-grade question, and Figure 40C shows the high school question.



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds grass foxes caterpillars flowers honeybees

Figure 41. Middle-school level food web problem on the new assessments and an example of how one might solve it.

It may also be beneficial to determine the retention of knowledge from students' experiences in control and test groups. In order to determine retention, participants would be asked to complete a parallel assessment to the Posttest they took immediately following their learning experience at specific intervals after their experience. For example, students may take an assessment 1 month, 3 months, 6 months, or even 1 year after their learning experience. This analysis could determine if students in the test or control group retained knowledge better than the other and would provide a more detailed analysis of student learning in informal science environments and how it compares to formal science learning.

In alignment with the Trinity River Audubon Center's theme of nature conservation, the Food Web Demonstration would be updated to include manmade disasters such as river pollution, groundwater contamination, or an oil spill. An additional possibility for future work involves identifying requirements for individuals to earn Girl and Boy Scout badges. Both groups lead programs that emphasize nature conservation and exploration. Related Boy Scout Merit Badges include Animal Science, Backpacking, Bird Study, Environmental Science, Forestry, Hiking, Nature, Soil and Water Conservation, and Sustainability (Boy Scouts of America 2015). Girl scouts have multiple levels of Badges: Brownies can earn the Hiker badge, Juniors can earn Gardener and Flowers badges, Cadettes can earn Trailblazing and Trees badges, Seniors can earn the Adventurer badge, and Ambassadors can earn the Water badge (Girl Scouts 2015).

It would be beneficial in the future to add a space on the Consent Form for participants to write their grade level. Because at least one of the classes contained a combination of grade levels and the assessments for seventh and eighth grades were identical, it was not possible to distinguish all participants' grade levels which may have skewed results. It would also be useful to label the seventh- and eighth-grade assessments separately, so the participants' grade levels would be evident from their assessments alone. The updated assessments now show only one grade level.

Knowing specifically what participants liked and did not like about the field trip would be useful for future research, especially in enhancing motivation and interest.

The attitude assessment portion of the new Posttest includes two open-ended questions: “What did you like *most* about today’s activities?” and “What did you like *least* about today’s activities?” Docents should be explicit about what that means—the participants should evaluate actual parts of the experience, not external factors such as the weather, for instance. Answers to those questions would be illuminating for both the researcher and the staff at TRAC in order to improve experiences for participants.

Conclusion

Informal learning is a vital facet of science education that may encourage new generations of learners, educators, and advocates to participate in science learning experiences. This study sought to determine whether content knowledge and attitudes could be improved from a newly-designed, three-part field trip experience at the Trinity River Audubon Center. Previous research has shown that informal learning experiences can enhance participants’ interest, understanding, and appreciation of scientific phenomena (Bartley 2009; Evans et al. 2014; Fenichel and Schweingruber 2010; Harlow 2012; Hung, Lee, and Lim 2012; Mohr-Schroeder et al. 2014; NRC 2009; Yoon et al. 2012).

It was hypothesized that participants would show increased content knowledge and improved attitudes toward informal science learning from participating in the field trip modules. Similarly to studies performed by Holmes (2011) Yoon et al. (2012), no significant increase in content knowledge was observed. These results may have occurred because the modules were too scaffolded which obscured the meaning behind the activities, or because the method of assessment was not appropriate for the experience. Additionally, no significant increase in attitude was observed, though attitude assessment items revealed that participants generally exhibited positive initial and final attitudes which did not allow for improvement. The proposed hypotheses could not be accepted nor rejected because the sample sizes were insufficient to draw valid conclusions according to the power calculation data.

Though the initial hypotheses proposed could not be supported nor refuted by the data collected for this work, collaboration with an informal learning venue and the creation and implementation of new field trip modules and collection of subsequent data were successful. Many opportunities remain for future research to be performed: new set of assessments was devised for future research that may allow for more detailed analyses of participants' content learning, and the results of this thesis provide insight into what learning goals require improvement to affect authentic learning during the field trip modules.

This was a beta-tested pilot study for which preliminary data were collected from a small sample of participants. Data will continue to be collected in order to evaluate the proposed hypotheses and formulate valid conclusions.

The project described by this thesis provided innumerable learning experiences for the researcher, among which are project design, core-aligned curriculum development, lesson planning, graphic design, navigating the process of Institutional Review Board approval, successful collaboration with an informal science learning venue, and data collection and analysis. This project was a pioneering study that may pave the way for other students who wish to create unique, memorable, and lasting science experiences for any learner.

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APPENDIX A

Institutional Review Board Approval Letter

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: December 17, 2014

TO: Ms. Sarah Wehner
Biology

FROM: Institutional Review Board - Denton

Re: Approval for Measuring Changes in Concept Comprehension and Attitudes Toward Informal Science Learning from Three Learning Modules Implemented at the Trinity River Audubon Center (Protocol #: 17763)

The above referenced study has been reviewed and approved at a fully convened meeting of the Denton Institutional Review Board (IRB) on 9/5/2014. This approval is valid for one year and expires on 9/5/2015. The IRB will send an email notification 45 days prior to the expiration date with instructions to extend or close the study. It is your responsibility to request an extension for the study if it is not yet complete, to close the protocol file when the study is complete, and to make certain that the study is not conducted beyond the expiration date.

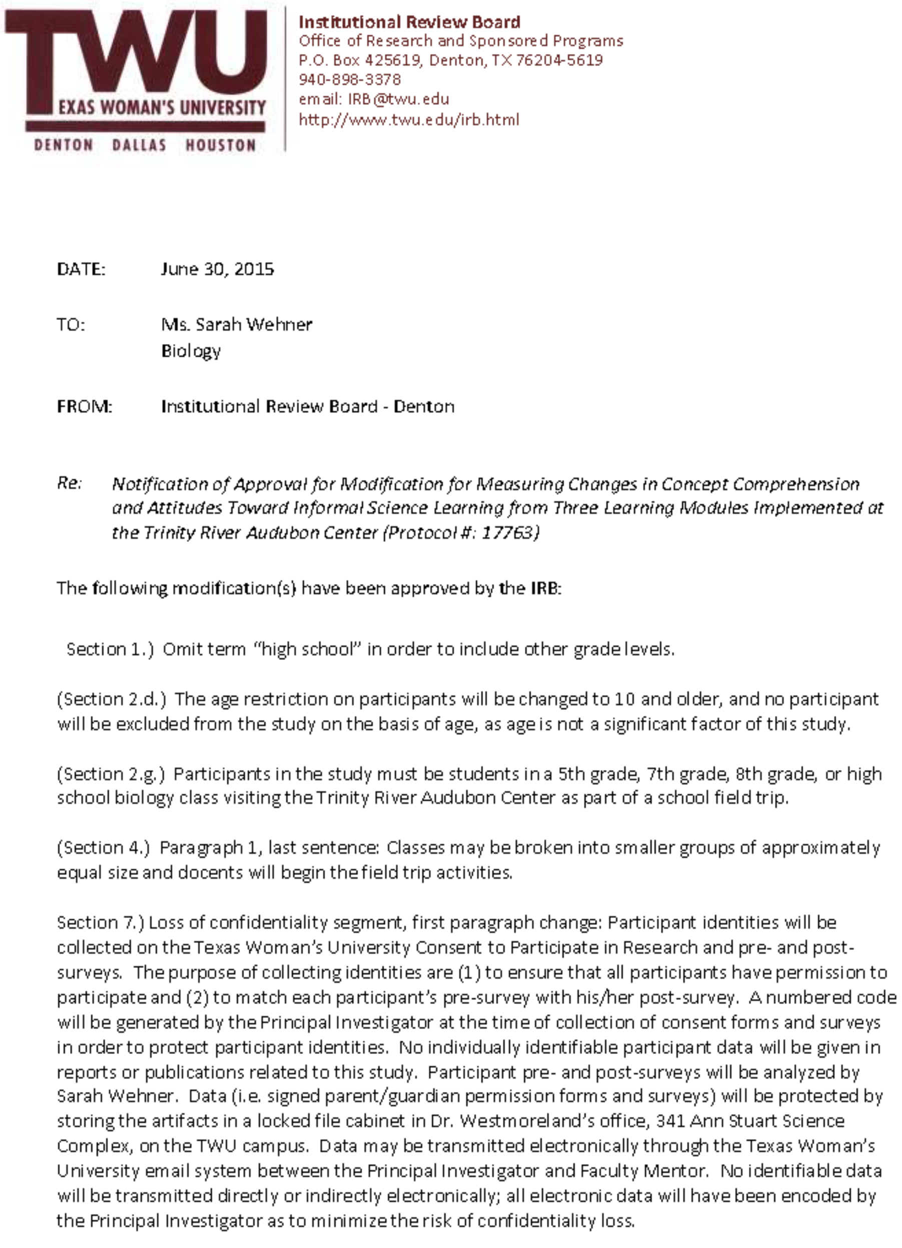
If applicable, agency approval letters must be submitted to the IRB upon receipt prior to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Sarah McIntire, Biology
Dr. Sandra Westmoreland, Biology
Graduate School

APPENDIX B

Institutional Review Board Modification Approval Letter



Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: June 30, 2015

TO: Ms. Sarah Wehner
Biology

FROM: Institutional Review Board - Denton

Re: Notification of Approval for Modification for Measuring Changes in Concept Comprehension and Attitudes Toward Informal Science Learning from Three Learning Modules Implemented at the Trinity River Audubon Center (Protocol #: 17763)

The following modification(s) have been approved by the IRB:

Section 1.) Omit term "high school" in order to include other grade levels.

(Section 2.d.) The age restriction on participants will be changed to 10 and older, and no participant will be excluded from the study on the basis of age, as age is not a significant factor of this study.

(Section 2.g.) Participants in the study must be students in a 5th grade, 7th grade, 8th grade, or high school biology class visiting the Trinity River Audubon Center as part of a school field trip.

(Section 4.) Paragraph 1, last sentence: Classes may be broken into smaller groups of approximately equal size and docents will begin the field trip activities.

Section 7.) Loss of confidentiality segment, first paragraph change: Participant identities will be collected on the Texas Woman's University Consent to Participate in Research and pre- and post-surveys. The purpose of collecting identities are (1) to ensure that all participants have permission to participate and (2) to match each participant's pre-survey with his/her post-survey. A numbered code will be generated by the Principal Investigator at the time of collection of consent forms and surveys in order to protect participant identities. No individually identifiable participant data will be given in reports or publications related to this study. Participant pre- and post-surveys will be analyzed by Sarah Wehner. Data (i.e. signed parent/guardian permission forms and surveys) will be protected by storing the artifacts in a locked file cabinet in Dr. Westmoreland's office, 341 Ann Stuart Science Complex, on the TWU campus. Data may be transmitted electronically through the Texas Woman's University email system between the Principal Investigator and Faculty Mentor. No identifiable data will be transmitted directly or indirectly electronically; all electronic data will have been encoded by the Principal Investigator as to minimize the risk of confidentiality loss.

(Section 10.a.) Identifiable data that will be collected are Consent Forms signed by students and parents and pre- and post-surveys described in this document. The purpose of collecting identities are (1) to ensure that all participants have permission to participate and (2) to match each participant's pre-survey with his/her post-survey. A numbered code will be generated by the Principal Investigator at the time of collection of consent forms and surveys in order to protect participant identities. No individually identifiable participant data will be given in reports or publications related to this study.

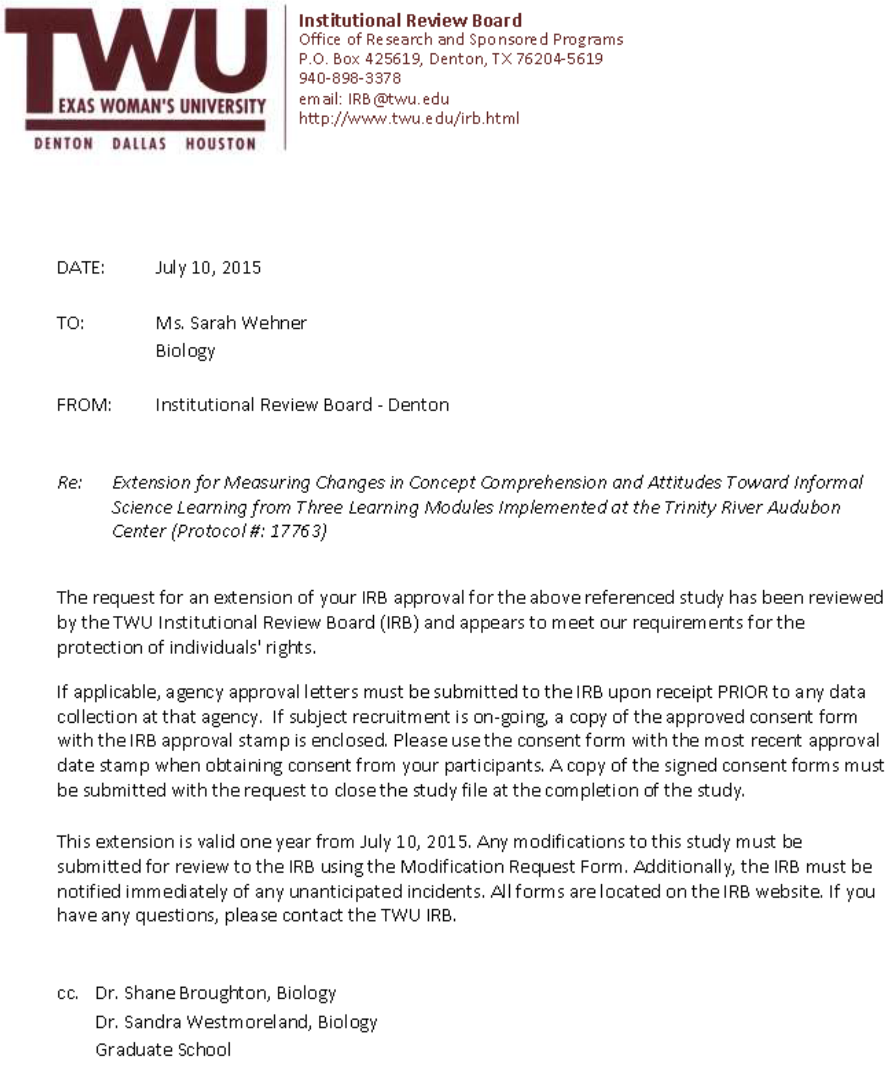
(Section 10.c.) Identifiable data will be destroyed within 6 months of the conclusion of this study. The study is scheduled to be completed by 31 December 2015. Destruction of artifacts will commence on or

before 31 May 2016. An extension for this project will be requested following the approval of these revisions.

cc. Dr. Sandra Westmoreland, Biology

APPENDIX C

Institutional Review Board Extension Approval Letter



Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: July 10, 2015

TO: Ms. Sarah Wehner
Biology

FROM: Institutional Review Board - Denton

Re: Extension for Measuring Changes in Concept Comprehension and Attitudes Toward Informal Science Learning from Three Learning Modules Implemented at the Trinity River Audubon Center (Protocol #: 17763)

The request for an extension of your IRB approval for the above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. If subject recruitment is on-going, a copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

This extension is valid one year from July 10, 2015. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Shane Broughton, Biology
Dr. Sandra Westmoreland, Biology
Graduate School

APPENDIX D

Grade 5 Pretest and Posttest

Full Name ____ Grade 5

Eagles catch fish in lakes with their talons. They fly with the fish to a tree branch and tear the fish into small pieces. Which foot below represents the bird that most likely catches and eats its food the way an eagle does?

A


B

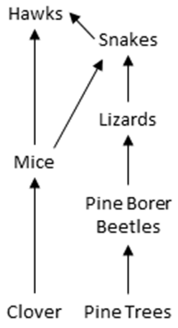

C


D


In a food chain, energy does **NOT** flow directly from –

- **A** producer to consumer
- **B** producer to decomposer
- **C** consumer to producer
- **D** consumer to decomposer

Using the food web below, answer the following two questions.



What role do mice play in this food web?

- **A** Consumer
- **B** Producer
- **C** Predator
- **D** Decomposer

What change would most likely occur if all the producers in this ecosystem were removed?

- **A** The mouse population would increase.
- **B** All the animals would either die or move away.
- **C** All the animal populations would increase.
- **D** The beetles would become the new producers.

PRE

Continued on back ⟶

Some facts about birds called cattle egrets are listed below.

1. They have yellow bills and light orange legs.
2. They are often found in the same field as cattle.
3. They eat ticks off cattle while the cattle graze.
4. They make nests in trees away from predators.

Which of these facts best describes how these birds depend on other animals to survive?

A Fact 1 **B** Fact 2

C Fact 3 **D** Fact 4

Please answer the following questions honestly.
Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I really wanted to come to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I think I will enjoy my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Approximately how many hours do you spend outdoors per week?

○	○	○	○	○
0-1 Hour	2-3 Hours	4-5 Hours	6-7 Hours	More Than 7 Hours

Which of the following outdoor activities would you *most likely* do?

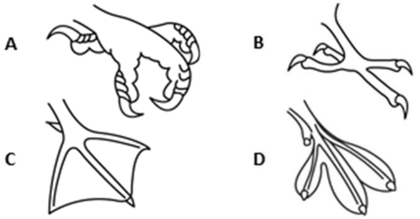
○	○	○	○	○
Play soccer	Go on a hike	Walk around downtown	Ride a bicycle	I would not go outside

PRE

Thank you for participating.

Full Name ____ Grade 5

Mallards are ducks that use their feet to swim across bodies of water to hunt for small water plants to eat. Which foot below represents the bird that most likely lives in a similar environment to the mallard?



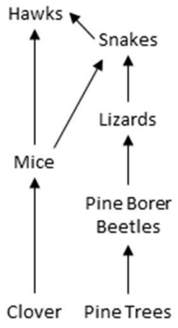
In a food chain, energy flows directly from –

- **A** decomposer to consumer
- **B** decomposer to producer
- **C** consumer to producer
- **D** producer to decomposer

Using the food web below, answer the following two questions.

What role do hawks play in this food web?

- **A** Prey
- **B** Producer
- **C** Predator
- **D** Decomposer



What change would most likely occur if all the predators in this ecosystem were removed?

- **A** The snake population would increase.
- **B** The snake population would decrease.
- **C** All the animals would either die or move away.
- **D** The pine tree population would decrease.

POST

Continued on back ⟶

Some facts about birds called cattle egrets are listed below.

1. They have thick, pointed, yellow bills.
2. They are often found in the same field as cattle.
3. They eat ticks off cattle while the cattle graze.
4. They make nests in trees away from predators.

Which of these facts best describes how these birds are adapted to eat their preferred food?

A	Fact 1	**B**	Fact 2
C	Fact 3	**D**	Fact 4

Please answer the following questions honestly.
Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I am glad I came to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I really enjoyed my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Based upon my experiences today, I am likely to spend more time outdoors.

○	○	○	○	○
Very Likely	Likely	Neither	Unlikely	Very Unlikely

I would like to visit Trinity River Audubon Center again.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I would like to visit other nature centers like the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

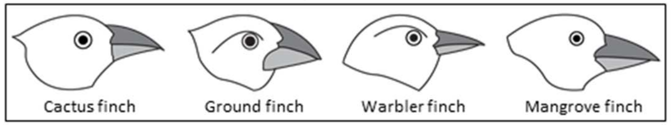
POST **Thank you for participating.**

APPENDIX E

Grades 7 and 8 Pretest and Posttest

Full Name ________________________________ Grade 7/8

The finches of the Galápagos Islands are similar to one another, but have many different beak shapes. What is the most likely explanation as to why the Warbler finch has a thinner and sharper beak than the others?

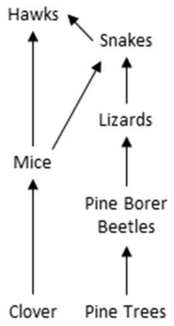


- **A** The Warbler finch needs a thinner beak to defend itself against predators.
- **B** The Warbler finch originated from a different bird than the other species.
- **C** The Warbler finch is adapted to eating smaller food than the other species.
- **D** The Warbler finch sharpened its beak on a rock and passed that trait to its offspring.

Using the food web below, answer the following three questions.

Which statement most appropriately reflects a feeding relationship in the food web below?

- **A** Hawks are predators and mice are prey.
- **B** Beetles are producers and lizards are consumers.
- **C** Clover are parasites and mice are hosts.
- **D** Beetles are parasites and lizards are hosts.



Pine borer beetles live in and eat the wood of pine trees. This makes them –

- **A** Producers
- **B** Consumers
- **C** Predators
- **D** Prey

Natural and manmade disasters can greatly harm ecosystems. Which organism would suffer the most immediate harm by the effects of a major drought?

- **A** Lizards
- **B** Clover
- **C** Snakes
- **D** Hawks

PRE

Continued on back ⟶

Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are narrow and spiny **1b** Leaves are flat and broad	Loblolly pine Go to **2**
2a Single leaves (single leaf) **2b** Many leaflets (grouped leaves)	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge has teeth	Dogwood American elm
4a Leaflet edges are smooth **4b** Leaflet edges have teeth	Persian silk tree Black walnut

- **A** Dogwood
- **B** American elm
- **C** Persian silk tree
- **D** Black walnut

Please answer the following questions honestly.
Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I really wanted to come to the Trinity River Audubon Center.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

I think I will enjoy my experiences today.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

Approximately how many hours do you spend outdoors per week?

○ 0-1 Hour ○ 2-3 Hours ○ 4-5 Hours ○ 6-7 Hours ○ More Than 7 Hours

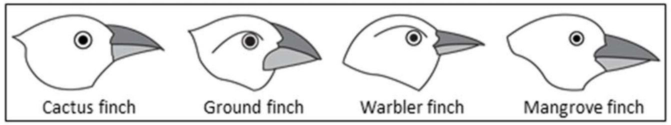
Which of the following outdoor activities would you *most likely* do?

○ Play soccer ○ Go on a hike ○ Walk around downtown ○ Ride a bicycle ○ I would not go outside

PRE **Thank you for participating.**

Full Name ______________________________ Grade 7/8

The finches of the Galápagos Islands are similar to one another, but have many different beak shapes. What is the most likely explanation as to why the Ground finch has beak that is shorter and more blunt than the others?



A The Ground finch is adapted to eating harder food than the other species.

B The Ground finch wore down its beak on a rock and passed that trait to its offspring.

C The Ground finch needs a sturdier beak to defend itself against predators.

D The Ground finch originated from a different bird than the other species.

Using the food web below, answer the following three questions.

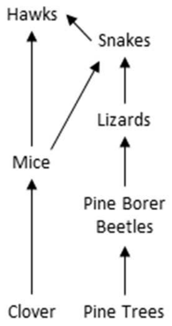
Which statement most appropriately reflects a feeding relationship in the food web below?

A Mice are predators and clover are prey.

B Pine trees are producers and beetles are consumers.

C Clover are parasites and mice are hosts.

D Beetles are parasites and lizards are hosts.



Clover use the sun to produce their own food from the process of photosynthesis. This makes them –

A Producers **B** Consumers

C Predators **D** Prey

Natural and manmade disasters can greatly harm ecosystems. Which organism would suffer the most immediate harm by the effects of a major fire?

A Mice

B Hawks

C Snakes

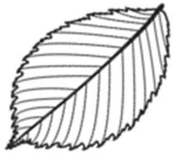
D Trees

POST

Continued on back ⟶

Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are narrow and spiny **1b** Leaves are flat and broad	Loblolly pine Go to **2**
2a Single leaves (single leaf) **2b** Many leaflets (grouped leaves)	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge has teeth	Dogwood American elm
4a Leaflet edges are smooth **4b** Leaflet edges have teeth	Persian silk tree Black walnut



A Dogwood

B American elm

C Persian silk tree

D Black walnut

Please answer the following questions honestly. Mark the appropriate bubble. This will not be seen by your teacher or affect your grade.

I am glad I came to the Trinity River Audubon Center.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

I really enjoyed my experiences today.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

Based upon my experiences today, I am likely to spend more time outdoors.

○ Very Likely ○ Likely ○ Neither ○ Unlikely ○ Very Unlikely

I would like to visit Trinity River Audubon Center again.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

I would like to visit other nature centers like the Trinity River Audubon Center.

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

POST **Thank you for participating.**

APPENDIX F

High School Biology Pretest and Posttest

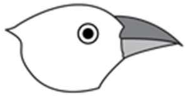
Full Name ____ High School

The finches of the Galápagos Islands have many different beak shapes that are adapted for eating various foods. Which of the finches below would be most likely to eat small insects?

A 

B 

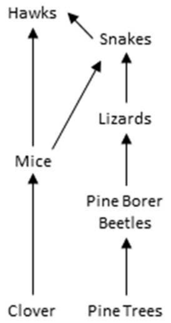
C 

D 

Choose the statement that most accurately represents why biodiversity is important in ecosystems.

- **A** Some organisms rely on only one food source.
- **B** Some organisms eat a variety of different foods.
- **C** An organism that eats a variety of foods is more likely to survive if one food source is depleted.
- **D** Different ecosystems support different organisms.

Using the food web below, answer the following two questions.



Which of the following is the most likely consequence of the beetles becoming extinct?

- **A** The snake population will increase.
- **B** The mouse population will increase.
- **C** The snakes will starve.
- **D** The pine tree population will increase.

Natural and manmade disasters can greatly harm ecosystems. Which organism would suffer the most immediate harm by the effects of a major drought?

- **A** Mice
- **B** Hawks
- **C** Snakes
- **D** Clover

PRE

Continued on back ⟶

Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are spiny **1b** Leaves are broad	*Pinus taeda* Go to **2**
2a Single leaves **2b** Many leaflets	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge is serrated	*Cornus florida* *Ulmus americana*
4a Leaflet edges are smooth **4b** Leaflet edges are serrated	*Albiza julibrissin* *Juglans nigra*

- **A** *Cornus florida*
- **B** *Ulmus americana*
- **C** *Albizia julibrissin*
- **D** *Juglans nigra*

Please answer the following questions honestly. Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I really wanted to come to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I think I will enjoy my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Approximately how many hours do you spend outdoors per week?

○	○	○	○	○
0-1 Hour	2-3 Hours	4-5 Hours	6-7 Hours	More Than 7 Hours

Which of the following outdoor activities would you *most likely* do?

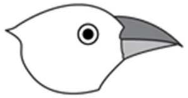
○	○	○	○	○
Play soccer	Go on a hike	Walk around downtown	Ride a bicycle	I would not go outside

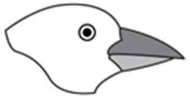
PRE **Thank you for participating.**

Full Name ____ High School

The finches of the Galápagos Islands have many different beak shapes that are adapted for eating various foods. Which of the finches below would be most likely to eat dry seeds and nuts?

A 

B 

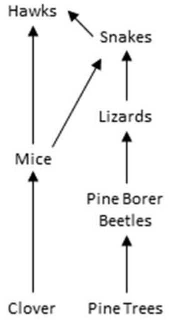
C 

D 

Choose the statement that most accurately represents why biodiversity is important in ecosystems.

- **A** Some organisms rely on only one food source.
- **B** Some organisms eat a variety of different foods.
- **C** An organism that eats a variety of foods is more likely to survive if one food source is depleted.
- **D** Different ecosystems support different organisms.

Using the food web below, answer the following two questions.



Which of the following is the most likely consequence of the snakes becoming extinct?

- **A** The beetle population will increase.
- **B** The lizards will starve.
- **C** The mouse population will increase.
- **D** The pine tree population will decrease.

Natural and manmade disasters can greatly harm ecosystems. Which organism would suffer the most immediate harm by the effects of a major fire?

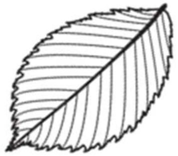
- **A** Mice
- **B** Trees
- **C** Snakes
- **D** Hawks

POST

Continued on back ⟶

Use the dichotomous key to identify the type of leaf shown below. The leaf belongs to which species?

1a Leaves are spiny **1b** Leaves are broad	*Pinus taeda* Go to **2**
2a Single leaves **2b** Many leaflets	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge is serrated	*Cornus florida* *Ulmus americana*
4a Leaflet edges are smooth **4b** Leaflet edges are serrated	*Albiza julibrissin* *Juglans nigra*



- **A** *Cornus florida*
- **B** *Ulmus americana*
- **C** *Albizia julibrissin*
- **D** *Juglans nigra*

Please answer the following questions honestly. Mark the appropriate bubble.
This will not be seen by your teacher or affect your grade.

I am glad I came to the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I really enjoyed my experiences today.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Based upon my experiences today, I am likely to spend more time outdoors.

○	○	○	○	○
Very Likely	Likely	Neither	Unlikely	Very Unlikely

I would like to visit Trinity River Audubon Center again.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

I would like to visit other nature centers like the Trinity River Audubon Center.

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

POST

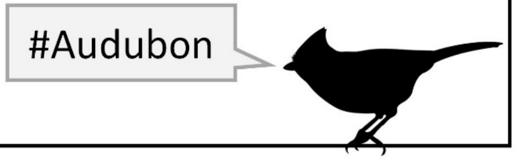
Thank you for participating.

APPENDIX G

Eco-Investigation Science Journal

Eco-Investigation

Science Journal



Name ____

School ______________________________________

Date ____

TRINITY RIVER Audubon
CENTER
trinityriveraudubon.org

The Central Flyway

Why is our home amazing?

Each year, millions of birds migrate between Canada and South America along the Central Flyway, a stretch of land across the central United States. Here in North Texas, birds migrate in the fall and spring, and 98.5% of all migratory birds species in the United States are found in Texas. Some have thousands of miles to travel and cannot make it unless they have "rest areas" to find food and regain energy to complete the long flight.

As you learn about our ecosystems today, consider what makes our home so amazing for people and birds. Decide what you can do to create a great "rest stop" for the birds who share our community.

Our **Amazing** Home!

You don't need to travel the world to experience nature. Investigate the world around you, your amazing home.

Did you know…

TRINITY RIVER WATERSHED

The Trinity River provides drinking water to 11 million people. At 710 miles long, it crosses diverse ecosystems and flows into the Gulf of Mexico near Galveston.

BLACKLAND PRAIRIE

This complex ecosystem is home to over 500 animal species. It is the most endangered ecosystem in the U.S. Less than 1% of the Blackland Prairie remains.

GREAT TRINITY FOREST

At 6,000 acres, it is the largest urban hardwood forest in America. This forest helps clean our air. It is an important part of our home that is ready to be protected, studied, and explored!

Bird Biodiversity

The Trinity River Audubon Center used to be an illegal ______________,

but the City of Dallas spent _____ years restoring the land.

You will visit three **ecosystems** today. Which of those do you think will have the greatest **diversity** of birds? Circle one.

TRINITY RIVER WATERSHED | **BLACKLAND PRAIRIE** | **GREAT TRINITY FOREST**

Why do you think so?

In which ecosystem did you see the greatest bird diversity?

TRINITY RIVER WATERSHED | **BLACKLAND PRAIRIE** | **GREAT TRINITY FOREST**

Do your findings support your initial hypothesis? Why or why not?

Think about the area you saw with the most diversity. What types of characteristics of the birds there make them ideal for their **habitats**?

Why do you think it is important that ecosystems have lots of **biodiversity**?

Use your **Trinity River Audubon Center Bird Identification Guide** to help you identify birds you see along your walk and fill in the table below. Check the appropriate box to indicate where you saw the birds. If you cannot find a bird on your ID guide, describe it (example: bright red with crest, orange beak).

Species Common Name	River	Prairie	Forest
Your Total Species Diversity			
Total Class Species Diversity Count			

CLASSIFIED INFORMATION

A **dichotomous key** is a useful method of organizing groups of objects. Use the space below and the cards to find similarities and differences between the species. Use traits of your own choice to create your own identification key.

Similarities Among the Birds

Differences Among the Birds

Hummingbird
Cardinal
Pigeon
Egret
Owl

Do you think there is only one way to classify these birds?
Why or why not?

Use the space below to draw the dichotomous key you created with your teammates.

What issues do you think scientists may encounter when using biological **taxonomy** to classify organisms?

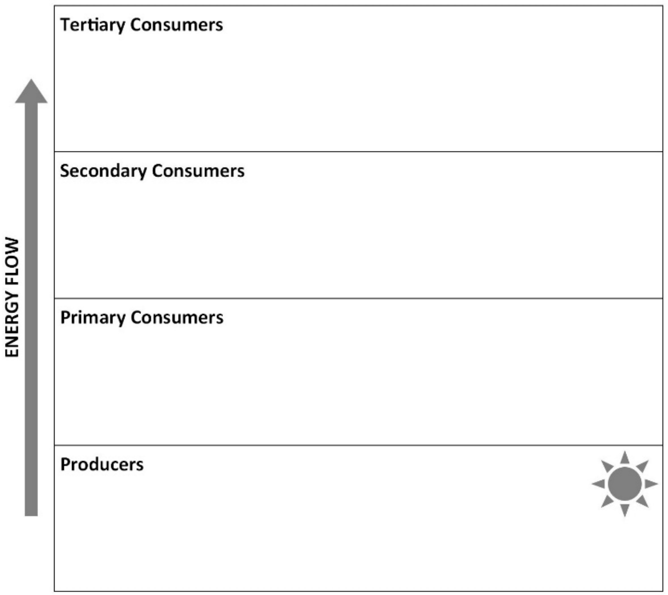
What makes a bird a bird and not another category of animal?

Organism Interactions

As you explore the exhibit hall, complete the table below. Note relationships between physical traits and their possible functions.

Organism	What does it eat?	How is at adapted for what it eats?

Construct a **food chain** from the organisms in your table. Draw arrows to indicate the flow of energy through the chain.



Examine the **food chain** you created. Are all **trophic levels** occupied?

What might your food chain need to be a complete **ecosystem**?

What trophic level is missing from the food chain?

What does it mean when we say that energy flows?

From where does much of Earth's energy originate?

What is an event that may harm an ecosystem?

What trophic level is most likely to be harmed by the above event?

What surprised you about the **food web** demonstration?

What is something you can do to protect the plants and animals around your home?

Key Terms

Adaptation — the adjustment or changes in behavior, physiology, and structure of an organism to become more suited to an environment.

Biodiversity — the existence of a wide range of different types of organisms in a given place at a given time. A high level is desirable.

Consumer (Heterotroph) — an organism that is unable to synthesize its own food and must feed on other organisms or organic matter.

Decomposer — an organism that recycles nutrients by feeding on dead or decaying organic matter.

Dichotomous Key — a reference tool where a series of choices between alternative characteristics leads progressively to identification of a species.

Diversity — the number and variety of species present in an area and their spatial distribution among habitats.

Ecosystem — a system that includes all biotic (living) and abiotic (nonliving) factors in an area that function together as a unit.

Food Chain — a feeding hierarchy in which organisms are grouped into trophic levels and shown in a succession to show feeding relationships.

Food Web — many food chains linked together to show a more accurate model of all possible feeding relationships among organisms.

Habitat — the location or environment where an organism is most likely to be found.

Producer (Autotroph) — an organism capable of making its own food via photosynthesis.

Taxonomy — the classification of organisms in a hierarchal system.

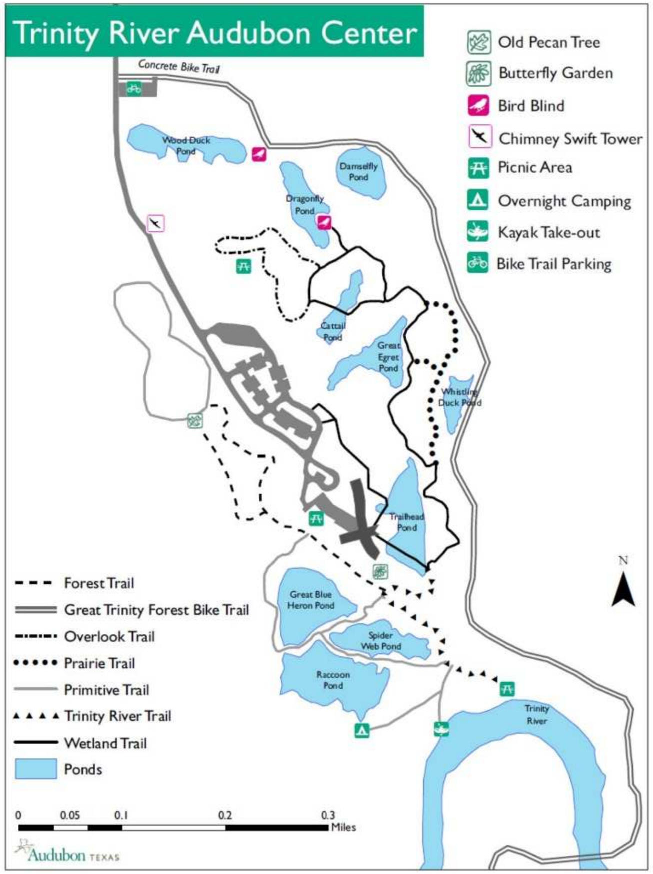
Trophic Level — a position in a food chain or ecological pyramid occupied by a group of organisms with a similar feeding mode.

Conservation Actions

How to make your home, school, and community bird-friendly.

- **SAVE WATER.** Birds and other wildlife share our community and all animals need water to live.
- **FEED BIRDS AND PROVIDE BIRD HOUSES.** This will help and let you study them more closely.
- **REMOVE LITTER POLLUTION.** Birds and other wildlife mistake litter for food. Pick up after yourself and others.
- **MAKE WINDOWS BIRD-FRIENDLY.** Use soap, tape, or stickers to make glass more visible. Glass kills millions of birds each year.
- **KEEP CATS INSIDE.** For the safety of both birds and cats, do not let your cat out unsupervised. Pet cats kill millions of birds each year and can drastically affect a local population of birds.
- Learn to **IDENTIFY BIRDS** and **SHARE YOUR DATA** with scientists around the world by visiting eBird.org and logging your sightings.
- **TURN OFF LIGHTS AT NIGHT.** Save money and energy to help migrating birds on track in the night sky.

Many people are working together to protect our birds.
How will you help? Share your ideas with us at trac@audubon.org.



This journal was created by Sarah Wehner of
Texas Woman's University in collaboration
with the Trinity River Audubon Center.

How can you be active in your community?

Second Saturday Habitat Restoration

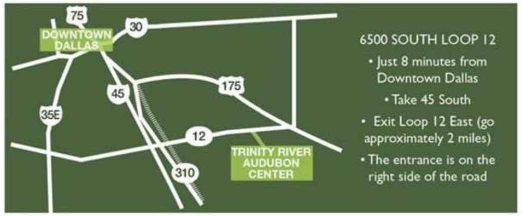
9am - 12pm, Second Saturday of each month

Help Trinity River Audubon Center clear and expand trails, remove invasive species, or restore habitats. 11 years + with adult supervision.

Paid Internships at TRAC

Available to individuals 16 and older

Ask your trail guide for more information.



Connect with us!

facebook.

Instagram

tumblr.

twitter

FREE ADMISSION

ALL DAY
Family Pass
(10 People)

Hours:
Monday: Closed
Tuesday - Saturday: 9am - 4pm
Sunday: 10am - 5pm

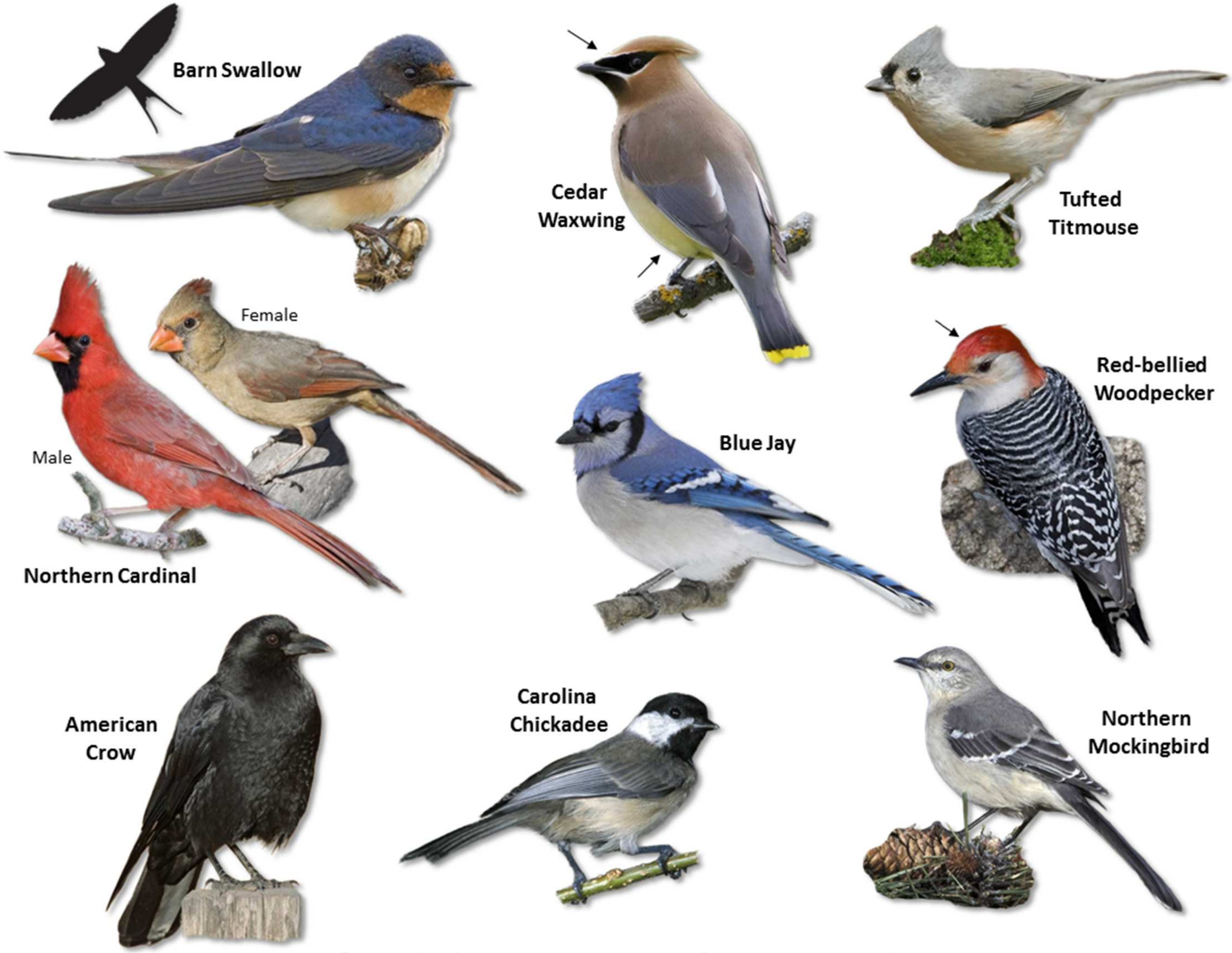
ENTRADA GRATIS

APPENDIX H

Trinity River Audubon Center Bird Identification Guide

Trinity River Audubon Center Bird Identification Guide

Images © National Audubon Society, Inc. For more information visit www.audubon.org.



Images © National Audubon Society, Inc. For more information visit www.audubon.org.

APPENDIX I

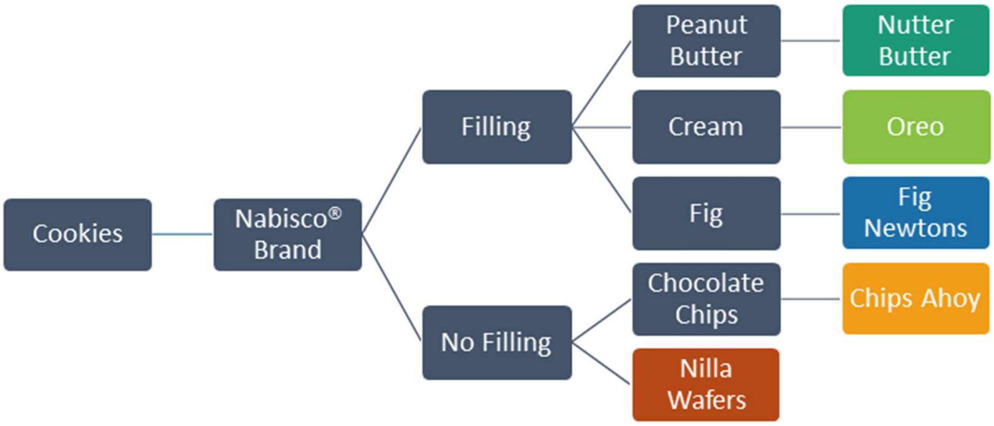
Example Dichotomous Key

What is a dichotomous key?

The word "dichotomous" means "splitting into two distinct parts", like branches on a tree. Dichotomous keys can be used to sort items into separate categories. Consider the example below using cookies.

Find similarities and differences among the cookies. Based upon your observations, you can begin to sort them. For example, Oreos, Nutter Butters, and Fig Newtons all have fillings, while the other two do not. Chips Ahoy has chocolate chips and Nilla Wafers do not.

Nilla Wafers™	**Chips Ahoy™**	**Oreo™**	**Nutter Butter™**	**Fig Newtons™**
vanilla cookie	vanilla cookie	chocolate cookie	peanut butter cookie	vanilla cookie
no filling	chocolate chips	cream filling	peanut butter filling	fig filling
round	round	round	peanut-shaped	square



Dichotomous keys are based upon similarities and differences.
There are many correct answers!

APPENDIX J

Bird Classification Cards

Ruby-Throated Hummingbird

Archilochus colubris

Taxonomic Order: Apodiformes (“without feet”)

Size	3-3.5 in (7-9 cm)
Habitats	Forest edges, meadows, grasslands, parks, gardens, backyards
Habits	Precision flyers: can hover, stop, or dart in any direction in an instant
Activity	Diurnal (daytime)
Food	Nectar, tree sap, mosquitoes, gnats, fruit flies, small bees, spiders, caterpillars, aphids
Predators	Domestic and feral cats, hawks

To hear the bird’s call, scan the QR code below.

Male

Female feeding chick

Images © National Audubon Society

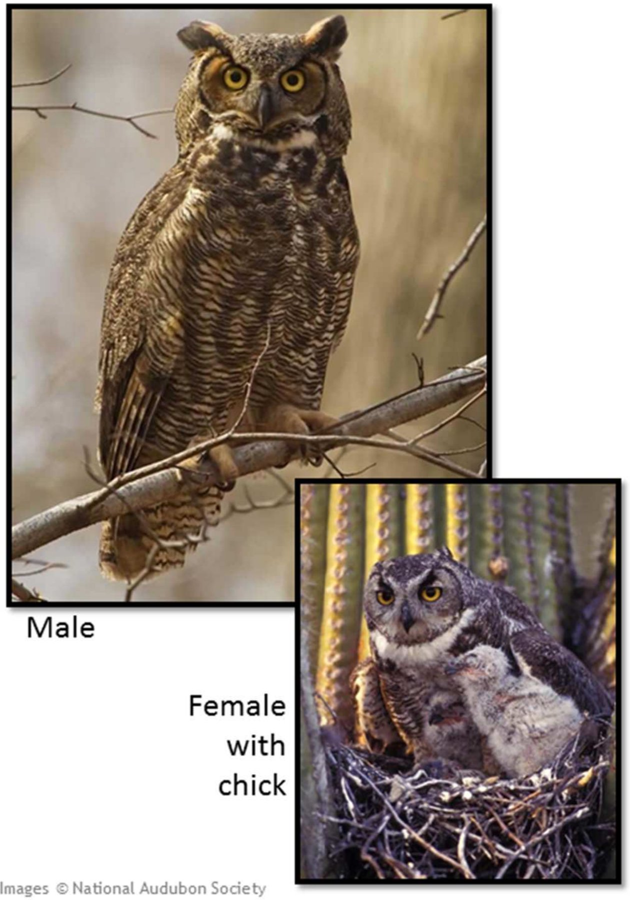
Great Horned Owl

Bubo virginianus

Taxonomic Order: Strigiformes (owls)

Size	18-25 in (45-64 cm)
Habitats	Forests, particularly young forests with open fields, swamps, deserts, tundra edges, orchards, cities, suburbs, parks
Habits	Nest in tree cavities, deserted buildings, cliff ledges, sometimes adopt abandoned nests; glides silently due to fluffy plumage that muffles sound
Activity	Nocturnal (nighttime)
Food	Rabbits, mice, lizards, frogs, beetles, smaller birds
Predators	Golden eagles where present

To hear the bird's call, scan the QR code below.



Male

Female with chick

Images © National Audubon Society

Northern Cardinal

Cardinalis cardinalis

Taxonomic Order: Passeriformes (songbirds)

Size	8-9 in (20-23 cm)
Habitats	Backyards, parks, woodlots, shrubby forest edges
Habits	Extremely territorial in springtime, often attacking their own reflections in windows or mirrors of cars
Activity	Diurnal (daytime)
Food	Seeds, fruit, insects during breeding season
Predators	Owls, falcons and hawks, snakes, raccoons, domestic and feral cats

To hear the bird's call, scan the QR code below.

song

warning call

Images © National Audubon Society

Great Egret

Ardea alba

Taxonomic Order: Pelecaniformes (aquatic birds)

Size	35-41 in (89-104 cm)
Habitats	Freshwater, brackish, and marine wetlands
Habits	Probe for prey in water and mud using their long beaks; nest with other egrets high in trees away from predators
Activity	Primarily Diurnal (daytime)
Food	Fish, amphibians, reptiles, birds, small mammals, invertebrates such as crayfish, shrimp, worms, and insects
Predators	Raccoons, crows, vultures, humans due to habitat destruction

To hear the bird's call, scan the QR code below.

Images © National Audubon Society

Homing Pigeon (Rock Pigeon)

Columba livia domestica

Taxonomic Order: Columbiformes (doves and pigeons)

Size	11-14 in (27-36 cm)
Habitats	Cities and towns, farmland and fields, rocky cliffs
Habits	Innate homing ability; return to nests for multiple breeding seasons
Activity	Diurnal (daytime)
Food	Seeds, fruit, food left by humans
Predators	Falcons, opossums, raccoons, hawks, owls, domestic and feral cats, sometimes gulls, crows, and ravens

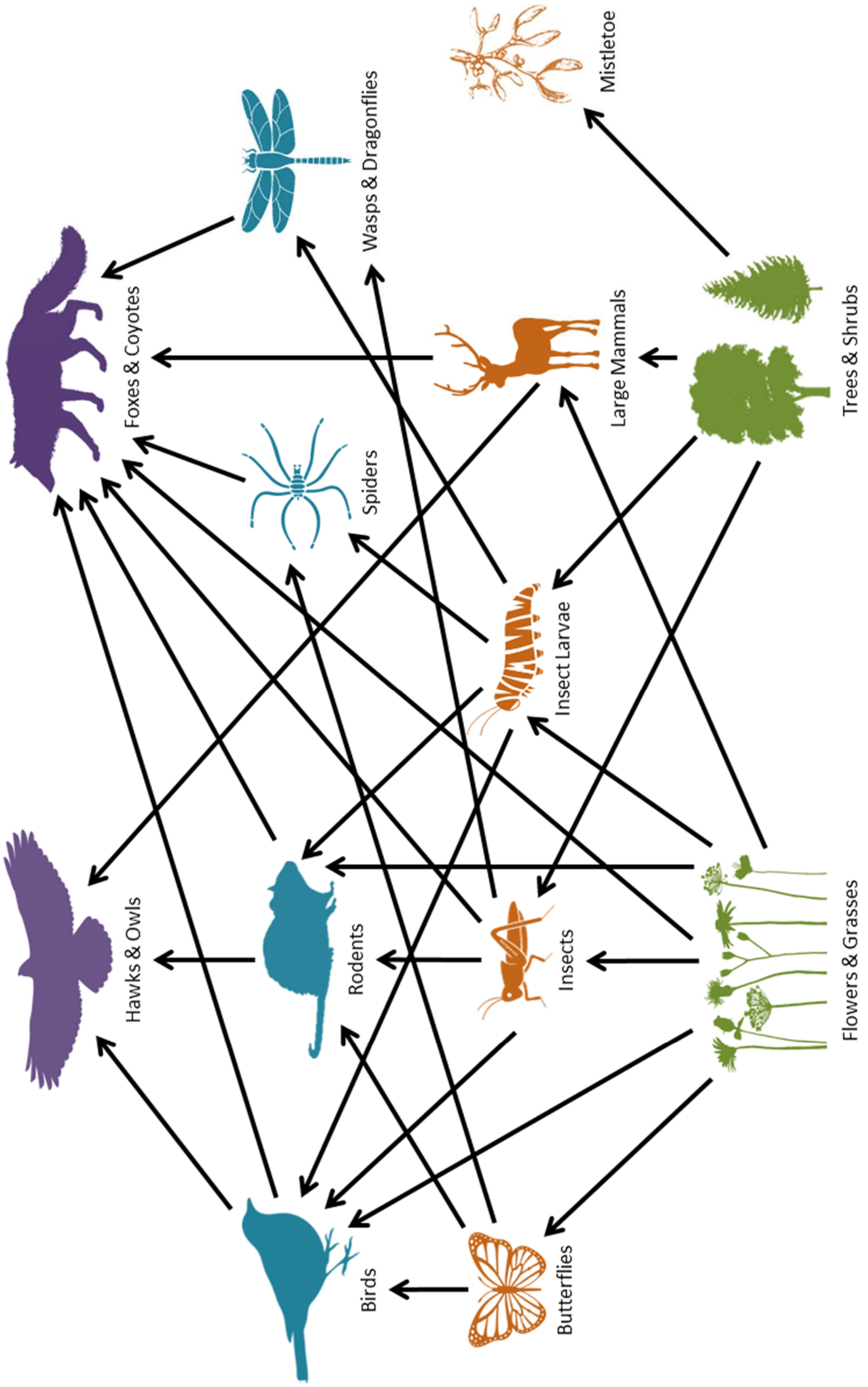
To hear the bird's call, scan the QR code below.

Color variations due to selective breeding

Images © National Audubon Society

APPENDIX K

Food Web Demonstration


Hawks & Owls
Foxes & Coyotes
Birds
Rodents
Spiders
Wasps & Dragonflies
Butterflies
Insects
Insect Larvae
Large Mammals
Mistletoe
Flowers & Grasses
Trees & Shrubs

APPENDIX L

Eco-Investigation Advertisement

TRINITY RIVER Audubon CENTER

The Trinity River Audubon Center, in partnership with Texas Woman's University, presents a new Eco-Investigation for student field trips.

This new Eco-Investigation field trip has been carefully constructed to reflect selected science TEKS (Texas Essential Knowledge and Skills) for grades 5, 7, 8, and high school biology. Students will embark upon a three-part field trip in which they will

- Explore three unique ecosystems: Blackland Prairie, Great Trinity Forest, and Trinity River Watershed.
- Use a key to identify various bird species seen in each ecosystem.
- Use the Scientific Method to make predictions, gather information, and formulate conclusions.
- Work with their peers to create their own dichotomous identification key for a selection of bird species.
- Consider eating adaptations of various organisms found within the exhibit hall.
- Construct a food chain using the organisms they find.
- Observe the consequences of natural disasters on a food web.

A brief pretest and posttest will be administered to determine what the students have learned during and how they feel about their field trip experience. The pretest and posttest have also been mindfully created to reflect questions that will be seen on their next STAAR (State of Texas Assessments of Academic Readiness) examination.

All students will be invited to participate in a research study conducted by Sarah Wehner, a graduate student at Texas Woman's University and co-creator of this Eco-Investigation. The results of students' pretests and posttests will be collected and analyzed for student learning objective achievement and attitudes toward their field trip experience. No individual identifying data will be used for any purpose. For more information, see the following documents:

- Letter to Teachers Regarding Research Study
- Script for Wehner Research Study Recruitment
- Texas Woman's University Consent to Participate in Research

Contact Sarah at swehner@twu.edu or 940-XXX-XXXX if you have additional questions.

APPENDIX M

Letter to Teachers Regarding Research Study

Letter to Teachers Regarding Research Study

Dear Teacher,

My name is Sarah Wehner and I am a graduate student at Texas Woman's University pursuing a master of science degree in biology with an emphasis in science education. My thesis research goal is to determine how learning in an informal science environment (i.e. outside the classroom) affects students' science learning comprehension and attitudes toward learning science.

You and your class have been invited by a member of staff at the Trinity River Audubon Center (TRAC) to participate in an Eco-Investigation field trip. The three field trip modules your class will engage in were created by me, my faculty advisor Dr. Sandra Westmoreland, and Jenna Hanson, the Director of Education at TRAC. We have carefully devised this series of modules to reflect selected Texas Essential Knowledge and Skills (TEKS) covered in four levels of science classes (listed below).

To participate in this research study, your students and their parents or legal guardians must consent to allow me to collect data, which consists of two surveys – one taken before the field trip and a similar one taken after. Each of these surveys includes five multiple-choice questions similar to those the students will experience during their next Science State of Texas Assessments of Academic Readiness (STAAR) exam, be it end-of-year or end-of-course. The surveys will be taken at TRAC on the day of the field trip; you will not be responsible for distributing or collecting them.

Please provide each student with a copy of the following documents in addition to the form provided by TRAC to participate in the field trip program:

1. "Script for Wehner Research Study Recruitment"
2. "TEXAS WOMAN'S UNIVERSITY CONSENT TO PARTICIPATE IN RESEARCH"

I also request that on the day that you send the consent forms home with students, you read the attached document, "Script for Wehner Research Study Recruitment" to your class. Students must be informed of my research intent and its voluntary nature. There is a space on Page 2 of the Consent Form for students to initial that they have heard the script. They may initial that portion at the time of the reading.

If you have any questions, comments, or concerns, you may contact me or my faculty mentor. Our contact information is listed below. If you would like to view the results of this study, please contact me and I will share them with you at its conclusion. Thank you very much for your time and consideration.

Sarah Wehner, BS
Graduate Teaching Assistant
Department of Biology
Texas Woman's University
swehner@twu.edu
940-XXX-XXXX

Sandra Westmoreland, PhD
Assistant Professor
Department of Biology
Texas Woman's University
swestmoreland@twu.edu
940-898-2560

APPENDIX N

Script for Research Study Recruitment

Script for Wehner Research Study Recruitment

This script will be read to students during recruitment to voluntarily participate in the research study "Measuring Changes in Concept Comprehension and Attitudes toward Informal Science Learning from Three New Learning Modules Implemented at the Trinity River Audubon Center". This script is to be read to students by the teacher of the class visiting the Trinity River Audubon Center. A copy of this script will be provided to parents of students to review at their convenience.

> You are invited to participate in a research study for Sarah Wehner, a graduate student at Texas Woman's University. The three activities you will participate in at the Trinity River Audubon Center (TRAC) were created by her and her faculty mentor with help from a staff member at TRAC. You will contribute to her research study by taking two short surveys: one at the beginning of your field trip and one at the end of your field trip. The survey will determine what you learned and how you feel about your experiences at Trinity River Audubon Center. Neither of the surveys will affect your grade. The researcher will not use your name in any of her research.
>
> Your participation in this study is completely voluntary, and you are not required to complete the surveys. You may opt out at any time without penalty. If you wish to participate in the study, please review and sign the "Texas Woman's University Consent to Participate in Research" form that is attached to a copy of this script. If you are under 18 years of age, a parent or legal guardian must also give permission for your participation in this research. Your grade and field trip experience will not be affected if you choose to decline the surveys. To avoid the risk of loss of confidentiality, your consent forms and surveys will be stored in a secure, locked location during and at the conclusion of this study. We appreciate your consideration.

APPENDIX O

Consent to Participate in Research Form

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Measuring Changes in Concept Comprehension and Attitudes toward Informal Science Learning from Three New Learning Modules Implemented at the Trinity River Audubon Center

Investigator:	Sarah Wehner, BS	swehner@twu.edu	940-XXX-XXXX
Advisor:	Sandra Westmoreland, PhD	swestmoreland@twu.edu	940-898-2560

Explanation and Purpose of the Research

You are being asked to participate in a research study for Ms. Wehner's master's degree thesis at Texas Woman's University. The purpose of this study is to the measure the effect of three new learning modules implemented at the Trinity River Audubon Center (TRAC) on students' content knowledge and attitudes toward learning in an informal science environment like TRAC. You have been selected to participate in this study because your class will be attending TRAC on a class field trip.

Description of Procedures

You have been or will be read a script describing the research proceedings by a teacher, and a copy of the script is attached to this form. As a participant in this study, you will be asked to complete two surveys in addition to your field trip activities at TRAC, which will take a total of 4 hours of your time, not including travel time. These surveys will take approximately 15 minutes each and you will take one before the field trip activities and one after the completion of the activities. Completing these surveys will in no way affect your grade or field trip experience.

Potential Risks

The first potential risk of this study is that you may feel coerced into participating in the study by teachers, parents, or peers. This study is completely voluntary and you may withdraw at any time without penalty. If you have not already been read a script describing the research procedure and its voluntary nature by your teacher, one is attached to this form that you may review.

Another potential risk in this study is loss of anonymity. Due to the group nature of the field trip activities, it is possible that your questionnaire answers may be seen by other students, teachers, parents, or TRAC staff. Staff will allow you to complete your assessments away from others in order to minimize this risk.

Finally, there is a risk of loss of confidentiality. Your personal identity will be collected on this consent form and the pre- and post-surveys. Your name will only be collected (1) to ensure that all participants have permission to participate and (2) to match your pre-survey with your post-survey. Your name will not be used in the final research paper; a code will be generated to pair the pre- and post-surveys that will not be related to your identity. Student questionnaires will be seen only by Sarah Wehner and Dr. Sandra Westmoreland, and when not in use, the papers will be stored in a locked filing cabinet in Dr. Westmoreland's office in the Ann Stuart Science Complex on the Texas Woman's University Denton campus. In the case that signed forms and completed surveys are sent by mail, there is a possibility of loss of confidentiality by mail misdirection or non-delivery. This risk will be minimized by assigning any mail a high priority and requiring signature confirmation upon delivery. There is a potential risk of loss of confidentiality in all email, downloading, and internet transactions. This will be minimized by encoding all identifiable data before any internet transaction, so your name will not be attributed to the data. All documents still in possession of the principal investigator or faculty advisor will be destroyed by shredding on or before January 1, 2015, or at the conclusion of this study.

Confidentiality will be protected to the extent that is allowed by law.
Se protegerá la confidencialidad en la medida que la ley lo permita.

Approved by the
Texas Woman's University
Institutional Review Board
Date: 7/10/15

______ Participant Initials

Texas Woman's University
Consent to Participate in Research

The researchers will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

Los investigadores tratarán de prevenir cualquier problema que pudiera suceder a causa de este estudio de investigación. Usted deberá hacer del conocimiento de los investigadores tan pronto exista un problema, y ellos le ayudarán. Sin embargo, TWU no provee servicios médicos ni ayuda financiera para atender daños o heridas que pudieran suceder debido a su participación en este estudio.

Participation and Benefits

Your involvement in this study is completely voluntary and you may withdraw from the study at any time. If you would like to know the results of this study we will mail them to you.*

Questions Regarding the Study

You will be given a copy of this signed and dated consent form to keep. If you have any questions about the research study, please contact the researchers at any time before, during, or after the research proceedings; their phone numbers and email addresses are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

Usted recibirá una copia firmada y fechada de esta forma de consentimiento. Si tuviera cualquier pregunta acerca de este estudio de investigación, favor de dirigir sus preguntas a los investigadores; sus números telefónicos se encuentran en la parte superior de esta forma. Si usted tuviera preguntas acerca de sus derechos como participante en este estudio o acerca de la forma en que este estudio se está llevando a cabo, puede ponerse en contacto con la Oficina de Investigación y de Proyectos Auspiciados por Fondos Externos de la Texas Woman's University al número 940-898-3378 o por correo electrónico a IRB@twu.edu.

________ I agree that I have been read a script describing the research proceedings and I understand that my participation is completely voluntary. (Participant Initials)

____
Full Name of Participant

______________________________________ ______________
Signature of Participant Date

______________________________________ ______________
Signature of Parent or Legal Guardian Date

Approved by the
Texas Woman's University
Institutional Review Board
Date: 7/10/15

____
Participant Initials
Page 2 of 3

Texas Woman's University
Consent to Participate in Research

*If you would like to know the results of this study tell us where you want them to be sent:

Name ____

Email ____ or

Address ____

____

____

Approved by the
Texas Woman's University
Institutional Review Board
Date: 7/10/15

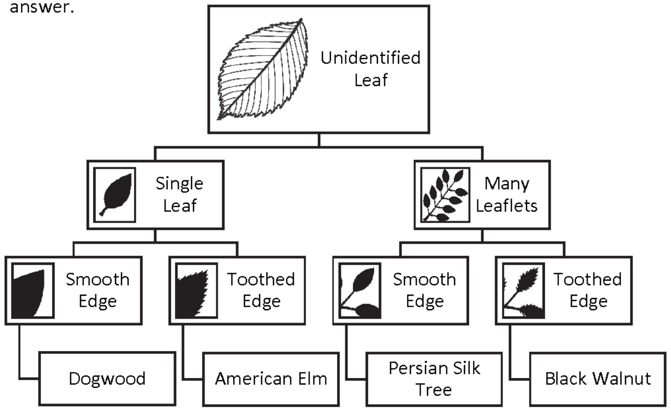
____
Participant Initials
Page 3 of 3

APPENDIX P

Updated Grade 5 Pretest and Posttest

First and Last Name ____ Grade 5

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds foxes flowers honeybees

What organisms are the first to recover after a major natural disaster?

PRETEST

Continued on back ⟶

Name one adaptation that helps a Great Egret (pictured) get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Have you visited the Trinity River Audubon Center before?

○ Yes ○ No ○ Don't Know

Did you want to come to the Trinity River Audubon Center?

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

Do you think you will enjoy your experiences today?

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

About how many hours do you spend outdoors per week?

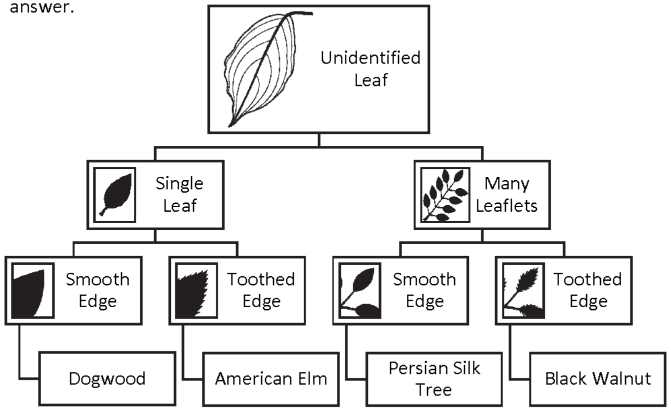
○ 0-1 Hour ○ 2-3 Hours ○ 4-5 Hours ○ 6-7 Hours ○ More Than 7 Hours

Name one activity are you *most likely* to do outdoors.

PRETEST **Thank you for participating.**

First and Last Name ____ Grade 5

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds   foxes   flowers   honeybees

What organisms are the first to recover after a major natural disaster?

POSTTEST   **Continued on back ⟶**

Name one adaptation that helps a Great Egret (pictured) get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Are you glad you came to the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Did you enjoy your experiences today?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Based upon today's activities, are you likely to spend more time outdoors?

○	○	○	○	○
Very Likely	Likely	Neither	Unlikely	Very Unlikely

Would you like to visit other centers like the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

What did you like *most* about today's activities?

What did you like *least* about today's activities?

POSTTEST   **Thank you for participating.**

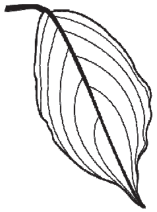
APPENDIX Q

Updated Grade 7 Pretest and Posttest

First and Last Name ____Grade 7

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

1a Leaves are narrow and spiny	Loblolly pine
1b Leaves are flat and broad	Go to **2**
2a Single leaves (single leaf)	Go to **3**
2b Many leaflets (grouped leaves)	Go to **4**
3a Leaf edge is smooth	Dogwood
3b Leaf edge has teeth	American elm
4a Leaflet edges are smooth	Persian silk tree
4b Leaflet edges have teeth	Black walnut



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds grass foxes caterpillars flowers honeybees

What organisms are the first to recover after a major natural disaster?

PRETEST **Continued on back ⟶**

Name one adaptation that helps a Great Egret get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Have you visited the Trinity River Audubon Center before?

○	○	○
Yes	No	Don't Know

Did you want to come to the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Do you think you will enjoy your experiences today?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

About how many hours do you spend outdoors per week?

○	○	○	○	○
0-1 Hour	2-3 Hours	4-5 Hours	6-7 Hours	More Than 7 Hours

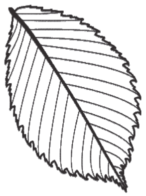
Name one activity are you *most likely* to do outdoors.

PRETEST **Thank you for participating.**

First and Last Name ____ Grade 7

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

1a Leaves are narrow and spiny **1b** Leaves are flat and broad	Loblolly pine Go to **2**
2a Single leaves (single leaf) **2b** Many leaflets (grouped leaves)	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge has teeth	Dogwood American elm
4a Leaflet edges are smooth **4b** Leaflet edges have teeth	Persian silk tree Black walnut



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds grass foxes caterpillars flowers honeybees

What organisms are the first to recover after a major natural disaster?

POSTTEST

Continued on back ⟶

Name one adaptation that helps a Great Egret get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Are you glad you came to the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Did you enjoy your experiences today?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Based upon today's activities, are you likely to spend more time outdoors?

○	○	○	○	○
Very Likely	Likely	Neither	Unlikely	Very Unlikely

Would you like to visit other centers like the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

What did you like *most* about today's activities?

What did you like *least* about today's activities?

POSTTEST **Thank you for participating.**

APPENDIX R

Updated High School Pretest and Posttest

First and Last Name ______________________________________ High School

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

1a Leaves are narrow and spiny **1b** Leaves are flat and broad	*Pinus taeda* Go to **2**
2a Single leaves **2b** Many leaflets	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge is serrated	*Cornus florida* *Ulmus americana*
4a Leaflet edges are smooth **4b** Leaflet edges are serrated	*Albiza julibrissin* *Juglans nigra*

Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds   spiders   grass   foxes   caterpillars   hawks   flowers   honeybees

What organisms are the first to recover after a major natural disaster?

PRETEST **Continued on back ⟶**

Name one adaptation that helps a Great Egret get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Have you visited the Trinity River Audubon Center before?

○ Yes ○ No ○ Don't Know

Did you want to come to the Trinity River Audubon Center?

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

Do you think you will enjoy your experiences today?

○ Strongly Agree ○ Agree ○ Neither ○ Disagree ○ Strongly Disagree

About how many hours do you spend outdoors per week?

○ 0-1 Hour ○ 2-3 Hours ○ 4-5 Hours ○ 6-7 Hours ○ More Than 7 Hours

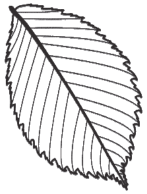
Name one activity are you *most likely* to do outdoors.

PRETEST **Thank you for participating.**

First and Last Name ______________________________________ High School

Use the dichotomous key to identify the type of leaf shown below. Circle your answer.

1a Leaves are narrow and spiny **1b** Leaves are flat and broad	*Pinus taeda* Go to **2**
2a Single leaves **2b** Many leaflets	Go to **3** Go to **4**
3a Leaf edge is smooth **3b** Leaf edge is serrated	*Cornus florida* *Ulmus americana*
4a Leaflet edges are smooth **4b** Leaflet edges are serrated	*Albiza julibrissin* *Juglans nigra*



Draw a food web using all of the following organisms. Show the flow of energy and separate trophic levels.

birds grass foxes caterpillars flowers honeybees

What organisms are the first to recover after a major natural disaster?

POSTTEST **Continued on back ⟶**

Name one adaptation that helps a Great Egret get its food.

Why is biodiversity important in an ecosystem?

Please answer the following questions honestly.
Mark the appropriate bubble or write in the space provided.
This will not be seen by your teacher or affect your grade.

Are you glad you came to the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Did you enjoy your experiences today?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

Based upon today's activities, are you likely to spend more time outdoors?

○	○	○	○	○
Very Likely	Likely	Neither	Unlikely	Very Unlikely

Would you like to visit other centers like the Trinity River Audubon Center?

○	○	○	○	○
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

What did you like *most* about today's activities?

What did you like *least* about today's activities?

POSTTEST **Thank you for participating.**

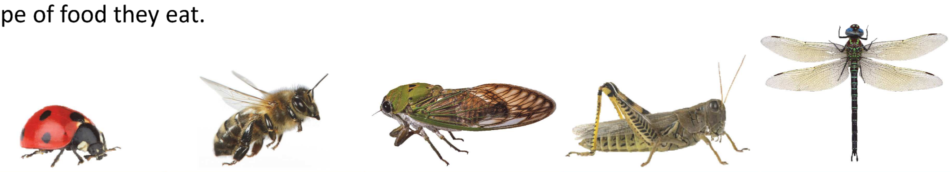
APPENDIX S

Updated Example Dichotomous Key

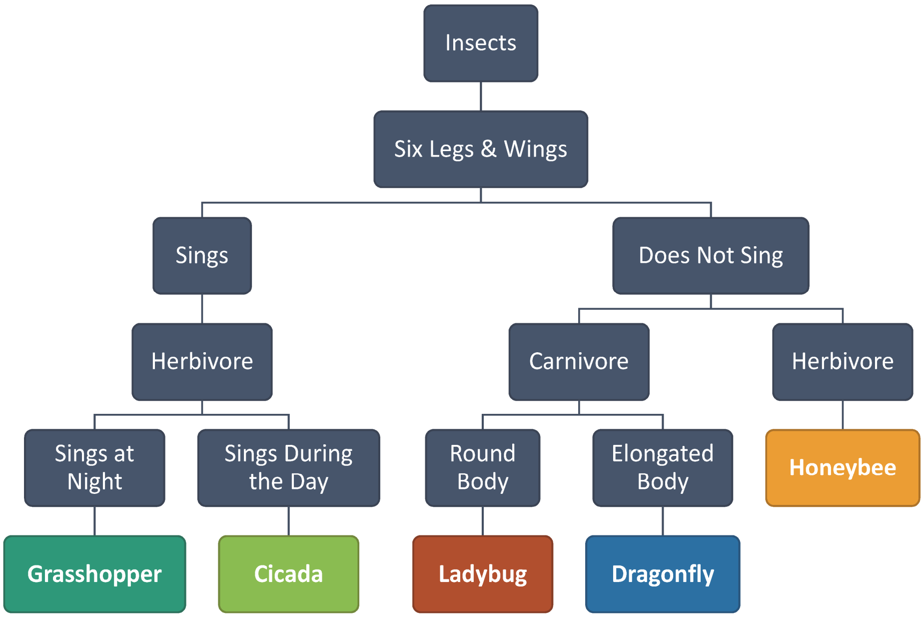
What is a dichotomous key?

The word “dichotomous” means “splitting into two distinct parts”, like branches on a tree. Dichotomous keys can be used to sort items into separate categories. Consider the example below using insects.

Find similarities and differences among the insects. Based upon your observations, you can begin to sort them. In this example, the insects are sorted by their ability to sing and the type of food they eat.



Ladybug	**Honeybee**	**Cicada**	**Grasshopper**	**Dragonfly**
does not sing	does not sing	sings, day	sings, night	does not sing
carnivore	herbivore	herbivore	herbivore	carnivore



Dichotomous keys are based upon similarities and differences.
There are many correct answers!