The North American Conservation Education Strategy:

State Science Standards and K-12 Field Science Practice

A white paper of the Association of Fish & Wildlife Agencies' North American Conservation Education Strategy

Funded by a Multistate Conservation Grant of the Sport Fish and Wildlife Restoration Program

Produced by the Pacific Education Institute

Conservation Education = Conservation

State Science Standards and K-12 Field Science Practice

By

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Pacific Education Institute

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Looking for Real-World Science in State Education Standards

To advance our knowledge of the world, scientists rely on a systematic process of inquiry requiring multiple research methodologies. Controlled experiments constitute one approach: This method tests cause-effect relationships and is most common in laboratories, where variables are easier to control. For research that can only be conducted outside in the natural world, different methodological approaches must be used. Variables are difficult to control outside of the lab, and researchers often seek to answer a different set of questions when working in the field. Methodologies that facilitate this latter type of scientific inquiry can be categorized under three headings: descriptive, comparative and correlative (Windschitl, Ryken, Tudor, Koehler and Dvornich, 2007). In a descriptive investigation, scientists observe and describe parts of a natural phenomenon or system. A comparative study involves collecting data for different groups, locations, or times and then developing a comparison, while correlative investigations allow researchers to discover relationships between two or more variables. These methodologies are a well-established part of professional scientific studies and allow events, life forms, and locations to be systematically described, compared, and analyzed for relationships. Often, they are the necessary precursors to controlled experiments: Typically before researchers can test cause-effect relationships—especially in the macro-environment—they must identify variables, establish their pattern of behavior, and test for correlations.

Given this range of methodologies, it is reasonable to expect public schools to provide instruction in all four types of inquiry: experimental, descriptive, comparative, and correlative. Likewise, state standards for science education should recommend that multiple science inquiry methodologies be included in the science curriculum. This expectation accords not only with professional scientific practice, but also with the National Science Education Standards (NRC, 1996 and 2000) which emphasize the importance of fully engaging students in scientific inquiry so they develop a comprehensive understanding of science and scientific knowledge. The Association of Fish and Wildlife Agencies, therefore, recently sponsored an examination of each state's science standards to determine if they reflect multiple science inquiry methodologies, including those suited to field research. This survey revealed that the science education standards of very few states address field science inquiry methodologies. As a whole, the national education system lacks a common framework for conducting field science inquiry, and it appears most state standards simply assume the experimental design methodology is applicable to scientific inquiry in the field. To ensure that the full range of science inquiry methodologies is included in science education nationwide and that students understand how science is conducted *outside* of the laboratory, the education standards of most states will need to be modified.

Surveying State Science Education Standards

States use standards as benchmarks to assess student performance. To determine whether science education standards address the full range of methodologies used in scientific inquiry, the standards adopted by each state (including Washington D.C.) were downloaded from state department of education websites (Rorie and Cox, 2007). Each state's standards were then compared to the "comparison of field investigations model" developed by Windschitl, et al. (2007). The objective was to determine whether field investigation—and in particular, the use of descriptive, comparative and correlative methodologies—is included in the standards. This survey also assessed whether state standards refer to the controlled experiment model and if so, how much of the experimental method is included. Finally, the authors examined each state's standards to determine:

- Which methodological approach to science inquiry receives the most attention.

- Whether the standards include references to natural resources.
- How readily the field investigation model can be incorporated into the standards.

For those states that test science, the tests were also assessed to see whether and to what extent they include scientific inquiry, field investigation, and references to natural resources. We noted the types of questions used to evaluate science learning, and whether the states use norm-referenced testing, which evaluates student performance by comparing it to the performance of other students, or criterion-referenced testing, which evaluates student performance by comparing it to a fixed standard. A description of the "comparison of field investigations model" and further discussion of the criteria used to conduct this survey can be found in the appendices.

Results of the Survey

The standards of most states emphasize the experimental model of inquiry commonly used in laboratories. While many also incorporate elements of the descriptive model of inquiry, most neglect a critical part of this model: identification of the setting (geographical or time) in which the inquiry is conducted. About half the states surveyed included components of the comparative inquiry model, but again, only two included mention of setting. The correlative model was least represented in state standards. Only two states out of the 51 surveyed had developed standards that included significant components of all four inquiry models and could therefore be said to provide a balanced approach to science education. (See Appendix 2, Figure 1 and Table 1, for a detailed presentation of these results.)

Several state standards stood out from the rest, either for their good fit for field investigation or for their very poor fit for field investigation. The three states that most supported field investigation were Missouri, Alaska, and New Hampshire. Not only were the standards of these states inclusive of many inquiry methodologies, they also defined scientific inquiry in terms that were broad enough to make inclusion of field investigation easy. For example, Missouri expects students to, "Recognize different kinds of questions suggest different kinds of scientific investigations" (Missouri Department of Elementary and Secondary Education, 2005, pg. 92). Field investigation could easily be included here, along with explicit references to the three inquiry models (descriptive, comparative, and correlative) commonly used in field research.

Alaska's standards are similarly designed and can easily support explicit mention of field investigation models. Alaska expects students to "develop an understanding of the processes of science used to investigate problems, design and conduct repeatable scientific investigations, and defend scientific arguments." In addition, they should "develop an understanding that the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review" (Alaska Department of Education, 2005, pg. 1). New Hampshire, meanwhile, describes science as "…an inquiry activity that seeks answers to questions by collecting and analyzing data in an attempt to offer a rational explanation of naturally-occurring events" (New Hampshire Board of Education, 2006, pg. 5). This statement is representative of other similarly broad statements that, with a little specification, could easily support field investigation.

Because Missouri, Alaska, and New Hampshire define inquiry in its most basic form, their standards allow for specification of the variety of forms inquiry can take. The less effective standards, on the other hand, are vague and often fail to describe even basic scientific inquiry. Florida's standards, for example, include statements such as, "The student uses the scientific processes and habits of mind to solve problems" (Florida Department of Education, ND, pg. 1). Florida's standards overall include no particular method of inquiry and never explain what scientific processes are meant. One of Utah's standards illustrates another problematic approach: "Conduct a simple investigation when given directions” (Utah Department of Education, 2002, pg. 5). None of the other statements accompanying this standard explains what is included in an investigation. Likewise, Utah’s standards fail to define the difference between a simple and a complex investigation. It is impossible to tell if field investigation is included, or if “a simple investigation” is based on the experimental model.

While such vague standards do give educators the option to include field investigation in their own classroom practices, they do not support statewide implementation and assessment. Moreover, some states fail to include scientific inquiry as a standard in and of itself. Instead, teachers are expected to address inquiry through the content areas. For example, the only mention of inquiry in Kentucky’s standards appears in a subset of the state educational goals: “Students understand scientific ways of thinking and working and use those methods to solve real-life problems” (Kentucky Department of Education, 2006, pg. 2). Within the content areas, there are descriptions of some of the parts of scientific inquiry, but an overarching process is never discussed. While this may provide individual teachers with the opportunity to address field investigation and other methods of inquiry in their classrooms, it does not ensure all students will receive well developed instruction in all the forms of scientific inquiry.

Washington State’s Standards

Washington State’s standards emphasize controlled experiments in science inquiry and provide an overview of field investigation as a means of science inquiry (without referring to the three field investigative models) in Appendix E of the science education standards (Washington Office of the Superintendent of Public Instruction, 2005). The presence of field investigation in the Washington State Standards appendix has led to several changes. Test developers (who are often master teachers) have been propelled to include field investigation in test items which are now being reviewed for future state testing. Community providers of outdoor experiences for schools now frame their outdoor environmental science experiences with field investigation language. The Pacific Education Institute has documented more field study experiences being offered to science classes since the development of the field investigation model, and teachers are asking for guidelines.

National Science Education Standards

The *National Science Education Standards* (1996) encompass standards for science teaching and professional development of teachers of science, including content, assessment, and education systems and programs. While the *Standards* outline best practices for developing student abilities and understanding using inquiry oriented investigations, they do not reflect the various practices used in scientific communities (Stromholt, 2007). Specifically, the *Standards* describe the necessary components of the scientific process, but do not detail the many forms scientific inquiry can take, including field investigations.

The *Standards* describe inquiry as “a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena” (NRC, 1996, chap.7, para.19). While they state that inquiry must be emphasized in order for students to experience science as it actually works, they do not outline the possible frameworks for inquiry investigations as they are carried out in scientific communities (Stromholt, 2007).

The *Standards* Professional Development Guidelines for teachers also fail to describe inquiry investigations in enough detail to address an expansion of the narrow view of inquiry present in most schools and classrooms. The *Standards* recommend that professional development of teachers of science include participation in inquiry investigations in order for teachers to understand valid scientific methods and ideas. The professional development recommendations, however, provide no guidance on how to facilitate inquiry investigations with students using the various practices of inquiry represented in the scientific community (Stromholt, 2007).

Modifying State Science Education Standards to Include Field Inquiry

The standards of only two states (Alaska and New Hampshire) received a ‘balanced’ rating, indicating that their standards reflect the full range of science inquiry methodologies (see Appendix 2 Table 1 and Appendix 3). Eighty-four percent of the states received ‘controlled experiment’ ratings, demonstrating that the definition of scientific inquiry currently used by most educators overemphasizes one form of inquiry. The standards of most states will have to be modified if they are to support comprehensive science education. How much work will be required to add field investigation to the standards varies. Nineteen states would need only greater specificity in the wording of their standards to include field inquiry, while 17 require more extensive modification to broaden the description of scientific inquiry and explicitly include all four research methodologies. The standards of most states already contain components of the descriptive inquiry methodology (about 71 percent), although most include it primarily as a foundation for the experimental method. A little more than half (about 53 percent) include components of the comparative methodology; far fewer (about 40 percent) address any part of the correlative methodology. By contrast, the standards of most states address most or all parts of the experimental method (88 percent). Almost 95 percent of the standards also included references to natural resources, however, so there is clearly fertile ground for including field investigation.

Forty-six states test science, and almost 74 percent of the tests used by these states include scientific inquiry questions. Half of the states also include references to natural resources, and almost half use a mixture of multiple choice questions and constructed response questions on their tests (Appendix 4, Table 2). This mixture is ideal for testing science inquiry in general and field investigation in particular. These results also suggest many states already consider scientific inquiry a priority and should therefore be receptive to modifications designed to incorporate the full range of inquiry methodologies (Appendix 5).

Based on the recommendations of the National Research Council (NSES 1996), programs are being developed by federal and state agencies, school districts, and other organizations that allow students to experience science outside of the classroom. Studies show field based environmental education programs actively engage students, help them to retain science content, create positive social-emotional impacts, and promote greater stewardship (Rillero and Haury 1994, Abraham 2002). Due to the wide variance of state standards and district guidelines, there is no national consensus for a field science inquiry framework.

Field Studies in Practice

In a nationwide study conducted for the Association of Fish and Wildlife Agencies, Wolfe and Cox (2007) analyzed one hundred and ninety-six field-based K-12 science inquiry programs located throughout the United States identifying the focus of field science programs and the types of field investigation models used (see reference list: Field Studies In Practice).

The K-12 field studies program providers were identified through web sites, journals and direct phone conversations with federal and state agencies, local governments, and departments of education. These programs provide services through workshops and field experiences to K-12 educators and/or their classrooms. Sixty-one percent of all the field based science education programs in this investigation studied living systems. Thirty-two percent were associated with physical science while roughly seven percent of the programs were associated with earth systems and space investigations. In an analysis of their field studies offerings, roughly eighty percent of the programs provided descriptive field studies, 60 percent provided comparative studies and 50 percent offered correlative field study experiences.

The Wolfe and Cox (2007) study found that successful programs that included all three forms of field investigations (descriptive, comparative, and correlative) were collaborative efforts in which multiple professionals and associated organizations designed their field programs with educators. Field studies program providers generally partnered with state agencies (Fish & Wildlife, Natural Resources) and the local school districts. Without the co-operation of the agencies, many of the programs would not have access to the lands and facilities needed to support their field studies with K-12 students.

The Wolfe and Cox (2007) study demonstrates the growing interest of community, state and national groups to provide teachers and students with field science experiences. This study did not find any indication of a field investigation framework in place for these field studies program providers. However the range of field experiences currently offered indicates the value the Windschitl et al. (2007) field investigation framework and guidelines will have for these providers to assist educators to meet National Science Education Standards (NRC, 1996) which emphasize the need for multiple forms of inquiry.

Implications

Scientists in the field use a variety of investigative strategies and recognize that different methodologies suit different questions and stages of research. Yet, this continuum or progression of inquiry is currently unaddressed in most states' science standards. In most states, science education is focused on the experimental method—although few standards address this method exclusively. Most states recognize intuitively that descriptive studies are a foundation for other parts of the inquiry process, although most omit the intervening stages of research and instead proceed immediately to experimental design (see Appendix 2, figure 1). Yet, even those that include comparative and, to a lesser extent, correlative studies, fail to recognize the progressive and sequential nature of these types of inquiry. In general, most standards place descriptive studies in the primary grades, which indicates a basic understanding that observation skills must come first. Components of comparative, correlative, and experimental methodologies, on the other hand, appear in the standards randomly and at various grade levels, reflecting no real awareness of the order or sequencing of the inquiry process. Obviously, it would be better for educational standards to present the inquiry methodologies in logical sequence. Moreover, while it does make sense to introduce descriptive studies in the lower grades, this methodology should not be abandoned in the later grades. Because scientific inquiry is a process, students should be taught to follow the sequence of inquiry methods, from descriptive all the way through experimental (if situations permit controlled experiments) or to whichever inquiry type is the furthest their investigation can be taken.

As state standards are adjusted to include field inquiry, it is also worth noting that this type of inquiry, by definition, takes place in the field. While some descriptive, comparative, and correlative studies can be done in the classroom, a better understanding of how these types of investigations work in the real world can only be gained by venturing outdoors. If students are to understand how professional scientists function in their workplaces, they must have the opportunity for hands-on experience in the forests, wetlands, coastal regions, and watersheds in which scientists conduct research. Standards that acknowledge the importance of the geographical setting of an investigation give teachers the incentive to provide their students with outdoor field experience. Well-crafted science education standards also ensure rigorous inquiry methods are used, and students learn not only facts and concepts, but also develop a more complex understanding of relationships and systems.

The results of this survey suggest that all states would benefit from a reevaluation of their current standards and concerted efforts to include multiple science inquiry methodologies, as recommended by the National Research Council's National Science Education Standards (1996 and

2000) and described by Windschitl et al. (2007). Moreover, if state standards clearly assert the importance of descriptive, comparative, and correlative inquiry, all educators will have the incentive and support they need to include instruction in field investigation, and all students will receive a comprehensive education in science. Students will graduate from the education system as scientifically literate adults, with real-world experience, an understanding of the methods and skills employed by professional scientists in the field, and a better grasp of the complex natural systems that form our world. As a result, students will be better prepared for their roles as citizens and stewards of our natural resources.

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Wyoming State Board of Education (ND). *PAWS: Science Released Items*. Retrieved on August 19, 2007 from http://www.k12.wy.us/.

Reference List: Field Studies In Practice

The following is a list of programs, associations, agencies, and universities that were included in the K-12 field science in practice investigation via direct and indirect contact and web review conducted by D. Wolfe and J. Cox (2007).

Program Names:

- 4-H Environmental Camp
- Adopt-a-Boat
- Advanced Biotechnology Institute (for high school students)
- After School Science Clubs
- Alaska Coastal Ecology
- Alaska Lake Ice & Snow Observatory
- Alaska Wildlife
- All Access Boston Harbor
- Alliance for Science
- Alternative Strategies for Preserving Tropical Ecosystems
- Ambassadors for the Environment
- An Exploration into Learning
- Animal Characteristics
- Apprentice Researchers
- Arboretum of Flagstaff
- Arizona Association for Environmental Education
- Astrobiology Summer Science Experience for Teachers (ASSET)
- Astronomy Camp - Educators
- Astronomy Camps
- Astronomy Research-Based Science Education
- Authentic Science Research in the High School ®
- Aviation and Space Education Workshop, Fort Worth, TX
- Backyard Discoveries
- Bayside Buddies
- Beauty and Charm at Fermilab
- Beluga Wetlands Ecology
- Biotech Frontiers
- Bird Academy
- Bird Field Trips
- Bosque Education Guide Teacher Workshop
- California Academy of Sciences
- Camp SEA Lab
- Center for Nanoscale Systems Institute for Physics Teachers
- Chabot Space and Science Center
- Children's School of Science, Inc
- Club Mud
- CMU Biological Station on Beaver Island
- Coastal Field Studies
- Coastal Walk
- Color Country Natural Resources Camp
- Coral Reefs
- Desert Sharks
- Desert Teacher Workshop
- Discovery Hall Programs Summer Marine Science Course
- Diversity of Lifestyles
- Dolphin Lab
- Earth Science Workshop
- Eco Adventures
- Eco Systems Exploration
- Ecologists
- Ecology of Grand Traverse Bay
- Ecology of Mashantucket
- Education Program
- Educational Education Council of the California - Environmental Education Field Guide
- Endangered Species & Other Programs
- Enfield Shaker Museum - Village Gardeners
- Environmental Outreach
- Environmental Education Days (EE Days)
- Environmental Field Days
- Estuary Live
- Evening Seminar Series
- Evolution of a Planetary System: Exploring our Origin
- Explore the Eugene Wetlands
- Explorer Program
- Explorers of the Ocean
- Extended M.S. in Natural Resources/Environmental Education for Elementary and Secondary Teachers
- Farm Bureau Volunteers & Adopt a Classroom
- Farm Experience
- Farm Tours and Workshops For Teachers
- Farm-To-School Tour
- Fitzgerald Marine Reserve
- Florida Teachers Tour
- Food Fiber and More
- Fossil Field Workshop
- Fresno's Tour to Peru
- From the Milky Way Galaxy to the Edge of the Universe, a Content-Rich Tour of the Universe
- From the Solar System to the Stars, an Inquiry-Based Tour of the Local Universe
- Frontiers in Physiology Fellowship
- Frontiers of Science Institute (FSI)
- Gator Lab
- General Biology Program for Science Teachers
- General Science in Childhood and Middle School Education
- Geology of Arizona
- Gerald E Eddy Discovery Center
- Glide School Partnership
- Graduate Field Courses for K-12 Teachers and Family Nature Camps
- Gulf Island Journey Middle School Camp
- Habitat Ecology Learning Program (HELP)
- Hands on the land
- Hands-on Biotechnology: DNA Fingerprinting and Genetic Engineering
- HEADS ON! For Healthy Living
- High School Archaeology Program
- High School Field School
- High School Marine Biology
- High School Marine Biology
- Horticulture & School Gardens
- Incredible Insects
- Indiana PEPP
- Infusing Critical & Creative Thinking into Science Classrooms
- International Science Frontiers
- Intertidal Life Field Exploration

- Jr. Naturalist Program
- Juneau Icefield Research Program, Alaska
- Just Grow It
- Kachemak Bay Onboard Oceanography
- Keeping Florida Green Workshop
- KFAC Summer Courses
- Kids Growing Food
- Laboratory Investigations and Field Experiences
- Laboratory Investigations and Field Experiences
- Laboratory Investigations and Field Experiences - Field Trip in a box
- Lawrence Hall of Science Summer Residence Camps
- LIFE - Apalachicola NERR
- Life Lab
- Living on the Edge
- Ludington State Park, River Study, Winter Walk, Pond Discovery
- MAITCA Summer Teacher's Training Conference
- Marine Biology
- Marine Ecology History and Cultural Heritage of the Florida Keys
- Marine Science / SCUBA Camp
- Materials "Day" Camp
- Michigan Technological University Summer Youth Program
- Middle School Archaeology Program
- Mildred E. Mathias Botanical Garden
- Mineral Education
- Mobile Science Lab
- Museum of Agriculture
- Nature of Learning
- Nature’s Treasure Hunt
- NAU Summer Institute
- NOAA Teacher at Sea Program
- North American Association for Environmental Education
- Northern Studies Field Course
- Northwest Regional Educational Library (NWREL)
- OceanCamp Summer 2000
- Oceanography Program
- Oceanology at Occidental College
- Orange County Wild
- Oregon Museum of Science and Industry Summer and Research Camps
- Outdoor Classroom Program
- Outdoor Science Park – Forces that Shape The Bay
- Particles and Prairies
- People & Animals: United for Health
- Placed Based Education
- Plate Tectonics , Water Education, Planetarium, etc.
- Prairie Wetlands Learning Center
- Pre-college School Summer Scholars Program
- Project Food, Land and People
- Project Learning Tree
- Project Wet
- Project Wild
- Project Wild
- Rainforest and Marine Biology Workshops
- REAP
- Research Experience for Teachers
- Rivers Project
- Sagehen Wildlife Biology Research Camp
- Saint Louis Zoo
- School Garden Program
- School to Farm Days
- School Yard EcoSystems
- Schoolyard Desert Discovery Project
- Schoolyard Gardens
- Science Quest
- SciTrek: Real Science, Real Research in a Safe, Environmentally Benign & Interdisciplinary Context
- Sea Camp
- Sea Explorers Summer Program
- SeaWorld / Busch Gardens Adventure Camps
- SeaWorld San Antonio Adventure Camps
- Secondary Student Training Program: Research Participation Program
- Seeds Of Nature, Human Interactions with environment
- Southwest Florida Marine Ecology
- Streamkeepers - Field Training
- Summer Agricultural Institute
- Summer Learning Adventures
- Summer Science Program
- Summer Student Program
- Summer Workshop
- Teaching Southwest Florida Marine Ecology
- The Prairie-Our Heartland
- The Whale Camp- Youth Programs
- Tidal Flat and Salt Marshes - North Carolina Maritime Museum Summer Science School
- TOPS @ Occidental College
- University of California Davis - Partnership for Plant Genomics Education
- Upward Bound Math and Science Program
- Use Food to Teach Science Workshop (Chicago, IL)
- Water Quality and Watersheds: A GIS Investigation
- Watershed Watch - In classroom
- Western Upper Peninsula Center for Science, Mathematics & Environmental Education
- Whale of a Mystery
- Where are all the animals
- Whodunit? The Science of Crime Scenes
- Wild Places
- Wolf State Lake Hatchery
- Young Curators Institute Demonstration and Theater
- Young Explorers Camp
- Young Scholars Program
- Zoo Preview
- ZooKambi

Agencies, Institutions & Affiliations:

- Acadia Institute of Oceanography
- Adopt-A-Stream Foundation, US Dept of Agriculture, Idaho Ag in the classroom, AASF
- Alabama Agriculture in the Classroom (AITC)
- Alaska Coastal Studies
- Alaska Department of Fish & Game
- Alaska Department of Natural Resources - Division of Forestry
- Alaska Islands & Ocean Visitor Center, US Fish & Wildlife Service, NOAA
- Albemarle-Pamilco National Estuary Program

- Albuquerque Aquarium Programs
- Albuquerque BioPark's Rio Grande Zoo
- American Geological Institute, University Of Arizona
- American Physiological Society
- Arboretum of Flagstaff
- Arizona National Livestock Show
- Arizona State University West
- Arizona Strip Interpretive Association
- Bay Area School Reform Collaborative Funders Learning Community
- Boston Experiential Environmental Education
- Boston Experiential Environmental Education, MIT SEA grant
- Bradley University
- Brevard County Extension, Florida Agriculture in the Classroom
- Bridgewater State College's City Lab
- Bristol-Myers Squibb
- Bronx Zoo Education Department
- Bronx Zoo Education Department/Wildlife Conservation Society, National Science Foundation
- Bureau of Land Management
- California Academy of Sciences
- California Coastal Commission
- California Geological Survey
- California Museum of Science and Industry
- California School Garden Program
- California Science Project
- California Science Teacher Association
- California Sea Grant Extension Program
- California State University
- California State University, Fresno
- Camp SEA Lab
- Cate School
- Center for American Archeology
- Central Michigan University
- Chabot Space & Science Center
- Chihuahuan Desert Nature Park
- Children's School of Science, Inc.,
- City of St. George
- Clark Atlanta University
- College of the Atlantic
- Colorado Foundation for Agriculture
- Colorado State University
- Community Foundation of Monterey County
- Connecticut Department of Agriculture
- Cornell University
- Council for Environmental Protection
- Crow Canyon Archaeological Center
- Crow Canyon Archaeological Center
- CTW Foundation
- Dauphin Island Sea Lab
- Denali Institute
- Denver Zoo
- Department of Education
- Department of Education Math & Science Bureau
- Discovery Trails
- Discovery Science Center, Orange County
- Dixie Applied Technology Center
- Dixie Soil Conservation District
- Dolphin Research Center
- Earthworks
- Eastern Connecticut State University
- Enfield Shaker Village and the Missionaries of LaSalette
- Environmental Education Council for the Californias
- Environmental Protection Agency
- EPSCoR
- Estuary Live, NOAA
- Federal Aviation Administration
- Fermi National Accelerator Laboratory
- Fitzgerald Marine Reserve
- Florida Department of Agriculture & Consumer Services
- Florida Department of Agriculture & Consumer Services, Bear Creek Educational Forest
- Florida Department of Environmental Protection
- Florida Fish & Wildlife Conservation Commission
- Florida State University
- FMI Corporation
- Foundation for Glacier and Environmental Research
- Geological Survey of Alabama
- Heritage College
- Idaho Forest Products Commission
- Indiana University
- Inland Seas Education Association
- Institute of Food Technologists (IFT)
- International Field Studies
- John G. Shedd Aquarium
- Jornada Experimental Range
- Jounston County community College
- Journal of Extension
- Kachemak Bay Educational Alliance
- Kaibab - Paiute Tribal Council
- Kansas Foundation for Agriculture in the Classroom (KFAC), USDA, Agriculture in the Classroom
- Kentucky Farm Bureau
- Kentucky State University
- Large Foundation
- Lawrence Hall of Science
- Litzsinger Road Ecology Center
- Louisiana Tech University
- Maine Agriculture in the Classroom
- Maryland Agricultural Education Foundation
- Mashantucket Pequot Tribal Nation
- Massachusetts Agriculture In The Classroom
- Massachusetts Society for Medical Research, Inc.
- Michigan 4-H Club, Michigan State Horticulture Department
- Michigan Alliance for Environmental and Outdoor Education
- Michigan Alliance for Environmental and Outdoor Education
- Michigan Department of Natural Resources
- Michigan Department of Natural Resources, Ludington State Park
- Michigan Tech Alive

- Michigan Technological University
- Missouri Botanical Gardens
- Missouri Department of Education
- Montana State University
- Morningside College
- Mote Marine Laboratory
- National Oceanic and Atmospheric Administration
- National Optical Astronomy Observatory, Tucson AZ
- National Science Foundation
- Nebraska Department of Curriculum and Instruction
- New Hampshire In The Classroom
- New Jersey Agricultural Society, USDA, New Jersey Department of Education
- New Jersey Farm Bureau
- New Jersey State Grange
- New Mexico Academy of Science
- New Mexico Museum of Natural History And Science
- New York Hall of Science
- NOAA
- NOAA B-WET Program
- NOAA's Office of Ocean Exploration
- North American Association for Environmental Education, NOAA, Environmental Protection Agency
- North Carolina Maritime Museum
- Northern Arizona Education Resource Center
- Northern Arizona University
- Northwest Regional Educational Library (NWREL)
- NY Agriculture in the classroom, Cornell University
- Oakland Museum of California
- Occidental College
- Office of Public Instruction
- Orange County
- Oregon Museum of Science and Industry
- Pebble Beach Company
- Potter Park Zoological Society
- Rainforest and Reef Conservation Fund Inc.
- Red Cliffs Desert Reserve
- Rensselaer Polytechnic Institute
- Rio Grande Botanic Gardens
- Rutgers
- Sacramento Zoo
- Salish Sea Expeditions
- Scandinavian Seminar
- School for Field Studies
- Sea World
- Sea World of San Antonio
- SEACAMP
- SETI Institute
- Sharing Success Programs
- Sonoma State University SSU PreCollege Programs
- Southern Illinois University, Edwardsville
- St. Louis Zoo,
- Stevens Point - College of Natural Resources
- Summer Science Program in Ojai, California
- Tarrant County College
- Taylor University
- Texas A& M University at Galveston
- The David and Lucille Packard Foundation
- The Jackson Laboratory
- The Lloyd Center for Environmental Studies
- The Maria Mitchell Association
- The Pennsylvania State University
- The Pennsylvania State University
- The Roxbury Latin School
- The State University of New Jersey
- The Whale Camp
- Troy State University
- U.S. Forest Service
- UCLA
- UCLA Stunt Ranch Santa Monica Mountains Reserve
- University of Minnesota
- University of Alaska Fairbanks
- University of Arizona
- University of California Davis
- University of California Southern California
- University of California, Berkeley - Lawrence Hall of Science
- University of California, San Diego
- University of California, San Diego - Birch Aquarium at Scripps Institution of Oceanography
- University of California, Santa Barbara - California Nanosystems Institute (CNSI)
- University of Cortland
- University of Florida
- University of Florida Center for Pre-collegiate Education and Training
- University of Hawaii
- University of Iowa
- University of Kentucky
- University of Maine, USDA
- University of Northern Colorado
- University of Wisconsin
- US Department of Interior - Bureau of Land Management
- US Department of Agriculture, Jornada Experimental Range
- US Fish & Wildlife, National Science Foundation
- Utah Division of Wildlife Resources
- Utah State University
- Waquoit Bay Science School at the Waquoit Bay National Estuarine Research Reserve (WBNERR)
- Washington County School District
- Watershed School
- Wayne State University
- Wellfleet Bay Wildlife Sanctuary, Mass Audubon
- Wesley College
- Wisconsin Center for Environmental Education
- Youth Impact International

Appendix 1

Comparison of Field Investigations Model (Windschitl et al., 2007)

For each of the three field inquiry methodologies (descriptive, comparative, and correlative), the Windschitl model outlines seven areas of questions:

1. Formulate investigative questions.
2. Identify setting within a system.
3. Identify variables of interest.
4. Collect data.
5. Analyze data.
6. Use evidence to support an explanation.
7. Discussion.

DESCRIPTIVE METHODOLOGY questions are designed to guide observations:

Windschitl et al. (2007) Seven Areas	**Descriptive Methodology Questions**
1. Formulate investigative questions.	"How many? How frequently? When does it happen?"
2. Identify setting within a system.	"What is the geographic scale or time frame of the investigation?"
3. Identify variables of interest.	"Are these variables measurable or observable?"
4. Collect data.	"Are there multiple measures over time or location to improve system representation? Does an individual measurement need to be repeated? How can I record and organize data?"
5. Analyze data.	"What mathematical models can I use, such as mean, median, mode, range, and percentages? How can I graphically organize my data into tables, line graphs, bar graphs, maps, or charts to present my data?"
6. Use evidence to support an explanation.	"Does my data answer the investigative question? How can I use my data to support my explanation? How far does my data relate to (limit to study site)? How does my data compare to standards or what is already known?"
7. Discussion.	"How do my results answer questions and add understanding of this system? How is my data like other similar systems? What factors might have impacted my research? How do my findings relate to the essential questions? What are my new questions? What action should be taken and why?"

COMPARATIVE METHODOLOGY questions are designed to make predictions, create hypotheses, and compare the data between groups or events:

Windschitl et al. (2007) Seven Areas	**Comparative Methodology Questions**
1. Formulate investigative questions.	“Is there a difference between groups, conditions, times, or locations?”
2. Identify setting within a system.	“What is the geographic scale or time frame of the investigation?”
3. Identify variables of interest.	“Is this a measurable variable in a least two different locations, times, organisms, or populations?”
4. Collect data.	“Are there multiple measures over time or location to improve system representation? Does an individual measurement need to be repeated? Was my sampling, measurement, or observations consistent for two or more locations? Were they representative of the site? How can I record and organize data?”
5. Analyze data.	“What mathematical models can I use, such as mean, median, mode, range, and percentages? How can I graphically organize my data into tables, line graphs, bar graphs, maps, or charts to present my data?”
6. Use evidence to support an explanation.	“Does my data answer the investigative question? How can I use my data to support my explanation? How far does my data relate to (limit to study site)? How does my data compare to standards or what is already known? Does the evidence support my hypothesis?”
7. Discussion.	“How do my results answer questions and add understanding of this system? How is my data like other similar systems? What factors might have impacted my research? How do my findings relate to the essential questions? What are my new questions? What action should be taken and why?”

CORRELATIVE METHODOLOGY questions are designed to create a hypothesis and discover the relationship between variables.

Windschitl et al. (2007) Seven Areas	**Correlative Methodology Questions**
1. Formulate investigative questions.	"Is there a relationship between two or more variables?"
2. Identify setting within a system.	"What is the geographic scale or time frame of the investigation?"
3. Identify variables of interest.	"Can these two (or more) variables be measured together and tested for a relationship?"
4. Collect data.	"Are there multiple measures over time or location to improve system representation? Does an individual measurement need to be repeated? Was my sampling, measurement, or observations consistent for two or more locations? Were they representative of the site? How can I record and organize data?"
5. Analyze data.	"What mathematical models can I use, such as mean, median, mode, range, and percentages? How can I graphically organize my data into tables, line graphs, bar graphs, maps, scatter-plots, r-values, or charts to present my data?"
6. Use evidence to support an explanation.	"Does my data answer the investigative question? How can I use my data to support my explanation? How far does my data relate to (limit to study site)? How does my data compare to standards or what is already known? Does the evidence support my hypothesis?"
7. Discussion.	"How do my results answer questions and add understanding of this system? How is my data like other similar systems? What factors might have impacted my research? How do my findings relate to the essential questions? What are my new questions? What action should be taken and why?"

EXPERIMENTAL METHODOLOGY questions focus on developing predictions and hypotheses to answer a cause-effect question about the relationship of variables. (The Windschitl et al. (2007) model did not include an experimental model in the table of research designs. Using Alabama's model of experimental investigation, we developed questions for each experimental design step (Alabama Department of Education, 2005).)

Seven Areas	**Experimental Methodology Questions**
1. Formulate investigative questions.	"What will happen in the future based on the observable characteristics of these variables? How does one variable affect another?"
2. Identify setting within a system.	*Note that identifying a setting in the experimental model does not require a geographical location, as with field investigation settings*
3. Identify variables of interest.	"How can I operationalize my variables? What do they look like in measurable terms? How can I control the variables so that only one aspect is changed at a time?"
4. Collect data.	"How do I manage or control my variables so that I can collect data on one change in them? What is the most logical way of working this experiment in order to answer my question and to test all variables?"
5. Analyze data.	"Based on the data I collected, should I accept my hypothesis (was it supported?) Or reject my hypothesis (was it not supported?)?"
6. Use evidence to support an explanation.	"What are my recommendations for future research? What is my new hypothesis based on the data I collected?"
7. Discussion.	

Appendix 2

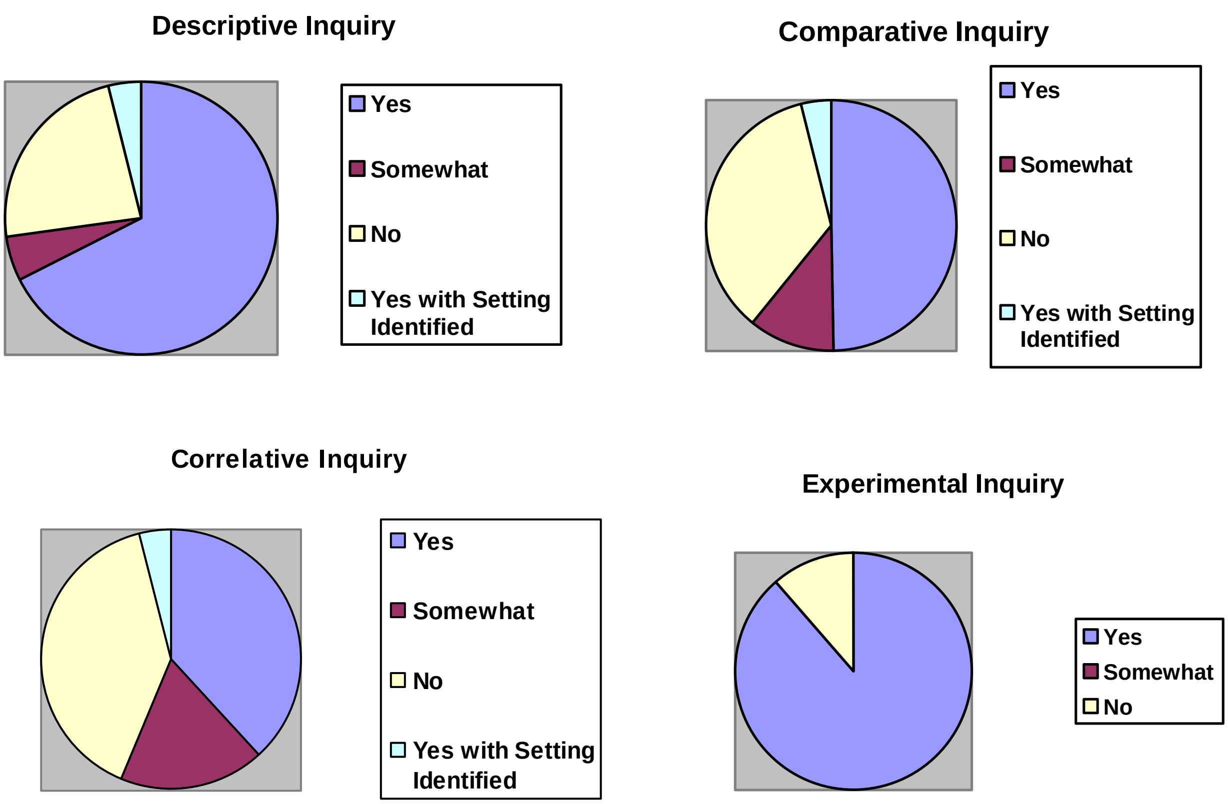
Comparing State Standards to the Windschitl et al. (2007) Model

Each state's standards were evaluated to determine whether they address the seven areas identified in the Windschitl et al. (2007) model. For each area, one of three answers was possible:

- ***Yes:*** If most or all of the questions/parts of the model area are included in the standards, the answer was "yes."
- ***Somewhat:*** If one or two of the questions/parts of the model area are included in the standards, the answer was "somewhat."
- ***No:*** If none of the questions/parts of the model area are reflected in the standards, the answer was "no."

Figure 1

Results of Science Inquiry Type Comparisons



Only two states rating 'yes' answers included identification of the setting as part of the inquiry process. Identification of the setting is obviously a critical component of field investigations.

Table 1

State Science Standards Comparisons

Percentage (number of states)	**Yes**	**Somewhat**	**No**
Descriptive			
Formulate Investigative Question	98.0% (50)	2.1% (1)	0
Identify Setting within a System	3.9% (2)	0	96.1% (49)
Identify Variables of Interest	100% (51)	0	0
Collect Data	47.1% (24)	5.9% (3)	47.1% (24)
Analyze Data	82.4% (42)	9.8% (5)	7.8% (4)
Use Evidence to Support an Explanation	90.2% (46)	9.8% (5)	0
Discussion	78.4% (40)	9.8% (5)	11.8% (6)
Comparative			
Formulate Investigative Questions	54.9% (28)	5.9% (3)	39.2% (20)
Identify Setting within a System	3.9% (2)	0	96.1% (49)
Identify Variables of Interest	45.1% (23)	3.9% (2)	51.0% (26)
Collect Data	23.5% (12)	37.3% (19)	39.2% (20)
Analyze Data	82.4% (42)	9.8% (5)	7.8% (4)
Use Evidence to Support an Explanation	88.2% (45)	9.8% (5)	2.0% (1)
Discussion	78.4% (40)	9.8% (5)	11.8% (6)
Correlative			
Formulate Investigative Questions	33.3% (17)	3.9% (2)	62.7% (32)
Identify Setting within a System	3.9% (2)	0	96.1% (49)
Identify Variables of Interest	27.5% (14)	7.8% (4)	45.1% (23)
Collect Data	23.5% (12)	37.3% (19)	39.2% (20)
Analyze Data	31.4% (16)	56.9% (29)	11.8% (6)
Use Evidence to Support an Explanation	88.2% (45)	9.8% (5)	2.0% (1)
Discussion	78.4% (40)	9.8% (5)	11.8% (6)
Experimental Method			
Formulate Investigative Questions	100% (51)	0	0
Identify Setting within a System	62.7% (32)	0	37.3% (19)
Collect Data	96.1% (49)	0	3.9% (2)
Analyze Data	98.0% (50)	0	2.1% (1)
Use Evidence to Support an Explanation	82.4% (42)	0	17.6% (9)
Includes References to Natural Resources	**92.2% (47)**	**0**	**7.8% (4)**
Main Emphasis Format **(See Appendix 3) for rating definitions**	Balanced 3.9% (2)	Vague 11.8% (6)	Experimental 84.3% (43)
Could Support Field Inquiry **(See Appendix 5) for rating definitions**	Specification 37.3% (19)	Modification 33.3% (17)	Major Modification 29.4% (15)

This table shows the percentages of state responses to the questions of this research. Overall, the states were split into thirds for their ability to support field inquiry

Appendix 3

Rating State Science Education Standards

To discover which inquiry methodology is emphasized in a state's standards, we looked at the wording of the standards and the amount of field inquiry included. If the standards included some or none of the field inquiry model parts, they received a **"Controlled Experiment" rating**. Some standards were worded in such a way that field investigation was actually excluded from scientific research. More often, standards that included some aspects of field investigation method presented these as part of a *basic* skill set, but omitted field investigation methods when outlining the more advanced skill set. For instance, the Alabama Department of Education (2005) standards state, "Basic process and application skills include observing, communicating, classifying, measuring, predicting, and inferring. Advanced process and application skills include controlling variables, defining operationally, formulating hypotheses, experimenting in a controlled environment, and analyzing data" (pg. 9).

If standards were vague in their wording and in their descriptions of what scientific inquiry is, they received a **"Vague" rating**. Often, standards warranting this rating had few field investigation parts and presented very little of the experimental model. This was also frequently the case when scientific inquiry standards were imbedded in the content, as in Kentucky's standards (Kentucky Department of Education, 2006).

If standards included significant parts of all four models and were worded in such a way that they encouraged multiple methods of inquiry, they received a **"Balanced" rating**. For instance in Missouri's standards, one of the grade level expectations is, "Recognize different kinds of questions suggest different kinds of scientific investigations (e.g., some involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve making observations in nature; some involve discovery of new objects and phenomena; some involve making models)" (Missouri Department of Elementary and Secondary Education, 2005, pg. 92).

Appendix 4

Evaluating State Science Tests

The point of state standards is to establish a baseline to assess student learning. If scientific inquiry in general, and field inquiry in particular, are to be included in state standards, they must also be included in the state assessments. We therefore examined the state tests to see if inquiry is assessed.

First, we identified the states that test science. According to the No Child Left Behind (NCLB) Act of 2001, all states must begin testing science in the 2007-2008 school year. We found many states field-testing their assessments in the 2006-2007 and 2007-2008 school years. Five states, however, do not test science and had announced no plans for field testing the area. Our comparisons were therefore done with the forty-six states that did have a science test.

NCLB (2001) also states that science will be tested three times in a child's education: Once at the elementary level, once at the intermediate level, and once in high school. Because the standards and benchmarks also vary by grade level, we noted which grades are being tested. For many states there are three grade levels of testing; others tested a range of grades; and still others tested only in high school. *For many states, the field inquiry components that are included in their standards are addressed primarily at the primary grade level.* Knowing that students will not be tested on their science skills until they are in high school can give us insight into why field inquiry was not included on the test.

This study also sought to assess the inclusion of field investigation in science tests by examining the available sample questions. Some states, especially those still field-testing their tests, did not have the sample questions available, although they did have blueprints or specifications of the test. While these did not provide the same level of information as sample questions, they did answer some of the questions we had about the tests.

- ***Are the students being judged by their ability compared to other students (norm-reference testing) or by their ability compared with the standards (criterion-reference testing)?*** For assessing scientific inquiry, *criterion referenced tests* make the most sense. Not surprisingly, *all of the state tests with sample questions, blueprints, or specifications were criterion referenced*.
- ***Is the scientific process, in any form, tested?*** We examined the test for any kind of hypothesis-building, judgment of process, controlling of variables, or other scientific inquiry-focused questions. For some tests this was the main focus, while others slipped in one or two questions.
- ***Is field inquiry tested?*** We looked for questions that asked students to use descriptive, comparative, or correlative skills in relation to a scientific problem. A few states received a 'somewhat' rating because of the vagueness of the questions. As with the standards, study of natural resources plays a large role in whether field investigations are included, so we also looked at whether natural resources were referenced in the tests. We broadened our definition of natural resources to include discussions of ecosystems, including food webs. 'Somewhat'

ratings included references that were almost about natural resources, but failed to fit into the category.

- ***What is the format of the test questions?*** Knowing how students are asked to respond to test questions also gives us information on how much of inquiry is tested. Multiple choice (MC) questions alone do not allow students to express their understanding of inquiry fully. These questions ask students to choose from a small group of answers. Constructed response (CR) questions ask students to write or sometimes perform actions in order to answer the question. The range of response to these questions can be from short answer (SA), which is a few words or sentences, to extended response (ER) which is a paragraph or short essay. There are also open-ended (OE) questions that allow students to do a performance task or other longer activity to answer the question.

Table 2

State Science Testing Comparisons

	Yes	**Somewhat**	**No**	**Unknown**	
Science Tested	**90.2% (46)**	0%	9.8% (5)	0%	
Sample Q's Available	**60.8% (31)**	0%	39.2% (20)	0%	
Scientific Investigation Tested	**73.9% (34)**	0%	4.3% (2)	21.7% (10)	
Field Investigation Tested	19.6% (9)	17.4% (8)	26.1% (12)	37.0% (17)	
Includes References to Natural Resources	**52.2% (24)**	4.3% (2)	6.5% (3)	37.0% (17)	
Grades Tested	3rd 10.9%(5)	4th 43.5%(20)	5th 54.3%(25)	6th 13.0% (6)	7th 26.1% (12)
Grades Tested	8th 67.4%(31)	9th 2.2%(1)	10th 19.6%(9)	11th 17.4%(8)	HS 32.6%(15)
Norm/Criterion Referenced	Criterion 73.9% (34)	Norm 0% (0)	Unknown 26.1% (12)		
Types of Questions	MC Alone 23.9% (11)	CR Alone 4.3% (2)	Mixed 47.8% (22)	Unknown 26.1% (12)	

This table shows the responses to the testing questions of this research. Although almost all states have science tests, many do not have information about their testing strategies. Almost three-quarters who do test science include questions about scientific inquiry.

Appendix 5

Modifying State Science Education Standards to Include Field Inquiry

Assuming that all standards could be modified to support field investigative methods, we asked how much change would be needed to incorporate field investigation in each state's standards. Another rating system was developed for this purpose:

- ***With specification:*** This rating meant that, without changing anything in the standards, field inquiry could be included with guidelines provided by the state authority. The wording of these standards allows for inclusion of alternate inquiry methodologies and includes a portion of the components of field investigation. Many of the 'vague' standards also received this rating. With specification and a greater inclusion of the field inquiry design components, these standards could very well support field investigation methodologies alongside the experimental method.
- ***With modification:*** This rating meant that, in order to include field investigation, the standards would need some rewriting. Often these standards focus entirely on the experimental model, but the presence of some components of field inquiry methodologies can be perceived. The main objective of rewriting the standards would be to broaden the description of scientific inquiry so that it explicitly includes other methods of research.
- ***With major modification:*** This rating meant that, in order to include field investigation, the standards would need to be revised extensively. The definition of scientific inquiry in these standards often excludes field investigation. The standards focus entirely on the experimental model, and any field inquiry components appear only as basic skills references.