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The purpose of this study was to examine and describe the ways various stakeholders (*CBW* project developer/coordinator, elementary and middle school teachers, and 5th through 8th grade students) envisioned, implemented and engaged in the citizen science project, *eBird/Classroom BirdWatch*. A multiple case study mixed-methods research design was used to examine student engagement in the cognitive processes associated with scientific inquiry as part of citizen science participation. Student engagement was described based on a sense of autonomy, competence, relatedness and intrinsic motivation.

A goal of this study was to expand the taxonomy of differences between authentic scientific inquiry and simple inquiry to include those inquiry tasks associated with participation in citizen science by describing how students engaged in this type of science. This research study built upon the existing framework of cognitive processes associated with scientific inquiry described by Chinn and Malhotra (2002).

This research provides a systematic analysis of the scientific processes and related reasoning tasks associated with the citizen science project *eBird* and the corresponding curriculum *Classroom BirdWatch*. Data consisted of responses to surveys, focus group interviews, document analysis and individual interviews. I suggest that citizen science could be an additional form of classroom-based science inquiry that can promote more authentic features of scientific inquiry and engage students in meaningful ways.

STUDENT COGNITION AND MOTIVATION DURING THE *CLASSROOM BIRDWATCH* CITIZEN SCIENCE PROJECT

by

Terry Morton Tomasek

A Dissertation Submitted to
the Faculty of The Graduate School at
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Doctor of Philosophy

Greensboro
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Approved by

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Committee Chair

To Joshua

and other students who are typically not interested in regular school science

but may find citizen science to be the type of science where they can be creative, chase

after their own curiosities, relate to others in meaningful ways and develop an

appreciation for the natural world.

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of The Graduate School at the University of North Carolina at Greensboro.

Committee Chair ____________________________________

Committee Members ________________________________

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Date of Acceptance by Committee

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Date of Final Oral Examination

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CHAPTER I

INTRODUCTION

> *"The goal of education is not to make scientists of students, but to provide them with access to experience-based science activities that provide them with new perspectives and insights into the complex world of science that is part of everything we do"(Rahm, Miller, Hartley, & Moore, 2003, p. 753).*

Citizen science is a term used to describe a partnership between professional scientists and members of the public who, following specific protocols, collect data about the natural environment and send the information to the professional scientists. Nonscientists have the opportunity to make real contributions to scientific research. Because of limited resources, scientists are often unable to gain a clear understanding of the details involved in many conservation efforts. There are simply not enough biologists and resource managers to cover an entire county, state or region. Because of this limitation, many natural resource decisions have been based on limited data. Citizen science projects allow scientists to collect more data over broader geographical areas, more frequently and for longer periods of time. For example, the House Finch Disease Survey is a citizen science project being conducted by the Cornell Lab or Ornithology. Citizen scientists from all over the United States and Canada contribute observation data of finches that visit their feeders noting whether the birds do or do not have diseased eyes from *mycoplasmaa gallisepticum* infections. Based on citizen science data, ornithologist suggest that approximately 180 million fewer House Finches exist today than would have if they had never been exposed to the House Finch eye disease (Labranche, Chu & Hochachka, 2003).

The benefits of citizen science data for scientists include space, time and size. A large geographic scale provides for a more global understanding of environmental conditions that would not be feasible without partnerships (Berkowitz, 1997). Citizen science volunteers can contribute long term data (collected over many years) that may not be feasible for most scientists. The massive size of these data sets makes for more comprehensive statistical analyses and predictive modeling (Trumbull, Bonney, Bascom, & Cabral, 2000).

While many scientists and non-scientists alike herald citizen science projects as opportunities to expand our understanding of the natural world, there can be some difficulties with these types of projects. The lack of quality control over data collection, the complexity of data collection protocols and the uncertainty of continued site monitoring may contribute to inaccurate information being reported. The amount of variability in data collection is often addressed with specific protocols. These protocols may be difficult to follow or require the use of expensive scientific equipment not available to citizen science volunteers.

The longest running citizen science project on record is the *Christmas Bird Count* developed and directed by the National Audubon Society. Since the early 1900's, scientists have used volunteer descriptions of bird sightings between December 14th and January 5th to document bird distribution patterns and estimate population changes across the Americas. In recent years, more than 50,000 observers have participated each year in a census event of early-winter bird populations across North, Central and South America (National Audubon Society, 2005). Despite the limitations of this type of study, researchers have found that population trends reflected in the *Christmas Bird Count* data sets tend to correlate well with those from census studies taken by more stringent means (Shipman, 1996). Recently, the *Christmas Bird Count* data were used to assess the impact of West Nile Virus on crows in the Northeast portion of the United States (LaBranche, Chu, & Hochachka, 2003). Additionally, preliminary analysis of this large data set has revealed that climate has not played a major role in large-scale shifts in bird species' ranges over the last forty years (LaBranche, Chu, & Hochachka, 2003).

More recently, citizen science projects have started to find their way into K-12 classrooms. A citizen science partnership between students, teachers and professional scientists provides an opportunity for inquiry-based interdisciplinary learning about the natural world. Rapid advances in technology, especially widespread use of the World Wide Web, may be a contributing factor to the emergence of this type of school science. Additional examples of citizen science as well as a history of citizen science projects associated with classroom use will be discussed in Chapter II.

This study will specifically investigate the citizen science project, *eBird,* and the corresponding elementary/middle school curriculum, *Classroom BirdWatch* (*CBW*). *eBird* citizen science participants submit bird observation information, such as bird type and location, via the Internet to a cumulative *eBird* database that is used by birdwatchers, scientists, and conservationists who want to know more about the distribution patterns of birds across the North American continent. All participants in *eBird* have access to the entire *eBird* historical database to find out what other *eBird*ers are reporting. The *CBW* curriculum is designed for elementary and middle school students. The instructional goals of the curriculum are to foster students' understandings of bird biology, ecology, adaptations, and biodiversity as well as to provide teacher and student support in the critical aspects of the scientific process during guided and independent scientific inquiry. Further details about *eBird* and the *Classroom BirdWatch* curriculum will be provided later in this chapter.

In the field of science education, the goal of 'scientific literacy for all' is nothing new.

> *Science for All Americans* (1990) is based on the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (American Association for the Advancement of Science (AAAS), 1990, p. xvii).

Few K-12 science education programs, however, have proven successful in meeting this high standard (Songer, Lee, & McDonald, 2003). Science educators continue to explore how new curricular approaches, models of engagement, and innovative school practices might promote the type of meaningful science learning that will lead to scientific literacy for a broader range of students (McGinn & Roth, 1999). Controversy still abounds regarding how school science should be taught in order to engage students in scientific ways of thinking (Lee & Songer, 2003). *The National Science Education Standards* state that students should learn science by doing science in the way scientists do science while at the same time developing life-long problem solving skills (AAAS, 1993; National Research Council (NRC), 1996). Students should be engaged in the type of scientific studies where they can ask and answer their own questions, especially the type of questions where answers might not be known prior to the investigation (NRC, 1996).

Projects that invite students to be involved in citizen science research in their own backyards or on their school grounds may provide the types of rich opportunities that will engage students in habits of thought associated with scientific investigations (Trumbull, Bonney, Bascom, & Cabral, 2000). Unfortunately, there is a limited understanding of this type of participation and the contribution such involvement might lend to an understanding of the scientific process (Caton, Brewer, & Brown, 2000; Moss, Abrams, & Kull, 1998) or student engagement in science. We know very little about the structure of successful citizen science projects that engage school-aged children in authentic components of science inquiry. We have limited research information regarding how citizen science projects are being implemented in K-12 classrooms. It has also been suggested that "our current view of the successful implementation of inquiry science is based on narrow and limited criteria" (Songer, Lee, & McDonald, 2003, p. 492). Participation in citizen science could support the most difficult aspect of the new science standards which is providing increased opportunities for students to be engaged in extended inquiry (NRC, 1996).

The purpose of this study is to expand understandings of classroom-based inquiry science by investigating citizen science participation of elementary and middle school teachers and students. This research provides a systematic analysis of the scientific cognitive processes and related reasoning tasks associated with the citizen science project *eBird* and the corresponding curriculum *CBW*. Citizen science could be an additional form of classroom-based science inquiry that might promote student engagement in authentic scientific inquiry. Miller and Meece (1999) suggest that teachers can promote student engagement by offering academic tasks of moderate challenge that progressively build on each other while offering a range of response options. Could citizen science be an intermediate step between simple school science and authentic science?

My goal was to expand the taxonomy of differences between authentic scientific inquiry and simple inquiry tasks to include those inquiry tasks associated with participation in a citizen science project and to further describe how students engaged in this type of science. To accomplish this goal, I examined the *eBird* citizen science project and its corresponding curriculum (*CBW*) from three perspectives: 1) the project/curriculum perspective and features of scientific inquiry that were promoted through its materials; 2) the student perspective regarding engagement as well as features of scientific inquiry that were practiced during citizen science participation; and finally, 3) the teacher perspective regarding student engagement as well as features of scientific inquiry that were practiced by students.

Importance of the Study

Inquiry and the National Science Education Standards (NRC, 2000), advocates that K-12 science instruction provide for a wide variety of science inquiry opportunities in the effort to promote scientific literacy for all. The current research literature is extensive in describing, reviewing and suggesting ways to promote scientific inquiry in classrooms (Lee, 2002; Mintzes & Wandersee, 1998; Shymansky, Hedges & Woodworth, 1990; Songer, Lee, & McDonald, 2003).

This dissertation study fills an important gap in this research literature. It provides documentation of classroom-based scientific inquiry from a wider range of pedagogical examples of science inquiry instruction than traditionally studied. That is, participation in citizen science is outside the range of traditional classroom contexts. Understanding this type of participation could lead to an expanded understanding of classroom-based inquiry. This work provides an opportunity to extend the discussion of science inquiry in the K-12 classroom by furthering the conversation regarding the images of successful science participation. Nancy Songer and colleagues call for, "more research that critically explores what it means to be 'successful' among a wider range of classroom contexts and audiences" (Songer, Lee, & McDonald, 2003, p.495). This study addressed that call.

This work will also serve to expand the developing infrastructure of support for large scale implementation of citizen science partnerships in the K-12 classroom. As more and more citizen science projects are introduced at the K-12 level, important questions regarding project structure and optimal implementation need to be considered. There is a need for collaborative research on inquiry-based instruction that is designed by teachers and science education researchers (Keys & Bryan, 2001). Citizen science fits this description of inquiry-based instruction because it is designed by teachers, scientists and science education researchers.

This research will be important to a wide audience. K – 12 classroom teachers will be interested in this work as a model for implementation of citizen science projects in their own classrooms. Promoting classroom teacher awareness of the availability of citizen science programs may be the first step in generating interest for this type of science inquiry. Science educators will be interested in this work as they consider the importance of sharing pedagogical content knowledge with future classroom teachers. Research scientists and natural resource professionals will be interested in this work as a model for ways to extend the possibilities of their work into the K-12 classroom.

Research Questions

The questions that will guide this research are:

1. To what extent did the tasks associated with the *eBird/CBW* citizen science project incorporate (promote) features of authentic scientific inquiry?
2. How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?
3. How did students describe the scientific inquiry cognitive processes utilized during their participation in the *eBird/CBW* citizen science project?
4. How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/CBW* citizen science project?

Rationale for the Study

The overarching goal of science education is to help students learn to reason scientifically (AAAS, 1993; NRC, 1996). Specifically, students at the intermediate level (grades 6-8) should be participating in experimental and other investigations, refining their understanding of what makes a good experiment with controllable variables, and establishing connections between explanations and experimental designs (AAAS, 1993). To accomplish this, *The National Science Education Standards* (NRC, 1996) recommend that students engage in inquiry science; however, the research presented by Chinn and Malhotra (2002) suggests that many current school inquiry tasks bear little resemblance to authentic scientific reasoning. More seriously, school science tasks may be reinforcing unscientific forms of reasoning that are oversimplified and are of limited use in our complex world.

If we think of cognitive processes and reasoning tasks associated with scientific inquiry as a continuum; school textbook-based science would be at one extreme while authentic scientific inquiry would be at the other. Students should have opportunities to work with more authentic tasks that have more complex underlying inquiry models (Chinn & Malhotra, 2002). Where would participation in a citizen science project fall on this continuum? How closely would the inquiry tasks promoted and practiced during citizen science resemble those of authentic science?

All students (and adults for that matter) need to be able to reason well about complex scientific evidence. For example, when making decisions about health or medical issues, when considering environmental and economic conflicts or even when utilizing evidence to make a decision about what type of car to buy, it is important to be able to reason and reach a satisfactory decision based on available evidence.

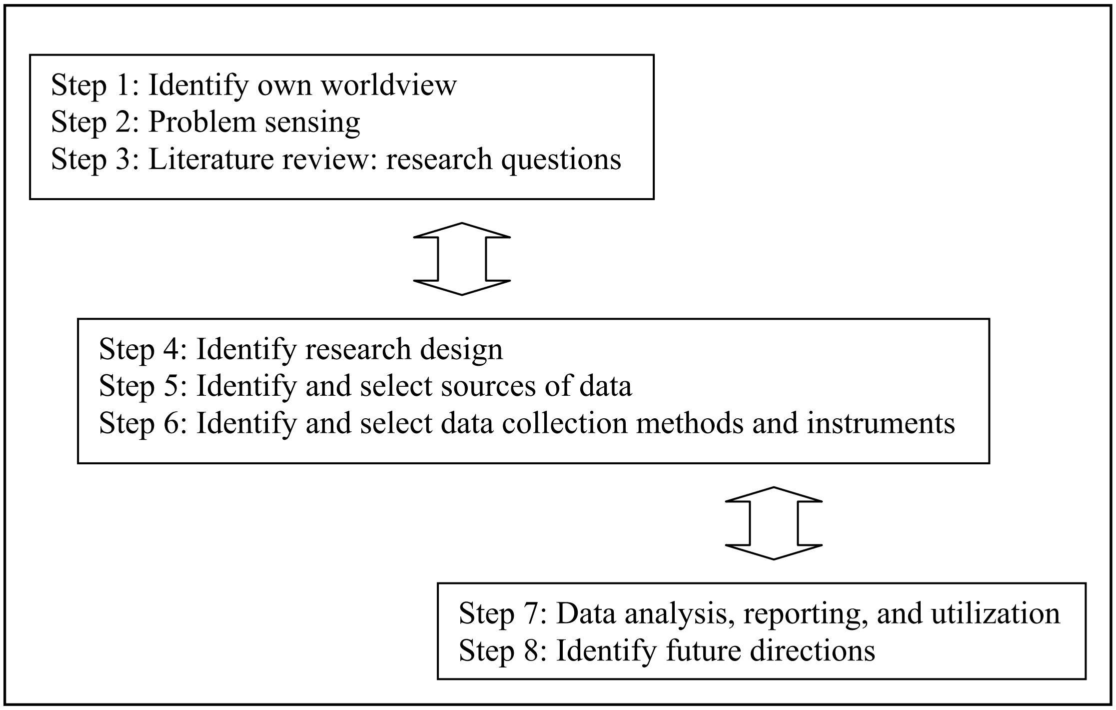
Citizens can participate in the conversations with science experts by gaining an understanding of the cognitive processes associated with scientific reasoning such as research design, data analyses techniques, and developing theories (O’Neill & Polman, 2004). Citizens need to be able to actively participate in these conversations because they are confronted with increasingly complex questions associated with an increasingly complex technological society. All citizens need to understand the nature of scientific knowledge and scientific practices in order to participate more effectively in policy decisions, and to interpret the meaning of new scientific claims for their lives (AAAS, 1993; NRC, 1996).

Little is known however, about how complex reasoning skills may be fostered during citizen science types of science inquiry. There is a pressing need for this type of research that analyzes an alternative approach to science inquiry in the form of citizen science projects.

Research Design

This research is a systematic inquiry into student engagement and the cognitive processes associated with scientific inquiry. The typical processes for planning and conducting a study are adapted from Mertens (1998) and are depicted visually in figure 1.

Figure 1. Steps in the research process



The research process is not linear but iterative in nature. The multi-directional arrows in the diagram are used to represent this condition.

To begin the research process, I have identified my own worldview. My theoretical orientation has implications for every decision made in the research process. I have conducted this research within the interpretive/constructivist paradigm. My goal was to interpret the meaning of scientific inquiry participation from the standpoint of citizen science project personnel as well as elementary and middle school teachers and students. There are two basic assumptions guiding the interpretive/constructivist paradigm. First, knowledge is socially constructed by people active in the research process. Second, researchers should attempt to understand the complex nature of lived experiences from the standpoint of the participants who have those experiences (Mertens, 1998). This theoretical framework impacts data collection procedures as well as data analyses. I have chosen a mixed-methods approach to data collection and a continuous comparative approach to data analyses. Qualitative methods including individual interviews, focus group interviews, and document reviews were utilized in this research. Quantitative methods using surveys were used to extend and inform qualitative analysis. Both data collection and data analyses will be described in detail in Chapter III.

Procedures for Data Collection and Data Analyses

This study employed mixed-methods, integrating qualitative and quantitative strategies during the data collection, analyses and inference phases of the investigation. A multiple case study strategy was used with the main unit for analysis being cognitive processes associated with science inquiry and student engagement. The contextual event surrounding the unit of analysis was participation in citizen science. The multiple cases were a fifth, seventh, and eighth grade class. A detailed description of each case group can be found in Chapter III.

Qualitative data were collected in the form of student focus group interviews, individual teacher and *CBW* project developer interviews as well as a document analysis of *eBird/CBW* materials and student-generated research reports. Quantitative data were collected from students and teachers in the form of surveys.

Data were analyzed in a continuous comparative fashion. Quantitative data were analyzed using *Statistical Package for the Social Science* (SPSS). Content analysis of qualitative data was completed using either *Non-numerical, Unstructured Data Indexing,* *Searching, and Theorizing* (NUDIST) software or comparative content analysis. As part of these analyses, some of the qualitative data were quantized by counting the frequency of occurrence of events. A more complete description of data collection and analyses is provided in Chapter III.

Limitations of the Study

The scope of this study was limited to three teachers involved in field-testing the *eBird/CBW* citizen science project. Compared to the number of fourth through eighth grade teachers nationwide, this is a very small percentage. The implementation of citizen science projects in the classroom is a relatively new adventure for K-12 educators. Even though the study population is limited, the importance of this research will be illuminative in nature.

Confining this study to three sites also limits the generalizability of the results to the greater population of teachers and students. However, broader implications for this research include curriculum development for other types of citizen science projects. Knowing how student cognitive processes associated with scientific reasoning emerge during participation in citizen science projects can serve to inform other organizations as they involve K-12 students in citizen science.

Finally, this study involved the analysis of self-reported data on teaching and learning practices, rather than observed practices, making it difficult to corroborate the accuracy of the respondents' answers. When using surveys, if there was a mismatch between the meaning intended by the researcher and the meaning assumed by the respondent, then the results of the survey would be of questionable use during analysis.

Efforts were made to address these validity issues during follow-up discussions with participants and to triangulate different datum sources when available. Member-checking was used to determine the accuracy of qualitative findings from interviews and document or records analyses. Once specific descriptions or themes were determined, they were shared with participants to make sure my inferences were accurate. Another university educator (not involved in data collection) reviewed the investigative process and the inferences made during data analyses to critically examine the research results being generated.

Terms Defined

Citizen Science

Citizen science refers to initiatives that involve volunteers who help collect natural science information that is used by scientists. The volunteers are ‘nonscientists’ gathering data for use by ‘scientists’ to investigate questions of research importance (Trumbull, Bonney, Bascom, & Cabral, 2000); therefore, citizen science is a partnership between the public and professional scientists. Relying on these volunteer researchers, scientists and regulatory professionals are able to track a particular species of animal or document changes in a specific habitat over time. This citizen science participation allows for a more detailed look at long-term conservation issues and provides a structure for public participation in environmental issues (Nerbonne & Nelson, 2004) as well as the opportunity to interact with scientists in the process (Brossard, Lewenstein, & Bonney, 2005). Citizen science relates in natural ways to the concerns, interests and activities of citizens as they go about their everyday business (Jenkins, 1999).

Citizen science is a participatory process that can involve all sectors of society: the general public, schools, industry and government. Most projects are aimed at people of all ages both inside and outside of formal educational settings. The citizen science type of research helps to bridge the gap between science and the community and between scientific research and policy, decision-making and planning. Citizens, including K-12 students, can be involved in this type of work rather than assuming that science is the exclusive domain of trained scientists. Citizen science participation fosters public awareness and may enhance community empowerment, decision-making and institutional change (Nerbonne & Nelson, 2004). This type of public involvement also improves public relations and increases public interest in science and technology (McGinn & Roth, 1999).

Citizen science projects are rapidly increasing in number (Cohen, 1997). This increase has been made possible due to the increased use of the Internet and computer access by K-12 schools. Most of the larger citizen science programs are sponsored by special interest groups such as the Kansas Collaborative Research Network and Annenberg Media, universities, state regulatory agencies, and the National Park Service. Some examples of citizen science projects sponsored by these groups include *Phenology* (mapping seasonal changes associated with spring), *Lichens and Sulfur Dioxide* (exploring environmental impacts of sulfur dioxide by studying the density and diversity of lichens), *Journey North* (tracking migration patterns of various wildlife species), *Monarch Larval Monitoring Project* (exploring larval monarch populations and milkweed habitat) and *Digging Down Into the Dirt* (a terrestrial invertebrate inventory).

Citizen science projects which are implemented in K-12 classrooms can be considered to be a form of student-scientist partnerships. For the purpose of this study, I have chosen to broaden the definition of scientist-guided student partnerships described by Tinker (1997) to include citizen science projects implemented in K-12 classrooms.

Citizen science in the K-12 classroom is a partnership between a teacher, a group of school children and a professional scientist. Scientists establish a research agenda, for example, their interests may include determining the biodiversity in a specific stream or habitat usage by a population of Eastern box turtles. Teachers introduce their students to the project and students begin their participation in the project by making observations. Depending on the project, the student observations can be specific to a particular type of organism or more general or habitat specific. Student observations are submitted to the professional scientists (either electronically or through the mail). The scientist or sponsoring organization provides educational materials designed for classroom use. These materials are used by classroom teachers to guide students to a deeper understanding about the biology, behavior, or ecology of a particular organism or habitat. As school children grow in their understanding and continue their observations, they may be encouraged to develop their own research questions. Guided by their classroom teacher, students may be encouraged to develop and carry out research projects related to the larger citizen science project. The outcomes of these student-generated projects are often shared with the larger citizen science research community. Citizen science projects in the K-12 classroom suggest a collaborative research community that includes researchers, teachers and students. The Internet is used as a tool to transcend geographic barriers, facilitating communication and collaboration across the community.

eBird and Classroom BirdWatch Citizen Science

eBird is a citizen science project developed by the Cornell Lab of Ornithology and the National Audubon Society. Bird studies are suited for citizen science type projects because bird species occur widely across geographic regions and researchers can not be everywhere at the same time. For the *eBird* citizen science project, anyone may submit information about any birds they see at any place, any time. Data from across the North American continent are combined, creating a broad-scale view of North American bird populations. Scientists at Cornell Lab of Ornithology use the data submitted to *eBird* in reports and conservation plans focused on the distributions and movement patterns of birds across the North American continent. *eBird* participants can also retrieve information from the *eBird* database. The use of large databases to examine evidence that has already been gathered has been shown to capture many features of authentic scientific reasoning (Chinn & Malhotra, 2002).

The Cornell Lab of Ornithology is a nonprofit membership institution whose mission is to interpret and conserve the earth's biological diversity through research, education, and citizen science projects focused on birds. Cornell Lab of Ornithology headquarters are located at the Johnson Center for Birds and Biodiversity located in Ithaca, New York. Funded by the NSF, the *National Science Experiments* were inaugurated in 1993 to involve the public in a series of guided projects in which participants would gather information desired by ornithologists. At the same time, participants would learn about birds and how to conduct scientific projects. Citizen science at Cornell Lab of Ornithology involves participants and scientists joined in a partnership to gather and synthesize information to better understand and protect birds and their habitats. By 1998, Cornell Lab of Ornithology was listed as the third-largest citizen science group in the United States behind Maine's Coastal Clean-up Program (largest) and the Kentucky Water Watch (second largest) (U.S. EPA, 1998).

In addition to publication in scientific journals, scientists have used citizen science data in other types of publications including two guides for land managers: 1) *Improving Habitat for Forest Thrushes*, and 2) *Improving Habitat for Scarlet Tanagers and other Forest-interior Birds*. These guides address important issues related to the protection of habitat that is required by specific declining bird species. Citizen science data have been used in studies that have investigated threats to bird populations from acid rain, habitat loss, and disease as well as yielded insights about natural processes such as geographical variation in bird behavior and demographics.

CBW is an inquiry-based, interdisciplinary science curriculum for elementary and middle grades students developed by educators at the Cornell Lab of Ornithology in consultation with curriculum experts at the Lawrence Hall of Science. The curriculum was developed with support from the National Science Foundation. It was pilot tested during the 2004-2005 school year and was field-tested during the 2005-2006 school year. Through *CBW*, students engaged in science inquiry by observing birds, asking questions about birds based on their observations, gathering data about birds to answer those questions, and sharing their findings through the *Classroom Birdscope* student research journal. The primary goal of the curriculum was to engage students in the process of inquiry. A secondary goal was for students to gain an understanding of overarching biological concepts such as bird behavior, ecology, adaptations and diversity. Students were encouraged to collect data about their local bird populations and submit the information electronically to scientists at Cornell Lab of Ornithology through the *eBird* citizen science project.

The *CBW* curriculum consists of four units, each made up of five explorations. The units could be used to build upon each other sequentially or as stand-alone modules. Science process skills were used and refined throughout the explorations, first as guided inquiry and later through independent inquiry. The focus of each unit included:

<u>Unit 1</u>: Bird identification and data submission: supports students as they learn to identify and count birds, as well as submit data to the *eBird* online database.

<u>Unit 2</u>: Bird biology: supports students as they learn how birds survive and reproduce.

<u>Unit 3</u>: Guided inquiry: supports students in the critical aspects of the scientific process.

<u>Unit 4</u>: Authentic inquiry: supports students in drawing evidence-based conclusions about the questions they generate.

Teacher resources that supported the exploration lessons included a Resource Guide, Student Journal, support materials and the *CBW* website (http://www.birds.cornell.edu/*CBW*). The resource guide contained articles with background information about each Exploration topic. The student journal provided reflective questions that could be used in student assessment. The journal also contained additional information for students, such as “Conservation Connections” and “Did you Know?” boxes. Support materials included a bird identification CD-Rom, bird flashcards and student handouts.

During the 2005-2006 school year, fourth through eighth grade teachers were field-testing the *CBW* curriculum. Forty teachers were recruited from rural, suburban and urban areas throughout the United States and were selected based on their applications and school demographics. Thirty-six of the field-test teachers provided extensive feedback to the *CBW* evaluation team. After revision, the *CBW* curriculum was released to the general public during the 2006-2007 school year. Throughout this dissertation, conducted from March to September of 2006, the citizen science project under study will be referred to *eBird/CBW* indicating the integration of the project (*eBird*) with the fifth through eighth grade curriculum (*CBW*).

Inquiry

The basic premise of inquiry is conceptualizing a question and then seeking possible explanations that relate to that question. Inquiry can be thought of as a state-of-mind that leads to certain cognitive processes and associated reasoning tasks. The cognitive processes associated with scientific inquiry are driven by inquisitiveness and curiosity. The *National Science Education Standards* (1996) define scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (NRC, 1996, p. 23). The outcome for scientists is to expand human knowledge of the natural world.

Students who use inquiry to learn science should engage in many of the same reasoning processes and activities as scientists (NRC, 2000). However, school science often involves teachers providing students with science facts and technical language to describe those facts. As a result, students often fail to see the value of this type of knowledge and therefore lack motivation for this type of science school learning.

Simple Inquiry Tasks

Simple inquiry tasks incorporate few if any features of authentic scientific inquiry (Chinn & Malhotra, 2002). When compared with authentic scientific inquiry, simple inquiry tasks would be found at the opposite extreme of reasoning tasks. Chinn and Malhotra (2002) describe three types of simple inquiry tasks: simple experiments, simple observations and simple illustrations.

Simple experiments are straightforward forms of investigation where a single independent variable is manipulated and the outcome is a single responding variable (dependent variable). For example, during Exploration 13 of the *CBW* curriculum, students investigate the research question, “Which paper airplane design do you think will fly the farthest? Students are instructed to introduce one variable to the airplane design and to measure distance traveled as the single responding variable.

In simple observations, students carefully observe and describe objects. For example, during the unit 1 capstone lesson of the *CBW* curriculum, students observe and identify birds by sound or sight using field guides. The data are entered into the *eBird* database.

When students follow a prescribed procedure and observe the outcome, a simple illustration form of inquiry occurs. This type of experiment serves to illustrate a theoretical principle that is clearly stated a priori in the student textbook. For example, curriculum materials might describe the theoretical principle between bird beak shape and food preference and then stipulate steps in an activity that will illustrate the stated principle. This would represent a simple illustration type of inquiry.

During this study, the reasoning tasks associated with these three types of simple inquiry will be combined to form one unit classified as simple inquiry. The specific reasoning tasks associated with simple science will be further described in chapter II.

Authentic scientific inquiry

Authentic scientific inquiry refers to the activities that scientists actually carry out while they are engaged in research (Chinn & Malhotra, 2002; Chinn & Hmelo-Silver, 2002). This type of inquiry may be associated with complex activity, the use of expensive equipment, the employment of elaborate procedures and theories as well as advanced techniques for data analyses and modeling (Dunbar, 1995; Galison, 1997; Giere, 1988). Depending on the science discipline, scientific inquiry will take many forms from field-based case studies in ecology to complex experiments using particle accelerators in physics. A common element of most scientific reasoning however, is a systematic comparison of some kind. Examples would be experiments in which variables are manipulated and controlled, correlational studies, causal studies, and comparative case studies that examine relationships. Six cognitive processes are commonly associated with scientific reasoning: 1) generating research questions, 2) designing studies, 3) making observations, 4) explaining results, 5) developing theories, and 6) studying research reports. Within each of these cognitive processes there is a continuum of reasoning tasks, from those associated with simple inquiry tasks on one extreme to those associated with authentic scientific inquiry on the other. The framework described by Chinn and Malhotra (2002) was used as an analytic tool to evaluate the inquiry tasks represented in citizen science to find out which features of authentic scientific inquiry are incorporated and which are not. These cognitive processes and reasoning tasks will be explained further in Chapter II.

Summary and Organization of Dissertation

The purpose of this dissertation study was to examine the implementation of a citizen science project with fifth through eighth grade teachers and students. This study focused on the citizen science project *eBird* and its corresponding curriculum *CBW*. This mixed-method, multiple case study was a systematic analysis of student engagement in citizen science. This study also describes the types of reasoning tasks associated with the cognitive process of scientific inquiry that were represented in the *eBird/CBW* citizen science project as well as the types of reasoning tasks used by students as part of their participation in the citizen science project. The reasoning tasks promoted during the project and utilized by the students were compared to simple inquiry tasks and authentic scientific inquiry tasks defined a priori from the research literatures.

This introductory chapter has provided a rationale for this study as well as a brief overview of the research design, data collection methods and data analyses procedures. Chapter II, the review of the literature, will provide a foundation for the study as well as additional examples of citizen science and a history of citizen science projects associated with classroom use. The literature review will also provide a discussion of student engagement, cognitive processes in science, and reasoning tasks associated with both simple and authentic scientific inquiry.

Chapter III describes the methodology for this study. The chapter provides a detailed description of the participants in the study to give the reader a contextual setting. The design of the study is outlined and a conceptual framework for the research is offered. Research procedures, data analyses steps and methods to address trustworthiness in research conclude this chapter.

Chapter IV presents the findings of the study. The chapter is organized by the four research questions described previously in this chapter. Findings are described using both qualitative and quantitative data.

The purpose of Chapter V is to present a discussion of the findings and to make generalizations and conclusions about these findings. As in Chapter IV, the discussion revolves around the four research questions. The major findings of this study are interpreted and compared to other studies discussed in the literature review. Completing the discussion is a synthesis of the interaction of student engagement and the cognitive processes associated with scientific inquiry utilized by students during citizen science participation. This dissertation ends with a discussion of implications and recommendations for citizen science implementation in the science classroom.

CHAPTER II

REVIEW OF LITERATURE

"The purpose of a literature review is [not] to determine the answers about what is known on a topic but to develop sharper and more insightful questions about the topic"(Yin, 2003, p.9)

The purpose of this study is two fold: 1) to describe the cognitive processes and reasoning tasks associated with scientific inquiry that is promoted and practiced as part of K-12 citizen science and 2) to examine student engagement during citizen science participation. This chapter begins with a historical look at environmental volunteer monitoring (precursor to citizen science) as well as provides an examination of how K-12 student-scientists partnerships have evolved to include citizen science participation. A sampling of citizen science projects whose target participants are the general population will be discussed. After this discussion of general population citizen science projects, five citizen science projects targeted at the K-12 classroom setting will also be described: 1) *Forest Watch*, 2) *Journey North*, 3) *Classroom FeederWatch*, 4) *Pathfinder Science* and 5) *Classroom BirdWatch (eBird).* The focus of this study is the *Classroom BirdWatch* curriculum aligned with the *eBird* citizen science project; therefore, a more detailed description of that project will be provided.

After the initial look at citizen science programs, this chapter continues with a discussion of the cognitive processes associated with scientific inquiry. Six cognitive processes will be described: 1) generating a research question, 2) designing a study, 3) making observations, 4) explaining results, 5) developing theories, and 6) studying others' research. For each cognitive process, reasoning tasks associated with authentic scientific inquiry will be compared to reasoning tasks associated with simple inquiry. For example, during authentic scientific inquiry, scientists coordinate results from multiple studies to develop theories. During simple inquiry students do not consult information from multiple studies to develop theories.

The final section of this chapter will provide a discussion of student engagement. Student engagement will be defined by four components: 1) a sense of autonomy, 2) competence, 3) relatedness and 4) intrinsic motivation. Students develop a sense of autonomy as they have opportunities to be responsible for their own learning. When students expect to complete a task successfully with appropriate effort competence is developed. Relatedness may refer to student felt connections to scientists at Cornell Lab of Ornithology, connections to each other or connections to their teacher. Intrinsic motivation is demonstrated when students are interested in and enjoy tasks without external prodding.

During this study, four research questions were explored. The first question is, to what extent did the tasks associated with the *eBird/CBW* citizen science project incorporate (promote) features of authentic scientific inquiry? This question is important because the choices made by curriculum designers have epistemological consequences with respect to the kinds of decisions that inquiry activities demand on students (Chinn & Malhotra, 2002).

The second research question is, how did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation? This question is important because the psychological needs of autonomy, competence and relatedness influence a person's self-regulated behavior (Brophy, 2004). If these needs are fulfilled, student motivation and engagement will be autonomous and their academic pursuits will be well aligned with their sense of self, reflecting their view of what is important or interesting. Satisfaction of these needs provides the "necessary conditions that allow people the freedom to engage in self-determined activity" (Brophy, 2004, p 186). In the case of this study, students may then participate in science based on intrinsic motivation in a manner that could potentially help them to be able to think, act and feel like real scientists.

The third research question is, how did students describe the scientific inquiry cognitive processes used during their participation in the *eBird/CBW* citizen science project? This question is important because school science inquiry tasks are often described as simple science in that they do not incorporate features of authentic scientific inquiry. Students conducting science inquiry in school often engage in passive ways by following a series of steps (Chinn & Malhotra, 2002). The proposition of this research was that participation in citizen science inquiry may allow students to be involved with more of the reasoning tasks associated with the cognitive processes of authentic science.

The fourth research question is, how did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/CBW* citizen science project? This question is important because the responses can be used to validate the information shared by the students because the expressed epistemological beliefs of students often seem hopelessly naïve even though their practices of inquiry may share much with scientific practices (Sandoval, 2005).

Hands-on, inquiry science is promoted in current science education reform as a means of providing students with opportunities to experience the processes associated with authentic science. One approach to introducing students to hands-on science is to involve students in environmental monitoring, student-scientists partnerships or citizen science projects. These descriptors are often used interchangeably. In the interest of clarity, I will describe each term from a historical perspective and provide examples for each type of inquiry experience.

Historical Perspectives

We all have photo albums jam-packed with photographs of our family members as they have grown and changed over the years. These snap-shots are representations of moments in time. Although they tell a story of our family's general change and growth they do not give a clear indication of the details. The same can be true of conservation ecology. Scientists study various populations in the environment with this snap-shot approach. Because of limited human and material resources, scientists are often unable to gain a clear understanding of the details involved in many conservation efforts. There are simply not enough biologists and resource managers to cover an entire county, state or region. As a result of this constraint, many resource decisions have been based on limited data. Environmental volunteer monitoring, student-scientist partnerships or citizen science programs have been suggested as a means for addressing this limitation of resources in the area of conservation ecology.

Environmental Volunteer Monitoring

Environmental volunteer monitoring involves the use of non-paid workers to examine various elements of the natural environment over time. These volunteers may have training as professional scientists or they may be concerned citizens who want to learn more about the health of a local habitat. Several volunteer monitoring programs have existed for an extended period of time. For more than 100 years, the National Weather Service has trained volunteers to report daily measurements of rainfall and air temperature throughout the country. Since 1954, the National Fisheries Service has tracked fish populations by using volunteers to tag and release fish as well as report tag information on captured fish. Monitoring natural systems through data collection on various ecological parameters (e.g., water chemistry, vegetation composition, animal diversity, and geology) has become an increasingly popular vehicle for volunteer groups to take action in their local watersheds (Nerbonne & Nelson, 2004).

Starting in the late 1960's, water quality began to emerge as the dominant type of volunteer monitoring program (U.S. EPA, 1998). The subsequent passage of the Clean Water Act in 1972, which required states to assess the quality of their surface water, provided the catalyst for several of the early state-supported water quality volunteer monitoring programs. The nations largest and most comprehensive network of volunteer water monitors is associated with the *Save Our Streams Program* (SOS) initiated by the Izaak Walton League of America in 1969 (Firehock, 1994). As part of participation in this program, volunteers are asked to monitor their selected streams, for a year or more, collecting data that are used to track changes in the biotic (living) community of a stream. Volunteers examine the biotic community by collecting and identifying larval insects from stream bottoms. The presence or absence of certain insect groups serves as an indicator of water quality. A focus on stream water quality is important in consideration of the impacts of land use on watershed health. SOS coordinators review data for accuracy and validity and then report the data to several governmental agencies. The Izaak Walton League of America provides an extensive web site as well as printed resource materials to support volunteer monitors (http://www.iwla.org).

Based on the *National Directory of Volunteer Environmental Monitoring Programs* (U.S. EPA, 1998), 772 program groups were involved in some type of watershed monitoring during 1998. Many of these groups not only monitored the environment but were also active in cleanup and restoration efforts as well as community outreach activities. The concern for ecological degradation appears to be the most common motive for environmental volunteer monitoring (Nerbonne & Nelson, 2004). Although watershed monitoring is the most dominant form of volunteer monitoring, other activities were also reported including observing and tracking the invasion of non-native species, land use surveys, fish and wildlife surveys, and banding birds (U.S. EPA, 1998).

The sum of all volunteers (including teachers and students) reported by all programs in the 1998 directory was 462,209 participants. This number is lower that the actual number of volunteers because some of the larger monitoring organizations were unable to report individual numbers. For example, the National Audubon Society estimates that more than 50,000 people participant each year in the *Christmas Bird*

Count, yet this number was not reported. It is estimated that the actual number of volunteers is well over half a million (U.S. EPA, 1998). Over half of the programs listed in the directory included teachers and students as participants.

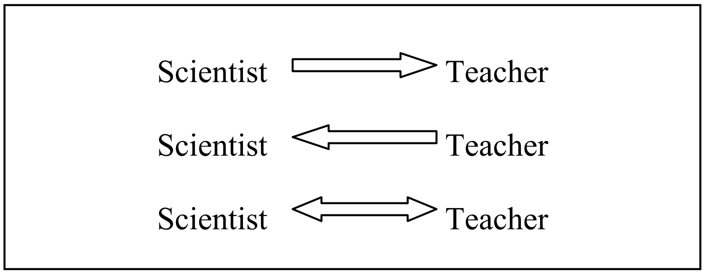
Data collected by volunteer monitors are utilized in a variety of ways by the programs responding to this national survey. The most common data use reported was educational (84% of respondents), followed by establishing baseline conditions (67%), screening for environmental problems (61%) and research (53%) (U.S. EPA, 1998). Based on a national survey of volunteer macroinvertebrate (stream insect) monitors, volunteer data were making a valuable contribution to some state and local databases, was influencing decisions about natural resources, and was helping to determine where restoration should occur (Nerbonne & Nelson, 2004). From this report, it would appear that volunteer monitoring data are being widely used to keep communities, elected officials, and resource management agencies informed about the condition of local water bodies (U.S. EPA, 1998).

Initial volunteer monitoring efforts were usually associated with collection and dissemination of data. During the early 1990s, a more holistic approach to volunteer monitoring began to emerge with trends towards an integration of monitoring with environmental action. Many water quality monitoring projects are now combining data collection with some type of community action and restoration of water bodies that have been adversely affected in some way (Lee, 1994). For example, the watershed education initiative known as the *Global Rivers Environmental Education Network* (GREEN) invited participants to not only collect and analyze local environmental water quality data but to also study current and historical patterns of land and water usage and then develop, share, and implement strategies for remediation and action on behalf of a polluted watershed (Donahue, Lewis, Price, & Schmidt, 1998). This watershed approach to natural resource management reflects a greater emphasis on the human relationship with a geographic place.

Student-Scientist Partnerships

In a student-scientist partnership (SSP), students are active participants with teachers and research scientists in a collaborative scientific research project (Barstow, 2001; Lawless & Rock, 1998; Moss, Abrams, & Kull, 1998; Tinker, 1997). Several critical components of a SSP have been suggested by Evans and her colleagues: 1) access to experts, 2) training sessions and support materials, and 3) opportunities to communicate scientific findings (Evans, Abrams, Rock, & Spencer, 2001). First, access to experts related to the specific scientific research should be provided so that teachers and students will have someone with whom to discuss questions and concerns. This access to experts can take three forms (Figure 2). Scientists may communicate information to teachers/students by way of printed training materials, printed content specific materials or web-based materials. Teachers may communicate information to scientists through comments with data submission or research reports. The most robust forms of access to experts would be scientists and teachers engaging in two-way communication. This may occur when scientists visit participating classrooms, students visit scientists' research sites, through email or by telephone.

Figure 2. Access to Experts



A second critical component of a SSP is that training sessions as well as support materials and clearly defined research protocols should be available for teachers. The extent of training sessions can be varied. Some programs have a one-time training session where others offer extensive follow up to their training sessions. Training sessions may be anywhere from one or two hours to one or two weeks. Different SSPs offer a variety of support materials. Some offer only printed materials. With advances in technology, many partnerships are now offering web-based support materials that provide a more dynamic interface. Some SSPs provide access to a ‘help desk’. This is usually in the form of an on-line (or telephone) question and answer format. There is considerable variation among SSPs with reference to clearly defined protocols. Some programs have open-ended protocols and some are very specific.

When student conferences are part of the program there is an opportunity for students to share what they have garnered from their research, defending their evidence as well as being encouraged to considered additional research avenues. This third critical component, communicating scientific understanding, can range from those conferences where multiple students share their work associated with a common SSP to events where students are sharing their research at more professional (adult) meetings related to a general field of study.

There is no one specific format for SSPs. Some partnerships are between a single scientist and one or two students. Some partnerships are between one or more scientists and a small group of students. Other partnerships may be between one or multiple scientists and entire classes of students. Tinker (1997) describes four models of SSPs: 1) scientist-led, 2) instrument-based, 3) scientist-guided, and 4) student-originated.

Scientist-led partnerships are those where the scientist defines the research program and protocols while students gather and analyze the data. Some scientist-led projects are characterized by a single scientist and one or a small group of students working with the scientist during non-school hours. In the case of several of the environmental volunteer monitoring programs discussed earlier, scientists often determine the protocols for data collection that students follow. The GLOBE (Global Learning and Observations to Benefit the Environment) program is an example of a scientist-led partnership that is targeted at the K-12 classroom. GLOBE is an international environmental science and education program that creates a partnership among students, their teachers, and the scientific research community. Student participants make selected measurements on the atmosphere, hydrology, land cover/biology and soils following protocols developed by the scientific research community. Students collect the environmental data in their local area and transmit their data via the Internet to an international database (www.globe.gov). GLOBE scientists then use the student data in their own research. Students have access to datum displays that are based on a combination of their data plus data collected by other schools around the world. The GLOBE curriculum was formally proposed in 1994 and is funded by the National Science Foundation (NSF). The main goal of the program is to promote the learning of environmental science while students are engaged in authentic science activities (Rock, Blackwell, Miller, & Hardison, 1997).

The second model of SSP is instrument-based partnerships. During these partnerships scientific instruments are placed in K-12 schools. Scientists and students use the equipment for different purposes and the student work is often of little interest to the scientists. For example, the Princeton Earth Physics Project, developed by Princeton University, places networked research seismographs in schools. Scientists are interested in small scale earthquakes that occur while students simply focus on major earthquake events that may occur (Cohen, 1997).

The third model of SSP is scientist-guided partnerships. During this type of partnership scientists define and support a topic of research, but students are involved in the design and implementation of the study. Protocols are established by the scientist but description of site, specific tests and other features of the local study are determined by the students. The GREEN project that was described earlier is an example of a scientist-guided partnership. Scientists define protocols for data collection but students are left to decide where they will collect water samples and examine land use patterns.

Finally, there are student-originated partnerships. During these SSPs the design of an experiment and the protocols used are largely determined by student interest. Scientists act as consultants, advisors or reviewers. Scientists involved in this type of partnership are open to suggestions by teachers and students.

Depending on the nature of the partnership and the degree of involvement, students may benefit from participation in an SSP in a variety of ways. The partnership could offer a context-rich, integrated, and hands-on approach to learning scientific processes as well as subject-specific content (Barstow, 2001; Ginger, Moran, Weinbeck, Geer, Snow & Smith, 1996; Tinker, 1997). Long-term interest, deeper understanding, and an appreciation of science can happen if the processes of science as well as its products are emphasized in the partnership (Caton, Brewer, & Brown, 2000). Student mentoring by ‘real’ scientists may be a source of expertise otherwise unavailable to K-12 students (Moss, Abrams, & Kull, 1998).

There are numerous benefits for research scientists from a SSP including increased geographic coverage, long-term data collection and increased volume of data. A larger geographic scale provides for a more global understanding of environmental conditions that would not be feasible without partnerships (Berkowitz, 1997; Lawless & Rock, 1998; Trumbull, Bonney, Bascom, & Cabral, 2000). Data generated by students from across a wide geographic area would be of interest to researchers who are studying species variation or population dynamics. SSP participants can contribute long-term data (collected over many years) that may not be feasible for most scientists. Additionally, the massive size of SSP datum sets and multiple measures of the same parameter improve data confidence and make statistical analyses and predictive modeling more comprehensive (Lawless & Rock, 1998; Trumbull, Bonney, Bascom, & Cabral, 2000).

One of the challenges faced by SSPs is generating the data required for the overarching scientific research goals while still trying to encourage students to develop their own questions within the context of their field sites and smaller datum sets (Evans, Abrams, Rock, & Spencer, 2001). The primary objective for the scientist is the generation of scientific knowledge while that of the student is the generation of the knowledge of science (Lawless & Rock, 1998). Scientists generate new scientific knowledge as they investigate natural phenomena. Participation in an SSP allows students to experience the process of science as well as develop better understandings of existing scientific knowledge. Even with these seemingly conflicting objectives, Tinker (1997) suggests that SSPs can play a critically important role in injecting real science into schools. The educational value, however, depends on the skill of the teacher, the availability of related curriculum materials that address appropriate student learning goals and the opportunities provided for active student participation in research (Tinker, 1997).

Citizen Science

Citizen science is exactly what the name implies: citizens doing science. The Cornell Lab of Ornithology pioneered the citizen science concept in the early 1990s with funding from the NSF and has spent the last decade developing, testing, and improving the citizen science methodology. Cornell Lab of Ornithology has engaged more than 100,000 citizens of all ages and backgrounds in a variety of projects aimed at answering different sets of environmental questions.

E.W. Jenkins (1999) describes citizen science as that which “relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business" (p. 704). People from all sectors of society volunteer to partner with scientists in collecting data related to a scientific research question of importance. Scientists use citizen-collected data to answer large-scale scientific questions (Ardia, Cooper, & Dhondt, 2006; Cooper, Hochachka, Butcher, & Dhondt, 2005; Cooper, Hochachka, Wesley, Phillips, & Dhondt, 2006; Hames, Rosenber, Lowe, Barker, & Dhondt, 2002; Hartup, Bickal, Dhondt, Ley, & Kollias, 2001). Citizen science volunteers usually receive some type of instruction on proper datum collection techniques and datum submission procedures. Over the years, citizen science has been billed as a method for bringing participants closer to nature as well as giving them a better understanding of the environmental issues affecting society.

How does citizen science relate to environmental volunteer monitoring and SSPs? I would suggest that citizen science implemented in the K-12 classroom is a form of volunteer monitoring and a type of SSP. For the purpose of this study, I have chosen to broaden the definition of scientist-guided student partnerships described by Tinker (1997) to include citizen science projects conducted in K-12 classrooms.

Citizen science in the K-12 classroom is an extended partnership between a teacher, a group of school children and a professional scientist. To successfully engage the 'nonscientific' audience, Carol Brewer (2002b) suggests that participants should be encouraged to become active stakeholders in the project. The project should allow participants to be stakeholders in both the research experience as well as the outcomes of study. Effort must be taken for students to feel like they are truly partners with scientists as opposed to just working for scientists (Moss, Abrams, & Kull, 1998).

Scientists establish the research agenda, for example, the investigation of biodiversity in a specific stream or habitat usage by a population of spotted salamanders, and specific protocols for observations and measurements; however, teachers and students should be encouraged to ask their own questions, collect and evaluate data, as well as present their results to others. This research agenda would be real as opposed to contrived. In other words, scientists and teachers would not hold the ‘correct’ answers to the research problem a priori. This real research would be the opposite of the confirmatory, ‘cook-book’ type inquiry processes traditionally associated with school science (Moss, Abrams, & Kull, 1998). Scientists should provide training in data collection, identification of organisms, safety and ethics (Brewer, 2002b).

Teachers introduce the project to their students and nurture an atmosphere of inquiry. Students begin their participation in the project by making observations and/or taking measurements. Depending on the project, the student observations can be specific to a particular type of organism or habitat or more general in nature. Student observations are submitted to the professional scientists (either electronically or through the mail). The data should be used by scientists to address the research question under study. The data should cover a large geographic area and be collected over a long period of time. Students and teachers should have access to these large datum sets for comparative and analysis purposes.

The scientist or sponsoring organization provides educational materials designed for classroom use. These materials are used by classroom teachers to guide students to a deeper understanding about the biology, behavior, or ecology of a particular organism or habitat as well as to introduce science process skills. The curriculum should provide appropriate student learning goals and opportunities for active student participation. Collaboration between teachers and research scientists is critical for support and assistance. Similarly, scientists need guidance on how to make the experience successful for the students (Brewer, 2002b).

As school children grow in their understanding and continue in their observations, they are encouraged to develop their own research questions. Guided by their classroom teacher, students are encouraged to develop and implement research projects related to the larger citizen science project. The outcomes of these student-generated projects are often shared with the larger citizen science research community. Student engagement in this type of independent inquiry is potentially seen as the most valued part of citizen science participation, however, data reporting to the sponsoring organization are often the limit to citizen science participation. The emphasis on data reporting over student research often comes from the sponsoring organization (Penuel, Shear, Korbak, & Sparrow, 2005).

Citizen science projects in the K-12 classroom suggest a collaborative research community that includes researchers, teachers and students. The general topic of the citizen science project should relate to the concerns and interests of the students involved. Teachers should emphasize the relevance of the topic under study to student lives and the larger global world. The Internet is used as a tool to transcend geographic barriers, as well as facilitate communication and collaboration across this community. Table 1 provides an outline of this definition of citizen science in the K-12 classroom.

Table 1. Definition of citizen science in the K-12 classroom.

General	▪ Partnership between teacher, group of school children and a professional scientist(s) ▪ Project relates to concern and interest of students ▪ Project is real (ie. not contrived or ‘cookbook’) ▪ Project relevant to life of student and connected to global importance ▪ Long-term, in-depth involvement of groups of students and their teachers
Scientist	▪ Establishes research agenda ▪ Establishes specific data collection protocols ▪ Provides for training in data collection, identification of organisms, safety and ethics ▪ Provides education and support materials for classroom use ▪ Direct contact with teachers and students ▪ Uses student data to address research question under study
Data	▪ Covers large geographic area ▪ Collected long-term ▪ Massive data set shared with all citizen science participants for comparative analysis
Teacher	▪ Introduces project to students ▪ Nurtures an investigative classroom culture ▪ Relevance of project to life of student and larger global world made explicit ▪ Provide scientist with guidance on making project useful to students
Students	▪ Makes observations and/or takes measurements ▪ Observations/measurements submitted to scientists ▪ Evaluate and analyze collected data ▪ Develop and implement their own research projects related to larger citizen science project ▪ Outcomes of individual projects shared with citizen science research community

The definition of citizen science used in this study would not include those environmental volunteer monitoring projects that are facilitated by governmental agencies or private nature centers where student groups make a one-time fieldtrip to the site. In this case, students visit a research site, learn about a project, collect data for the project and then return to their classrooms. Depending on the situation, student groups may take their data back to the classroom for further analysis. For example, the National Park Service provides a variety of projects associated with *Hands on the Land*, a national network of field projects linking students, teachers, and parents to their public lands. To participate in these projects, students visit a national park site, collect data, and post their findings to a web-based database at www.handsontheland.org/monitoring/checkup.cfm. This initiative is sponsored by a collaboration of five federal agencies (USDA Forest Service, Bureau of Land Management, US Fish and Wildlife Service, National Park Service, and Natural Resource Conservation Service), a non-profit foundation, schools, and other private sector partners. The value of these projects notwithstanding, I have decided not to include them in my definition of citizen science. I am making this delineation because of my focus on a more long-term and in-depth involvement of students and their teachers.

The definition of citizen science used in this study would also not include those situations where one or two scientists are working with a small group of students as part of an after-school or summer program. For example, the Bennett's Millpond Environmental Learning Project was developed by North Carolina State University. A high school teacher with a senior and junior high school student participate together as an environmental research team. Participants receive training, equipment loans, and compensation for their time by agreeing to meet the expectations and commitments of the program. The research team is expected to conduct environmental sampling at a selected location at least once per month, attend a week long summer workshop, participate in online discussions, keep a research journal and share the research at a yearly symposium (S. Karl, personal communication, November 10, 2005). The local nature of this project as well as the limited target participant population prevents this type of project from fitting the definition of citizen science described in this study.

Student Participation in Citizen Science

The nature of the citizen science experience should be very different from the traditional ‘cookbook’ approach to school lab work (Moss, Abrams, & Kull, 1998). The ideal citizen science project should have few canned or predetermined answers. It would be appropriate for students to fumble through datum collection techniques, critically analyzing their own methods, and perfecting their work through the course of the study. Students would analyze their own data, looking for patterns, but not necessarily looking for a single right answer.

Students should be aware of the problem that is driving the research agenda. For example, declining populations of certain amphibian species and a limited understanding of long-term population fluctuations has been the ecological problem that drives amphibian monitoring citizen science projects. When students believe their involvement in the research project is valid and important they may be more motivated to care about data collection. A sense of ownership in the research problem under study sets the stage for active participation in authentic science (Moss, Abrams, & Kull, 1998). When teachers engage students in discussions regarding what their data might mean it helps students to better understand the science behind the measurements they are making (Penuel, Shear, Korbak, & Sparrow, 2005).

Student benefits from active participation in citizen science projects have been suggested by a variety of researchers. Participation in this type of broader SSP may improve student relationships with nature (Riquarts & Hansen, 1998), environmental attitudes (Bogner, 1998), and appreciation for local ecosystems and species (Brossard, Lewenstein, & Bonney, 2005; Schlag-Mendenhall, 2001). Excitement and enthusiasm for authentic science may be generated through these types of research experiences (Barstow, 2001) and students may gain an appreciation of scientific research as well as the inherent difficulties in gathering quality data (Caton, Brewer, & Brown, 2000; Lawless & Rock, 1998; Selover, Dorn, Dorn, & Brazel, 2003). The process of science (what scientists do, how they do it, and why) as well as scientific results may be demystified for the nonscientist (Brewer, 2001 & 2002b; Caton, Brewer, & Brown, 2000; Cohen, 1997; Trumbull, Bonney, Bascom, & Cabral, 2000). Student-oriented field research has the potential to help students understand real problems of local community significance (Serman, Rudenjak-Lukenda, & Perkovic, 2000) and lead them to look at familiar species from a different perspective becoming a more critical observer (Brewer, 2002b; Lawless & Rock, 1998). This experience can provide a linkage between the 'real world' and school learning (Barstow, 2001; Moss, Abrams, & Kull, 1998). Participation may foster stronger connections to the ecology of a location with potential to change a person's behavior in a way that benefits habitats and species (Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005). These suggested benefits are achieved through the combination of direct participation in a scientific study, interaction with research scientists, and the use of high-quality educational materials provided by the sponsoring organization (Brossard, Lewenstein, & Bonney, 2005).

As with any instructional strategy, care must be taken during citizen science participation to insure that student learning remains the focus. Students must have a clear understanding of the questions guiding the research process as well as the purposes of the project. Students must be involved in data analyses, communication of results and possible social decisions. Analyses of data provide relevancy and meaning for doing scientific work (Moss, Abrams, & Kull, 1998). When students are unaware of or uninvolved in these critical elements of scientific inquiry they may see themselves simply as repetitive datum collectors. When students are encouraged to develop their own research questions and determine the direction of a project they experience the creative and explorative nature of science. When student learning is the focus of citizen science participation then students will be the guiding force of project participation and not the classroom teacher.

Following scientific protocols during citizen science participation is often problematic (Enyedy & Goldberg, 2004; Moss, Abrams, & Kull, 1998). If students focus on following datum collection protocols strictly they may feel as if they have no input into the scientific process: they are simply following another person's directions. When students follow strict and repetitive datum collection procedures they do not feel like scientists (Moss, Abrams, & Kull, 1998). On the other hand, if students do not follow strict protocols then data cannot be compared across time and space. Teachers must take great care to see that efforts needed to collect accurate data never overshadow the broader notion of scientific research.

Teacher Participation in Citizen Science

Potential benefits to teachers during citizen science participation are varied. Participation in a citizen science project with a class of students could provide the opportunity for a teacher to develop an increased appreciation for inquiry. Citizen science could be the vehicle for teachers to develop greater confidence in teaching using inquiry as well as a broader use of inquiry in the classroom. The use of a citizen science partnership may transform how teachers (and students) view and use their schoolyards for ecological studies (Brewer, 2002a). When teachers work on investigations with scientists, there is the possibility for increased interest in and understanding of the scientific processes (Caton, Brewer, & Brown, 2000).

Teachers may choose not to participate in these types of programs for a number of reasons. They may feel great pressure for their students to perform well on high-stakes accountability tests (Penuel, Shear, Korbak, & Sparrow, 2005). More complex inquiry tasks may take a substantial amount of classroom time (Chinn & Malhotra, 2002). This pressure often causes teachers to devote more time to the type of material on the accountability test thus crowding out the time and energy needed to try a more risky, in-depth inquiry science experience (Songer, Lee, & McDonald, 2003).

A lack of resources may be a factor in not participating as well as a lack of support from administration, technology experts, parents or university personnel. Teachers may cite their own time constraints in planning and preparing for citizen science activities. Budgets in many schools and districts are strained and potential support individuals may find they have limited time and energy to devote to such projects

(Caton, Brewer, & Brown, 2000). School constraints such as short class periods and large numbers of students may discourage teachers from participation.

Some teachers may be unaware of the existence of citizen science projects or they may lack initiative and autonomy that is critical to engage in citizen science projects (Songer, Lee, & McDonald, 2003). Even if aware of citizen science programs, some teachers may choose not to participate because of challenges in teacher-scientists collaborations. Teachers may find it difficult to cross the hierarchies that often exist between scientists and science educators in a way that makes true collaboration and exchange possible. Teachers may point to a limited science background and training or negative experiences in science courses as other reasons not to participate (Brewer, 2002a).

Teachers may not participate in citizen science because they lack familiarity and comfort with inquiry science teaching practices (Penuel, Shear, Korbak, & Sparrow, 2005; Windschitl, 2001). Inquiry science teaching is a complex process that involves the use of a wide array of science skills as well as pedagogical skills. For example, inquiry science is often more open-ended and student directed. Teachers must be willing to give up their authoritative stance of being in control of student behavior or being the keeper of all knowledge.

Some teachers may view the process of traditional science as rigid and offering little opportunity for creativity (Brewer, 2002a). With the schoolyard being perceived as only a playground, many teachers may have reservations about managing their students during outdoor lessons.

William Penuel and his colleagues (2005) suggest three ways that local partners can be used to support participation in citizen science type programs: 1) face-to-face mentoring for teacher participants, 2) opportunities to practice new teaching strategies in the context of pre-service teacher preparation and in-service teacher professional development, and 3) alignment with national and state standards. Local partners can serve to make connections between the broad goals of the curriculum and the local goals of educators.

Face-to-face mentoring has been shown to be an important predictor for different levels of data reporting (Penuel, Shear, Korbak, & Sparrow, 2005). Mentors can help citizen science teacher participants in a variety of ways. Mentors can model inquiry teaching methods, citizen science project learning activities, effective questioning strategies, and datum collection protocols. They can help teachers see connections between the citizen science curriculum and state standards as well as help teachers integrate citizen science into their existing curriculum. Mentors can help teachers set up equipment and solve problems related to making observations or taking measurements. Local mentors can help teachers identify questions to investigate that have particular relevance to the local environment (Penuel, Shear, Korbak, & Sparrow, 2005).

Pre-service and in-service teachers need sustained support over time and ongoing professional development to establish student-driven investigations in their own classrooms. Teachers play a critical role in promoting student-driven investigations; however, many teachers are uncomfortable with their own abilities to conduct scientific inquiry. A more experienced ‘other’ is needed to scaffold this process for teachers. For example, a university teacher educator might serve as a local partner in the implementation of a national citizen science project. The partner's role is to provide support in the areas of science content, datum collection, inquiry teaching, and student independent inquiry.

Project and curriculum designers should provide activities that are aligned with national and state standards and assessments as well as help teachers identify multiple opportunities for integrating participation across the curriculum. Mentors can work with teachers to identify opportunities to integrate citizen science into their curriculum in ways that would help the teachers meet their state standards. Local partners may be important to help teachers adapt the citizen science activity to fit within the constraints and demands that teachers face (Penuel, Shear, Korbak, & Sparrow, 2005).

Citizen Science For All

Christmas Bird Count (1900)

One of the oldest and longest running citizen science projects is the *Christmas Bird Count* (CBC) administered by the National Audubon Society. Since 1900, volunteers have annually collected bird census data in the early winter all across North America. Prior to the turn of the century, people participated in a holiday tradition known as the Christmas 'Side Hunt'. Individuals would choose sides for two teams. The teams would spend the day hunting birds. Whichever team came back with the largest number of birds was the winner. Concern began to arise among scientists and birders regarding the decline of some bird populations. Beginning on Christmas Day 1900, ornithologist Frank Chapman proposed a new holiday tradition, a Christmas bird census to count birds instead of hunt them. The first *Christmas Bird Count* involved twenty-seven volunteers and ranged from Toronto, Ontario to Pacific Grove, California. Approximately 18,500 individual birds representing 90 different species were recorded during that first event (National Audubon Society, 2005).

The primary objective of the CBC, to monitor the status and distribution of bird populations across the western hemisphere, has not changed during its 106 year history. Currently, the CBC is conducted between December 14th and January 5th. Volunteers are organized into groups and follow a specified route through a 15-mile diameter circle on a single day during the survey period counting every bird they see or hear. Since inexperienced observers are paired with seasoned CBC veterans, anyone can participate. During the 2005 counting season, 56, 623 volunteers participated in this citizen science project. These volunteers were from the United States, Canada, Latin America, the Caribbean, and the Pacific Islands. A total of 69,901,741 birds were identified representing 2561 different species (National Audubon Society, 2005).

Project FeederWatch (1989)

Project FeederWatch is a citizen science project collaboratively designed by the National Audubon Society, Cornell Lab of Ornithology, Bird Studies Canada and the Canadian Nature Federation. The project enlists backyard birders in monitoring bird populations. Since 1987, nearly 36,000 volunteers across North America have submitted counts of the birds at their backyard bird feeders. During the 2004-2005 winter bird season, 14, 270 volunteer citizen scientists supported *Project FeederWatch* (Bonter, 2005). These citizen scientists count the highest number of birds of various species seen at certain periods and report this information to scientists at Cornell Lab of Ornithology. Scientists use the data to establish large-scale movements of winter bird populations and monitor long-term trends in bird distribution, abundance and population densities.

Anyone can participate in this citizen science project. A $15 dollar annual fee provides participants with a research kit containing identification information, reporting forms and a newsletter (Sanborn, 2005). FeederWatching has three simple steps: 1) put up bird feeders, 2) identify and count the birds that visit, and 3) send the data to scientists at Cornell Lab of Ornithology. Since the project's inception, more than 16,000 individuals across North America have counted and recorded the kinds and numbers of birds observed at backyard feeders (Trumbull, Bonney, & Grudens-Schuck, 2005).

North American Amphibian Monitoring Program (1990)

In response to unexplained and seemingly rapid declines in amphibian populations worldwide, the *North American Amphibian Monitoring Program* (NAAMP) was initiated in the early 1990s by the United States Geological Survey Biological Resources Division. The NAAMP is a long-term monitoring program designed to track the status and trends of amphibian populations in the Canadian Provinces and the eastern United States (U.S.G.S., 2001). Five monitoring techniques have been implemented: 1) frog and toad call surveys, 2) terrestrial salamander monitoring, 3) aquatic surveys (including surveys for egg masses and tadpoles), 4) western North American surveys, and 5) atlases.

The call surveys and terrestrial salamander monitoring are the most common volunteer efforts (Griffin, 1998). Scientists at NAAMP developed frog and toad call survey protocols. A volunteer covers a route of ten stops which are at least one-half mile apart. NAAMP randomly generates the routes which are groundtruthed by local coordinators. Participants start their survey one-half to one hour after sunset. They drive to the first stop, turn off the automobile engine, wait quietly for about a minute and then listen intently for three minutes. Identified species are noted and assigned a relative abundance code to estimate how many individuals of each species are calling.

Salamanders do not call as audibly as frogs and toads, so other techniques are used to determine their presence and abundance in a habitat. Volunteers set out arrays of cover objects (wood and tin pieces) in nearby forests where salamanders are known to live. These artificial pieces of substrate are checked to document the number and type of amphibian species found underneath (Tomasek, Matthews, & Hall, 2005).

Seed Preference Test (1993)

With funding from the NSF, the National Science Experiments Center at the Cornell Lab of Ornithology began operation in 1993. The purpose of the center was to involve the public in a series of guided projects in which the participants would gather information for ornithologists while at the same time learning more about birds and about how scientific projects were conducted. Researchers at the Cornell Lab of Ornithology recruit more than 17,000 participants for their first citizen science project, the *Seed Preference Test,* conducted in the fall of 1993.

Participants received a research kit consisting of a 12-page instruction booklet, a tally sheet, ten computer-scanable datum forms, a full-color poster of common feeder birds, and an envelope for returning completed datum forms (Trumbull, Bonney, Bascom, & Cabral, 2000). The scientific question being investigated was, what kinds of seeds do birds prefer to eat at ground feeders? Participants did not contribute to the development of the scientific research question nor did they provide input into experimental procedures. Each volunteer was instructed to place a measured amount of three different kinds of bird seed on separate pieces of cardboard. When birds ate the seed, volunteers were to make accurate counts of how many individuals of each bird species visited each pile of seed in a specified amount of time.

Participants were mainly adults (median age 49 years) who had an interest in birds and science. Analyses of responses to a post-project survey revealed no difference in beliefs or knowledge about science after participation in the project; however, qualitative analyses of correspondence demonstrated that participation in the project did trigger thinking that fit various aspects of systematic inquiry, specifically observations and hypothesis generation (Trumbull, Bonney, Bascom, & Cabral, 2000). During the seed preference citizen science project, researchers were surprised at the number of responses and communications from classroom teachers describing their participation in the project. From this, project designers at the Cornell Lab of Ornithology began to consider ways to modify the model of citizen science to include this potential cadre of young K-12 partners (R. Bonney, personal communication, May 5, 2006).

The Birdhouse Network (1993)

The Birdhouse Network (TBN) was initiated in 1997 and is another Cornell Lab of Ornithology citizen science project. The scientific research focus of this project is on cavity-nesting birds such as blu*eBird*s, tree swallows and American kestrels. These types of birds need dead trees for cavity nesting; however, the number of dead trees has been declining, severely reducing the appropriate available habitat for the reproduction of these birds. Ornithologists recommend the human intervention of installation of artificial nest boxes to address this problem. TBN participants are asked to put up one or more nest boxes in their yards and/or neighborhoods and then to observe and report data on inhabitants of the nest boxes. The TBN citizen scientist collects location, habitat, and nest-box information and records the numbers of eggs (clutch size) and nestlings inside each nest box. Participants receive detailed explanations for the scientific protocols, biological information about specific birds, and practical information about nest box construction. Interaction with research scientists by phone, email or through an electronic mailing list is strongly encouraged. Scientists use the data to compare the breeding biology of birds in different areas of the country.

There were 798 TBN participants during the first year (1997-1998). This group was relatively homogeneous with the majority being white (98%), between the ages of 30 and 60 years (65%), holding a 4-year college degree or higher (79%), and engaged in a profession related to education (50%) (Brossard, Lewenstein, & Bonney, 2005).

There were three parts to the research agenda associated with this project: 1) participant attitude toward science and the environment, 2) knowledge of bird biology and 3) understanding of the scientific process. The project had an impact on adult participants' knowledge of bird biology but no statistical change was reported for participants' attitudes toward science or the environment or the participants' understanding of the scientific process (Brossard, Lewenstein, & Bonney, 2005).

House Finch Disease Survey (1994)

The *House Finch Disease Survey* began in January of 1994 when a citizen in the Washington, D.C. area called Cornell Lab of Ornithology with reports of house finches at their bird feeders with red, swollen eyes. Since that time, participants have helped scientists track the progress of the disease, *Mycoplasma gallisepticum*, by reporting sick and healthy individual house finches across North America. This strain of parasitic bacterium previously known to infect only poultry has also been documented in American goldfinches.

Participants attract feeder birds to their yard, watch the feeders and record the presence and absence of healthy and sick house finches and American goldfinches, and submit their observations to Cornell Lab of Ornithology via the Internet or through the U.S. Postal Service with paper datum collection forms. An analyses of citizen science data from 1995 demonstrated the occurrence of the disease was concentrated in the North Eastern United States. By February of 1998, citizen science data showed the progression of the disease to Midwestern states like Missouri and Iowa. Citizen science data from 2004 demonstrated that the house finch eye disease had spread all the way to the Pacific Coast with sightings reported in Washington state and Oregon (Cornell Lab of Ornithology, 2005b).

Birds in the Forested Landscapes (1996)

Habitats such as forests, prairies, and wetlands are being lost because of changing land uses, therefore, biologists must determine how much habitat is required to support viable populations of birds. Scientific evidence suggests that forest fragmentation (dividing large forest tracts into smaller pieces separated by non-forest habitat) is detrimental to some woodland bird species. To address these concerns, the Cornell Lab of Ornithology, Partners in Flight and the U.S.D.A. Forest Service designed and field-tested the citizen science project *Birds in Forested Landscapes* (BFL) during the 1996 bird breeding season. The initial goal of BFL was to determine how forest fragmentation and land use influenced the presence and nesting success of seven species of North American forest thrushes: Wood Thrush, Veery, Swainson's Thrush, Gray-cheeked Thrush, Varied Thrush, Hermit Thrush, and Bicknell's Thrush, as well as two forest raptors: Cooper's Hawk and Sharp-shinned Hawk (Rohrbaugh, 1997).

A BFL citizen scientist chooses a study species from BFL's list of species of conservation concern. Next, they randomly select a study site in suitable forest patches of various sizes. Participants visit the study site twice during the breeding season to visually and aurally survey the study species using recordings of the bird's vocalizations. Portable tape recorders or CD players are used to broadcast mobbing calls that serve to attract the attention of nearby birds, drawing them in momentarily so that they can be seen, heard, and counted. Data are recorded on habitat characteristics of the site and the surrounding landscape. Data are submitted to Cornell Lab of Ornithology either electronically or through the U.S. postal service.

Monarch Larva Monitoring Project (1997)

The Monarch Larva Monitoring Project is a citizen science project developed by researchers at the University of Minnesota. The purpose of the project is to collect long-term data on larval monarch populations and milkweed habitat. The overarching goal of the project is to better understand how and why monarch populations vary in time and space (Monarch Larva Monitoring Project, 2001). The project began in 1997. In 2002, funding from the NSF was used to develop a K-8 curriculum, *Monarchs in the Classroom*. Three separate guides are available: K-2, 3-6, and middle school. Each guide has background information on monarch biology, lesson plans, a bibliography and black-line drawings for duplication.

Volunteers conduct weekly monarch and milkweed surveys, measuring per plant densities of monarch eggs and larvae and milkweed quality. Since 1997, more than 600 participants have monitored 514 sites in 34 states and 2 Canadian provinces. Monitoring sites range from undeveloped areas such as nature preserves and restored prairies, to developed areas such as roadsides and backyard gardens (Monarch Larva Monitoring Project, 2001). Online and face-to-face training is offered for volunteers and communication with monarch scientists is via email.

Frogwatch USA (1999)

Created in 1999 by the United States Geological Survey (USGS), *Frogwatch USA* is a frog and toad monitoring program that relies on volunteers to gather data on amphibian populations. The long-term study is managed by the USGS and the National Wildlife Federation. As of 2004, there were more than 3,000 volunteers with *Frogwatch USA* who were monitoring more than 3,800 wetlands across the United States (National Wildlife, 2004). Volunteers choose their own monitoring site and then begin to record frog and toad species that are heard calling throughout the breeding season. The count allows scientists to see how frogs are faring in the face of mysterious deformities and population density changes (Ben-Ari, 2000). An additional goal of the project is to generate citizen interest and involvement in what is going on in the local environment.

Neighborhood Nestwatch (2000)

Neighborhood Nestwatch is a citizen science project developed and implemented by the Smithsonian Environmental Research Center that promotes scientific literacy and increased awareness and interest in the local natural environment for its participants. The project began in 2000 as an informal education program targeted at adults and families. Participants were provided with a packet of written materials that included a description of tasks, background materials and contact information. A Web site was also available with additional information on bird biology and ecology, downloadable datum forms as well as online data entry. During the initial stages of the project, researchers from the Smithsonian Environmental Research Center visited each participant annually during the breeding season to mist net and band birds that frequented and nested in participants' yards. Email and telephone contacts between participants and researchers were encouraged for additional support. Participants have been evenly distributed among three age groups: senior citizens, couples or singles in their late 30s to 50s and families with young children (Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005). In 2005, approximately two-hundred households were involved in collecting data about birds (Nestwatch, 2005).

Researchers report that science literacy, sense of place and relationship with the local landscape were increased (Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005). Strong gains were detected in understanding of bird biology, behavior and ecology; however, participants did not tend to comment on the scientific process during interviews. Analysis of email correspondence did suggest that the electronic form of communication did engage participants in the process of science. There was an increase in participant awareness of birds and the relationships between birds and habitat as well as the value of backyard habitat for plants and animals. Participants demonstrated a higher level of concern about the welfare of birds and reported changing their own behaviors to accommodate birds (Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005).

Evans and her colleagues (2005) suggest the critical component of the *Neighborhood Nestwatch* citizen science project was the face-to-face meetings between 'nonscientist' and scientist. Ensuing discussions allowed scientists to better address questions and interpret observations as well as allowed participants to observe how the scientists made decisions during the implementation of the research project. It was suggested that direct interactions empowered citizens by allowing them to feel like they were important partners in the research process.

eBird (2002)

eBird is a recent citizen science project co-developed by Cornell Lab of Ornithology and the National Audubon Society that was initiated in 2002 and revised in 2005. *eBird* is a continent-wide, year-round survey of North American birds. State-of-the-art Web technology provides the ability to track birds and share information with scientists, teachers, amateur naturalists, and other birders. The project allows citizen scientists to keep track of bird sightings year-round and to record their observations online. Participants of all ages identify birds in their local surroundings and submit the data electronically on the *eBird* website. Participants not only have access to their own observation data, but also to the data submitted by other *eBird* participants. The project is designed to gather the greatest possible information about size, distribution, and trends of bird populations. The mission of the project is to gather and interpret observational data for the conservation of biological diversity.

All *eBird* observations become part of a long-term database that can be used to ask questions about movements and distribution patterns of birds across the North American continent. The software program, *eBird* 2.0, was released in September of 2005. The focus of the newer version of the software was to increase the personal rewards that *eBird*ers gain from using *eBird* including being able to keep life lists, state lists and annual lists as well as the ability to generate real-time maps of bird distribution and real-time bar graphs showing birds seen at specific locations. The ability to generate up-to-the-minute range maps is a great way to demonstrate the dynamic nature of science. With the new software, participants can submit queries directly to the *eBird* database through the Avian Knowledge Network (AKN). The output is designed to provide the user with tabular reports for a species in a specific location over a specified date range (Audubon & Cornell Lab of Ornithology, 2006). For example, by defining date ranges an *eBird* user can look for seasonal distribution patterns in a particular bird species. *eBird* developers hope that revisions to the software will help “make birders better scientists” (B. Sullivan, personal communication, May 5, 2006).

At the end of January, 2006, over 20,000 *eBird* submissions had been recorded throughout most of the United States, Canada and Mexico. Top state contributors were Texas, California, New Mexico, New York and Virginia. High levels of contribution were generally contributed to regional partnerships. For example, two regional partnerships have been identified as driving forces in Texas citizen participation: Texas *eBird* and the Gulf Coast Bird Observatory's Avian International Monitoring Network *eBird* (Audubon & Cornell Lab of Ornithology, 2006).

As of March, 2006, there were more than 16,000 individual users of *eBird*. These users describe themselves as beginner birders (5.4%), intermediate birders (11.8%), advanced birders (33.3%), and expert birders (49.5%). Approximately 1,500 bird species have been reported. Regional bird experts review incoming *eBird* data for data quality. They may communicate with some observers as needed based on data that are flagged. For example, if an *eBird*er submited data that did not align with the current understandings of the distribution of a certain bird (seeing a bird in an area when it should not be in that area), a data editor might notice this anomaly and flag the entry until it could be corroborated with the person submitting the data.

Scientists are particularly interested in bird movements and ranges across North America, including migratory pathways, wintering and breeding ranges, arrival and departure dates, range expansions and contractions, and a host of other important environment relationships (Cornell Lab of Ornithology, 2005a). Conservationists would like to use the data to identify important areas for birds based on current range distributions and to track population trends that can be used to create management plans for endangered, threatened, and at-risk species of birds (Cornell Lab of Ornithology, 2005a).

Urban Bird Studies (2003)

The *Urban Bird Studies* is a group of citizen science projects designed by the Cornell Lab of Ornithology to learn more about birds in cities. Data are collected by citizen scientists of all ages and skill levels across North America and in other countries as well. Anyone can participate in two types of projects. The first type of project is a 'stand or sit project' where participates watch and count various types of city-dwelling birds from a stationary location. These types of data are used to understand how birds live in cities. The second type of project is a walking transect. The participant walks a straight line (called a transect) while counting and identifying birds. These types of data are used to learn about the density of birds in different areas. Bird density is important in bird biology and conservation.

The *Urban Bird Study* projects, initiated in 2003, are open year round. Depending on the project, important scientific questions vary: 1) *Birds in the City* (How do birds live in the city?), 2) *Crows Count* (How do crow group sizes change through seasons?), 3) *Dove Detectives* (What city habitats do doves and pigeons use?), 4) *Gulls Galore* (Why are gulls of different ages seen together?, and 5) *PigeonWatch* (Why are there so many colors of pigeons?) (Cornell Lab of Ornithology, 2004).

The *Birds in the City* project does not focus on a particular group of birds. Instead, participants choose a route for a bird walk and identify and count the birds seen within 50 feet of the line they are walking. The route can be a walk around the block or on the way home from school, work, shopping or the bus stop. Participants identify as many birds as they can identify comfortably. Scientists will use the data to calculate and compare densities of birds along the path of the bird walk. Long-term data will help to establish important baseline data on the densities of city birds that scientists can use to monitor changes through time (Chu, 2004).

During the *Crows Count* citizen science project, participants count crows or their relatives: jays, magpies, and ravens. Bird behavior such as feeding, preening, chasing and keeping a lookout (sentinels) are recorded on a tally sheet. The data are used by scientists to learn more about family group sizes in spring and summer, movements of birds in fall, and urban roosts in winter (Chu, 2004).

The *Dove Detectives* citizen science project takes a geographic view of how various dove species use urban and suburban landscapes. Participants count doves, fill out habitat forms and record what the birds are doing. These data are used by scientists to gain an understanding of how different species of doves are using their habitat, where the species overlap and whether there is any influence of one species on another (Chu, 2004).

The purpose behind the *Gulls Galore* citizen science project is to examine how gulls of various ages are using different habitats. Citizen scientists describe where they are observing gulls and then determine a birds' age based on plumage coloration. Cornell Lab of Ornithology scientists use the data to learn whether young gulls are more likely than adults to forage at dumps and other places where food is easy to find (Chu, 2004).

Citizen Science for K-12

Forest Watch (1991)

Forest Watch is a New Hampshire state-wide environmental monitoring project of tropospheric ozone damage to white pine trees (*Pinus strobus*). The project was guided by curricula developed by scientists at the University of New Hampshire during 1991. During the 1995-1996 school year, Moss, Abrams, and Kull (1998) examined high school student conceptions regarding the scientific process associated with engagement in the *Forest Watch* project. These researchers report that students' rudimentary conceptual understanding of scientific research rarely evolved over the course of the school year. Students demonstrated naïve notions of scientific questioning, viewed datum collection as only following repetitive prescribed steps, and had little experience with data analyses or the communication of scientific findings. Three critical factors were suggested as contributing to student perceptions: 1) insufficient exposure, 2) a lack of sense of partnership by students, and 3) the design of the project (Moss, Abrams, & Kull, 1998).

Journey North (1995)

Journey North is an Internet-based citizen science project that allows students to engage in a global study of wildlife migrations (http://www.learner.org/jnorth). The project was initiated in February of 1995 by the Annenberg Foundation and the Corporation for Public Broadcasting. Three sets of Journey North investigations are currently being offered: 1) seasonal migrations (monarch butterflies), 2) plants and the seasons (tulip gardens), and 3) sunlight and seasons (mystery class). Scientific protocols are provided for each project. There is no cost to teachers to participate in these projects.

Students from classrooms across the North American continent share observations with each other on the changes in spring and the appearance of a variety of animals: bald eagles, monarch butterflies, sea turtles, songbirds, peregrine falcons, caribou and loons. Scientists have fit some animals with electronic tracking devices that transmit location via satellite directly into classrooms using Internet technology. Students are encouraged to develop comparative studies of the natural world in a manner that allows them to think globally while looking locally.

The *Journey North* curriculum is a series of investigations that begin with challenge questions. To explore and address these questions, students must collect authentic data. The research questions are meant to be model questions of the types students should be asking in an inquiry setting (Annenberg/CPB, 2001). The website also provides assessment strategies, inquiry strategies, instructional strategies, reading strategies, lesson plans, and reading and writing connections.

Classroom Feederwatch (1997)

Classroom Feederwatch (*CFW*) was the first citizen science project designed by Cornell Lab of Ornithology specifically for elementary and middle-school classrooms. Students conduct a survey of winter birds that visit a birdfeeder located on the school grounds between November and April. The goals of the project are to collect data about continental bird populations across a large geographic area and to teach participants about birds and ornithological study through involvement in the scientific process. The *CFW* program dovetails with the *Project FeederWatch* monitoring program that was initiated in 1987. Both projects were designed by Cornell Lab of Ornithology in collaboration with the Audubon Society, Bird Studies Canada and the Canadian Nature Federation. The *CFW* curriculum was field-tested during the 1997-1998 school year and published for general distribution in 1999.

The format of the program involves professionals providing instruction in datum collection protocols. Teachers and students put up feeders and learn to identify approximately ten species of birds commonly found in their area. Students collect data about birds seen at feeders. They submit the data via the Internet to Cornell Lab of Ornithology scientists. Students have the option of asking their own research questions, analyzing data and reporting findings in the nationally published newsletter, *Classroom Birdscope*. Through project participation it was hoped that students would develop content knowledge about birds, learn about the iterative nature of scientific research, experience the importance of accurate communication of data and findings, and learn the basics of data analyses (Bonney & Dhondt, 1997).

Studies conducted by Deborah Trumbull and her colleagues (2005) reveal that student's understanding of inquiry and their ability to plan and conduct inquiry showed little increase after participation in *Classroom Feederwatch*. Several suggestions were made for possible curriculum revisions. First, it was suggested that the inquiry dimensions of the curriculum be more aligned to the practices reflected in the work of scientists within the discipline of ornithology. Second, the curriculum needed to scaffold the inquiry process for students. Students needed specific help in making the transition from science as a body of knowledge to science as an inquiry process. Third, students and teachers needed models that showed how scientists link content (birds) to inquiry (bird studies) because teacher and student underdeveloped content knowledge restricted inquiry (Trumbull, Bonney, & Grudens-Schuck, 2005).

PathFinder Science (1997)

PathFinder Science was established in 1997 by the Kansas Collaborative Research Network (KCAN) with funding from the US Department of Education and a Technology Innovation Challenge Grant. The website and projects were initiated in August of 2002 (http://pathfinderscience.net). Most *PathFinder* citizen science projects are scientist developed; however, several new projects have been suggested by participating teachers. The scientist establishes the protocols for datum collection while students collect data and submit the information on-line. Students have the opportunity to analyze their own data and submit online research reports. On-line background information is provided for all projects. The following are general project descriptions provided by *PathFinder Science* as of spring 2006:

- Water conservation- water usage patterns,
- Tardigrades- species diversity and distribution patterns,
- Kansas winter bird survey- a Midwest survey of winter birds visiting school and home feeders,
- Ozone monitoring- using ecobadges and milkweed plants to measure ground level ozone levels,
- Ultraviolet light concentrations- reporting levels of ultraviolet light,
- Global warming- tracking changes in carbon dioxide levels by counting stomata of leaves,

- Lichen density and diversity in response to sulfur dioxide concentrations,
- Stream monitoring- chemical, biological and visual surveys,
- Amphibian biomonitoring – effects of environmental pollutants on amphibian populations,
- Particulate monitoring – measuring amounts of particulate matter in the atmosphere.

Classroom BirdWatch (2006)

Classroom BirdWatch (*CBW*) is an inquiry-based, interdisciplinary science curriculum for elementary and middle school students developed by educators at the Cornell Lab of Ornithology in consultation with curriculum experts at the Lawrence Hall of Science. The curriculum was designed to engage students in scientific inquiry by observing birds, asking questions about birds based on their observations, gathering data about birds to answer those questions, submitting count data to the *eBird* database and sharing their findings through a student research journal called *Classroom Birdscope*. *CBW* is designed as a supplemental curriculum with the main goal of developing student abilities to understand and conduct scientific inquiry. A secondary goal is for students to gain an understanding of the overarching biological concepts associated with animal behavior, ecology, adaptations, and diversity.

Participating in this project, students become citizen scientists. They make important contributions to science by collecting data about their local bird populations and sending the information to the scientists at the Cornell Lab of Ornithology who study bird populations and develop bird conservation programs. The *CBW* bird count protocols and datum submission procedures are based on the *eBird* citizen science project. *eBird* allows the user access to a historical, long-term database of bird distribution patterns across North America. Databases can provide a rich, complex set of information from which students can use highly complex reasoning skills in data analyses and interpretation and development of theories (Chinn & Malhotra, 2002). Normally, databases do not involve students in designing research studies, however, by combining *eBird* (a database) and *CBW* (an inquiry-based curriculum), educators at Cornell Lab of Ornithology hope to engage students in a variety of aspects of data analyses, interpretation, and theory development as well as designing research studies.

The *CBW* curriculum consists of four units, each with five Explorations. As teachers and students work through the curriculum, science process skills are introduced and refined, first through guided inquiry, and later through independent inquiry. Supplemental materials supporting the Explorations include a resource guide, student journal, classroom materials and the *CBW* website. The themes of the units are:

- Unit 1- Identifying and counting birds and submitting count data to the *eBird* database via the Internet
- Unit 2- Understanding bird biology, especially how birds survive and reproduce
- Unit 3- Conducting guided inquiry as students and teachers engage in the critical aspects of the scientific process
- Unit 4- Conducting authentic inquiry as students draw evidence-based conclusions about the questions they have asked

An overview of the entire curriculum is provided in Table 2.

Table 2. Overview of *CBW* curriculum

UNIT 1: IDENTIFYING AND STUDYING BIRDS				
1. What Is That Sound? Starting with a Mystery Sound, students are introduced to the world of birds, focusing on how birds use sound to communicate.	**2. Schoolyard Silhouettes** Students practice identifying, counting, and recording the kinds of birds they see on an outdoor walk. Data will be entered into the *eBird* database later in the unit.	**3. Become a Bird Expert** Students will begin to learn how to identify birds and receive a flashcard bird on which they will focus throughout the lessons.	**4. Field Guide Fun** Students explore the use of field guides.	**5. Students as Citizen Scientists: Entering Count Data into *eBird*** *By entering their previous count data, students become citizen scientists.*
Classroom BirdWatching! *Students are invited to conduct regular stationary or traveling counts and enter their data into the eBird database.*				
UNIT 2: GAINING AN UNDERSTANDING OF BIRD BIOLOGY				
6. What Do Birds Need to Survive? Identify basic needs for bird survival, and discover how your schoolyard habitat does (or does not!) provide for these needs. Describe a bird's adaptations to its habitat.	**7. Bird Reproduction** Through a game, discover the challenges that birds face in order to successfully reproduce. Explore the breeding characteristics of your Flashcard Bird.	**8. Bird Migration** Explore the costs and benefits of migration. Discover migratory pathways for selected bird species, and then for your Flashcard Bird.	**9. Bird Life Cycles** Explore the importance of migration, molting, and breeding within a bird's annual life cycle.	**10. Building Consensus about a Bird Issue** Learn about an environmental issue that currently affects birds. Through role-play and research, come to a class consensus on what action(s) should be taken to help resolve the problem.
UNIT 3: THE SCIENTIFIC PROCESS: INVESTIGATING DATA AND DRAWING CONCLUSIONS				
11. How Do Scientists Study Animals? Learn about the scientific method as you discover some of the questions Lab scientists have about animals and the methods they use to answer those questions.	**12. Interpreting Data** Create line, bar, and pie graphs to help visualize sample data and classroom data.	**13. Kristin's Hypothesis** Examine data and generate tentative explanations for the patterns you see.	**14. What's in a Report?** Discover the important aspects of a scientific research paper as you read a previously submitted student report.	**15. The Methodology of Methods** Gain an understanding of the importance of methods within a scientific study.
UNIT 4: AUTHENTIC INQUIRY				
16. Fair Test Learn about designing an experiment and why controlling variables is important.	**17. What Kind of Question Is That?** Discover how various kinds of scientific questions can be answered through different methods.	**18. Planning My Study** Design an original project in order to answer a question that interests you. Create and implement a plan for data/information gathering.	**19. Preparing a Report** Prepare a scientific report of your work. Organize your data in tables and graphs, and analyze or draw conclusions about the data. Participate in a peer review process. Revise your report.	**20. Presenting My Project** Present your project as a poster, article for a newsletter, or oral presentation. Submit your work to the Cornell Lab of Ornithology.

The *CBW* curriculum has six major student learning goals: 1) science content, 2) science process skills, 3) communication skills, 4) collaboration, 5) effective use of technology, and 6) citizenship. Students have the opportunity to learn science content related to bird morphology, behavior, song and its function, flight, migration, reproduction, habitats, ecology and conservation. The science process skills emphasized in the curriculum are forming hypotheses, learning to observe, collecting and recording data, analyzing and interpreting data, and drawing conclusions. Students communicate information in a variety of ways by sharing their findings with other students and scientists at Cornell Lab of Ornithology through the student research journal, *Classroom Birdscope*. Presentations also may include oral reports and poster sessions. As students collaborate with their peers and scientists at Cornell Lab of Ornithology, they learn the importance of sharing data with others and building on past research. Through the *CBW* and *eBird* Websites, students gain direct experience with a practical application of computer technology and telecommunications. Participation in *CBW* helps students gain a sense of personal community identity. They become aware of conservation issues and learn how to become environmental advocates.

Development of CBW curriculum

In July of 2003, draft plans and outlines for the *CBW* curriculum were reviewed by Lawrence Hall of Science staff, the *CBW* advisory board, and pilot-test teachers. Master classroom teachers pilot tested various *eBird* datum collection protocols that students might use to count birds in and around their schoolyards. The *eBird* website was reviewed to discuss how it should be modified for use with *CBW*. The curriculum was significantly modified to better align with perceived student interests and abilities and to allow for more flexibility.

By April of 2004, draft plans for several Explorations were reviewed by staff at the Lawrence Hall of Science, advisory board members and pilot test teachers. Throughout the writing and revision process a great deal of discussion took place regarding levels of inquiry. Each individual Exploration was designed with an eye on developing many of the skills and habits of mind required to eventually conduct full independent inquiry.

During June of 2004 several Ithaca-area schools pilot-tested five Exploration lessons from unit one of the *CBW* curriculum as well as the corresponding student journal pages and resource guide materials. By September 2004, five draft Explorations for unit two were complete. Both units one and two were pilot tested with teachers in nine classrooms (4 in Ithaca, NY and 5 in St. Louis, Missouri). During this pilot-testing period, members of the curriculum development team observed each of the lessons being taught several times in both locations. Classroom observations focused on changes and additions that teachers made to the lesson as well as a general overall impression about how the lessons were received by students. Teachers also provided written feedback and comments on the lessons. Units one and two were further revised after this pilot study period in readiness for field testing during the 2005-2006 school year.

A second advisory board meeting was conducted in January of 2005 with the purpose of gathering additional feedback on units one and two as well as discussing a detailed outline of the Explorations planned for units three and four.

Fourth through eighth grade teachers were targeted to field test the *CBW* curriculum materials. All applications were due to the Cornell Lab of Ornithology by June 15, 2005. All types of teachers were invited to participate including new teachers, those with little experience with birds, those from schools with a high percentage of minority students and/or those with a high percentage of students who received free/reduced lunch. Those teachers selected to participate received free curriculum and support materials (including a bird identification CD-Rom and bird flashcards), a complementary subscription to *Birds of North American* online (a $40 value), the Cornell Lab of Ornithology home study course manual and optional online course (a $300 value), free Cornell Lab of Ornithology membership which included a one-year subscription to *Living Bird* magazine and *BirdScope* newsletter (a $40 value), as well as collaboration with Cornell Lab of Ornithology educators and scientists. Classrooms chosen as field-test sites were those that demonstrated a diversity of teaching and learning styles and a variety of student socioeconomic backgrounds.

Inquiry and Cognitive Processes

Engaging students with inquiry-based science activities is one way to address a main goal of science education: to help students learn to reason scientifically (AAAS, 1993; NRC, 1996). The *National Science Standards* (AAAS, 1990; NRC, 1996) drives the development of science curricula and current pedagogical practices utilized in science instruction. These documents take the stance that “scientists’ science” is the authentic inquiry science upon which school-science should be modeled. By “scientists’ science” I mean the science that scientists engage in as they investigate natural phenomena. The “scientists’ science” is reflected in the national goals related to inquiry learning for fifth through eighth grades:

- “Identify questions that can be answered through scientific investigations,
- Design and conduct a scientific investigation,
- Use appropriate tools and techniques to gather, analyze, and interpret data,
- Develop descriptions, explanations, predictions, and models using evidence,
- Think critically and logically to make the relationships between evidence and explanations” (NRC, 1996, p. 145).

Chinn and Malhotra (2002) present a theoretical framework for evaluating inquiry tasks in terms of how similar they are to authentic science. Three types of inquiry tasks were evaluated by these researchers: 1) authentic scientific inquiry as practiced by research scientists, 2) middle-school and upper-elementary-school science textbook inquiry activities, and 3) student science inquiry tasks developed by researchers in the fields of education and psychology. One purpose of this study is to examine where citizen science participation may fit within this framework of inquiry tasks.

Chinn and Malhotra (2002) argue that reasoning tasks related to the cognitive processes associated with school science are qualitatively different from the reasoning tasks associated with the cognitive processes needed to engage in authentic scientific research. The simple inquiry tasks associated with school textbook science are presented at one end of the inquiry continuum while authentic scientific inquiry falls on the opposite end of the continuum. “Simple inquiry tasks incorporate few, if any, features of authentic scientific inquiry” (Chinn & Malhotra, 2002, p. 178). For Chinn and Malhotra, doing science means engaging in practices defined and accepted by the larger scientific culture. Whereas the actions of the student-scientists are passive; while conducting simple inquiry tasks students resort to following a series of prescribed steps.

Chinn and Malhotra (2002) found that science inquiry tasks designed by researchers in the field of education and psychology were focused on a fairly narrow bandwidth of epistemological features related to generating and interpreting data. For example, students did not decide what kind of data to collect; therefore, they were unlikely to engage in epistemological considerations of what kind of data would be appropriate for a particular question. Students were not responsible for organizing and analyzing data; therefore, they were not likely to consider connections between evidence and explanations.

Simple inquiry tasks are divided by Chinn and Malhotra (2002) into three types: 1) simple experiments, 2) simple observations, and 3) simple illustrations. In simple experiments, students conduct a straightforward experiment while evaluating the effects of a single independent variable on a single dependent variable. For example, students investigate what types of birds (single dependent variable) prefer different types of bird seed (single independent variable).

In simple observation inquiry tasks, students carefully observe and describe objects. For example, students observe birds that gather at the bird feeder and record species counts. The observational data are collected and then entered into the *eBird* database.

During simple illustration inquiry tasks, students follow a specified procedure and observe the outcome. This type of experiment serves to illustrate a principle that is clearly stated a priori in the student textbook (Chinn & Malhotra, 2002). For example, curriculum materials might describe the principle between bird feet shape and bird habitat preference and then stipulate steps in an activity that will illustrate the stated principle. Although not found in the *CBW* curriculum, the nature of this activity would represent a simple illustration type of inquiry.

Authentic scientific inquiry refers to the type of research that scientists actually conduct. Authentic scientific inquiry is a complex activity where typically expensive equipment and/or highly specialized expertise are required. Elaborate procedures and theories are employed as well as advanced techniques for data analyses and modeling (Dunbar, 1995; Galison, 1997; Giere, 1988). For most school settings, limitations of space, time, money, and expertise prevent the implementation of these complex types of science inquiries. Instead, educators must develop science inquiry tasks that are more manageable in the school setting yet still capture the cognitive processes and the reasoning tasks associated with authentic science inquiry. Students need to directly experience a broad notion of scientific research to have an alternative model of scientific inquiry against which they can recognize their own shortcomings in their current understanding of what it means to do science (Moss, Abrams, & Kull, 1998). Can participation in citizen science provide the type of direct experiences needed to scaffold the development of student scientific cognitive processes?

Cognitive Processes and Associated Reasoning Tasks

Chinn and Malhtora (2002) describe six fundamental cognitive processes that scientists engage in when they conduct research: 1) generating a research question, 2) designing a study to address the research question, 3) making observations, 4) explaining results, 5) developing theories, and 6) studying others' research.

Generating a Research Question

During simple inquiry tasks students are provided with a research question by their teacher or by specific curricular materials. In authentic scientific inquiry, scientists develop their own research question based on observations or an analysis of other scientists' work. Students need to experience the types of science activities where they are guided by questions to seek information as evidence for explanations that may not already be known (Kuhn & Dean, Jr., 2005). This would be the opposite of traditional verification-type laboratory exercises that have been commonly used as science class activities. Developing research questions is an important part of scientific inquiry because it organizes and gives meaning to the inquiry (Lehrer, Schauble, & Petrosino, 2001). When students are given the opportunity to decide on phenomena to investigate and research questions to answer they demonstrate more interest and enhanced motivations (McGinn & Roth, 1999). Their investigations often go beyond the subject matter specified by the prescribed curriculum (McGinn & Roth, 1999). Table 3 provides an overview of the *generating research question* differences between simple inquiry and authentic scientific inquiry.

Table 3. Generating Research Questions

Simple Inquiry	Authentic Scientific Inquiry
Research questions provided to students by teacher or instructional materials	Develop own questions based on observation, curiosity and/or other scientists' work

Designing a Study

Selecting variables and planning procedures are important components of experimental design. During simple inquiry tasks, students often follow a series of prescribed steps. A single independent and dependent variable are usually pre-defined by someone other than the student. There are typically no explicitly stated controlled conditions during these types of activities, students simply follow steps as accurately as possible. When students don't decide on the type of data to collect they are unlikely to engage in the types of thinking and reasoning that are required to grapple with what types of data would be appropriate for a particular question.

During authentic scientific inquiry, procedures are usually very complex and scientists determine dependent, independent and controlled variables. Scientists employ complex reasoning in selecting multiple controlled variables based on causal models of processes being tested. They may also utilize external controls to verify that procedures and equipment are operating as intended. Scientists often measure many different variables including intervening variables and multiple outcome measures (Chinn & Malhotra, 2002). Table 4 provides an overview of the *designing a study* differences between simple inquiry and authentic scientific inquiry.

Table 4. Designing a Study

Simple Inquiry	Authentic Scientific Inquiry
Simple prescribed steps	Complex procedure developed by scientist
• Paired independent and dependent variables provided • Single prescribed control variable	• Multiple variables selected by scientist • Multiple controlled variables based on causal models
No external controls	External controls for equipment or procedure verification
• Single prescribed outcome measure • Observing prescribed features	Intervening and multiple outcome measures

Making Observations

Scientists' own personal interests and life experiences influence the way their research evolves (McGinn & Roth, 1999). During authentic science, scientists often use special methods to guard against perceptual bias when making observations (Chinn & Malhotra, 2002). For example, ornithologists will often use electronic equipment to record bird sounds that can be used to substantiate what the scientists believe they have seen and/or heard in the field (Gallagher, 2005). Issues of guarding against perceptual bias are seldom represented in simple inquiry science.

The accepted historical, philosophical and sociological view of datum collection is that data are collected with a knowledge claim in mind (Leach, 1998). Students typically have different views that reflect datum collection in experiments as disconnected from the theoretical basis from with they work. "Rather than evaluating knowledge claims and data, the purpose of experimental work is often reconceptualised as a process of description through careful data collection" (Leach, 1998, p. 58). Table 5 provides an overview of the difference between simple inquiry and authentic scientific inquiry with regard to *making observations*.

Table 5. Making Observations

Simple Inquiry	Authentic Scientific Inquiry
Perceptual bias not considered	Techniques employed to guard against perceptual bias
• Data collected to describe something • Data collected with no knowledge claim in mind	Data collected with knowledge claim in mind

Explaining Results

There are several important aspects of explaining results: 1) transforming observations, 2) finding flaws, 3) indirect reasoning, 4) generalizations, and 5) types of reasoning. During simple inquiry tasks, raw observations are reported (and in rare instances graphed) but extensive datum transformation is lacking. Students engaged in simple science tasks rarely are responsible for organizing and analyzing their data. As a result, students are unlikely to consider connections between evidence and explanations. For example, a textbook would tell students what kind of data to collect, how to collect the data and then provide a table template for students to record data as well as the specific type of graph needed to visualize the data.

Even though students may recognize experimental error they often take a very unscientific approach to responding to errors. For example, when students get unexpected results they presume the results are from faulty execution of procedures or interpretation of data (Richmond & Kurth, 1999) instead of the possibility that their hypothesis may not be supported (Chinn & Malhotra, 2002) or a simple reflection of the uncertainty that is a natural part of the research process (Richmond & Kurth, 1999). When they get expected results, students often do not consider the possibility that their procedures may be flawed (Chinn & Malhotra, 2002). A simple student error analysis might be, "I did not follow the steps correctly".

In authentic scientific inquiry, raw data usually undergo repeated rounds of datum transformation into other data format ultimately ending in some type of statistical procedure. Scientists spend a considerable amount of time taking into account possible errors in methods, data analyses and interpretation.

Direct and simple contrastive causal reasoning as well as straightforward generalizations are often associated with simple inquiry tasks while indirect and a broad array of complex reasoning tasks are employed in authentic scientific inquiry. During simple science experiments and observations, manipulated variables are the same as theoretical variables of interest leading to direct types of reasoning. During simple inquiry illustrations, observations and theoretical conclusions may be different; however, the text providing the inquiry task often defines this for students instead of encouraging students to reason in an indirect manner. For example, more sparrows visited the bird feeder so sparrows prefer the seed provided and other birds do not. During simple inquiry, students are rarely encouraged to generalize to other situations.

On the other hand, during authentic scientific inquiry, the variables that are measured are often not the same as the theoretical variables of interest. Scientists usually follow a complex chain of indirect inferences to connect the manipulated variable to the theoretical variable before arriving at a conclusion. Scientists also employ a board array of diverse reasoning strategies such as postulating alternative and unobservable mechanisms that might explain results. They may consider flaws in methods, analysis or inferences as well as look for ways to verify the validity of new methods. Scientists determine generalizability based on the experimental situation (Chinn & Malhotra, 2002). Table 6 provides an overview of the differences between *explaining results* reasoning tasks associated with simple inquiry and authentic scientific inquiry.

Table 6. Explaining Results

Simple Inquiry	Authentic Scientific Inquiry
Simple (graphing/drawing) or no data transformation	Data transformed into other data formats
Simple error analysis	Consideration of errors in methods, data analysis & interpretation
Direct reasoning	Indirect reasoning (manipulated variable different from theoretical variable)
Simple contrastive, inductive or deductive reasoning	Complex and multiple reasoning strategies
No generalizations to new situations	Generalizations considered based on experimental design

Developing Theories

Directly observing empirical phenomena to gather facts about the natural world is usually the focus of simple inquiry. There is little concern with constructing underlying theory or performing multiple studies on the same topic. If theoretical explanations are a part of the investigation, they are usually presented by the teacher or the text. Students rarely are provided with the experience to construct theoretical explanations on the basis of evidence. Simple inquiry tasks are often used to help the teacher explain the theory under study. On the other hand, authentic science inquiry is concerned with developing or revising theoretical models. Scientists coordinate results from many different types of studies by developing interpretive strategies for coordinating those results and resolving inconsistencies (Chinn & Malhotra, 2002). Table 7 provides an overview of the different *developing theories* reasoning tasks associated with simple inquiry and authentic scientific inquiry.

Table 7. Developing Theories

Simple Inquiry	Authentic Scientific Inquiry
• Direct observation of empirical phenomena • Direct observation illustrating theoretical mechanism	Construct theoretical explanations based on evidence
Multiple studies not considered	Coordinate results from multiple studies to develop theory

Studying Others' Research

An important part of the life of a scientific researcher is studying the work of other researchers. This review of the work being conducted in the field is important not only as background information but also to inform and direct all of the other cognitive processes stated previously. Scientists read research literature for a variety of reasons: 1) to learn about standard protocols for collection of certain types of data, 2) to learn about what variables need to be controlled and measured, and 3) to determine how to ground their research in the theoretical and empirical work of other scientists (Chinn & Malhotra, 2002). Before scientists can publish their research findings their work must be scrutinized by a complex method of peer review. In simple inquiry, students rarely read and study ‘expert’ research reports nor does their science inquiry work pass through a peer review process. Table 8 provides an overview of the different *studying others’ research* reasoning tasks associated with simple inquiry and authentic scientific inquiry.

Table 8. Studying Others’ Research

Simple Inquiry	Authentic Scientific Inquiry
Does not study research of others	Study research of others to inform practice
No peer review of findings	Peer review of findings

Based on this body of literature, Table 9 describes the initial coding that was used in the qualitative analyses of the data collected during this study.

Table 9. Cognitive Processes Coding

Cognitive Processes	Simple Science	Authentic Science
Generating Research Questions	▪ Questions provided by teacher ▪ Questions provided by curriculum	▪ Develop own questions based on observations ▪ Develop own questions based on others’ work ▪ Develop own questions based on curiosity
Designing a Study	▪ Single pre-defined independent and dependent variable ▪ Observing prescribed features ▪ No controlled condition ▪ Single controlled condition ▪ Single prescribed outcome measure ▪ Prescribed steps	▪ Variable determined by researcher ▪ Controls selected based on causal models ▪ Multiple controlled situations ▪ Critical reflection on methods ▪ External controls verifying procedures or equipment ▪ Intervening and multiple outcomes ▪ Steps designed by researcher

Making Observations	▪ Making measurements	▪ Technique to guard against perceptual bias
Explaining Results	▪ Data transformation, drawing ▪ Data transformation, graphing ▪ No data transformation ▪ Simple error analysis ▪ Direct reasoning (straight forward inference) ▪ Indirect reasoning defined by text ▪ Manipulated variables same as theoretical variables ▪ Simple contrastive or causal reasoning ▪ Simple inductive reasoning ▪ Simple deductive reasoning	▪ Data transformation, statistics ▪ Data transformation, other ▪ Complex error analysis (methodological flaws) ▪ Indirect reasoning ▪ Complex chain of inferences ▪ Manipulated variables different from theoretical variables ▪ Complex reasoning, responses to anomalous data: ❖ consider alternative mechanism to explain results ❖ ignore, reject or express uncertainty about data ▪ Complex reasoning, consider ways to verify validity of new methods ▪ Generalizations to new situations
Developing Theories	▪ Direct observations not connected to theory ▪ Direct observations illustrating stated theory	▪ Construct theories based on evidence ▪ Study at level of observable regularity ▪ Coordinate results from multiple studies ▪ Strategies to resolve inconsistencies in multiple studies
Studying Others' Research	▪ Reading about topic in science tradebooks	▪ Reading research of others ▪ Building on work of others ▪ Peer review of findings

Cognitive Processes and Science Education

Chinn and Malhotra (2002) found that science textbook inquiry tasks failed to incorporate elements of authentic scientific reasoning. No textbook activities allowed students to generate their own research question. In only 2% of the textbook activities were students allowed to select their own variables to investigate and only 4% of textbook activities asked students to consider how to control variables in simple ways. About 17% of the textbook tasks incorporated multiple observations. There was very little transformation of data (2%), no explicit concern with possible bias in observations, and little concern with experimental flaws (2%). No textbook tasks required students to develop theories about mechanisms and they rarely asked students to conduct multiple studies (2%). Students using textbook tasks never read real research reports. The inquiry activities in the set of textbooks evaluated captured few if any of the cognitive processes of authentic science.

Students in the pre-adolescent age range have been shown to develop science inquiry skills if they are provided with sustained engagement with situations that require the use of inquiry skills over extended periods of time (Kuhn & Dean, Jr., 2005). In classrooms modeled after authentic science, students would pursue investigations of their own interests, negotiate with their collaborating peers as to problems and solutions, and debate the merits of different processes for seeking solutions. Student action and products would be accountable to themselves, their peers and their teachers. The classroom would be organized as knowledge-producing communities in which knowledge is co-constructed among members (McGinn & Roth, 1999).

As part of an apprenticeship program, high school students came to see science as a cumulative body of work with ideas building upon each other across scientific communities (Richmond & Kurth, 1999). Before the apprenticeship experience, students described scientific research as short-term in which significant data were obtained by the end of each day's work in the lab. The immersed and authentic engagement of each apprentice was seen as important in helping them to develop more accurate understandings of science and the generation of scientific knowledge. Through the apprenticeship, students were provided access to the diverse 'tools' (scientific discourse, inquiry practices, cognitive processes and equipment usage) associated with the scientific community as well as multiple opportunities for informal feedback about their appropriate use. As the apprentice moved from the periphery of the scientific community toward the center, their ideas about what it meant to do science grew more complex, more realistic and richer (Richmond & Kurth, 1999).

Authentic Science and Student Engagement

The general approach of mapping the practice of scientists to the classroom has been argued from a variety of view points by several researchers (Barton, 1998; McGinn & Roth, 1999; Rahm, Miller, Hartley, & Moore, 2003). The argument is made that authentic science would be the science that becomes meaningful when it is seen within the context of student lives as opposed to the translocation of the ways that scientists do science. According to this alternative view, authentic science emerges from, and is negotiated within a complex system that includes the social, historical, political and physical contexts of the lives of all partners (Barton, 1998).

An authentic science progression is partially defined by Moss, Abrams, and Kull (1998) as a partnership between the scientific research community and the students and teachers in schools. However, simply having students do what scientists do does not guarantee that science is authentic to youth (Radinsky, Bouillion, Lento, & Gomez, 2001). For authenticity from the perspective of the student, science should be grounded in the students' daily experiences rather than the scientists' science. Authentic science is emergent and a product of negotiation and renegotiation, depending on the interaction of the partners over time (Rahm, Miller, Hartley, & Moore, 2003). An emergent authentic science evolves through collaborations and ongoing negotiations among the participants involved in a partnership. For students, citizen science becomes like authentic science when students are able to think, act and feel like real scientists.

Rahm, Miller, Harley & Moore (2003) suggest two characteristics of a type of science experience that would lead to an emergent notion of authentic science: 1) students, teachers and scientists having sustained involvement and experiences over time, as well as 2) each group experiencing a sense of ownership. Depending on the citizen science project, both of these may be possible for students. Citizen science partnerships may offer opportunities for student engagement in authentic practices as part of a real community. For authenticity to emerge from this type of participation, however, student participants would need to attribute meaningfulness and value to the promoted practices in such a way as to readily take up the emerging authentic science as presented. Given this frame-of-reference, I examined student engagement in light of four components: 1) sense of autonomy, 2) competence, 3) relatedness, and 4) intrinsic motivation.

Student Engagement

The self-determination theory of student motivation is described around the basic psychological needs for autonomy, competence and relatedness (Vansteenkiste, Lens, & Deci, 2006). Further, different qualities of student engagement are related to different types of motivation. Intrinsic motivation is directly linked to satisfaction of these same psychological needs (Vansteenkiste, Lens, & Deci, 2006); therefore, student engagement in this study will be defined by the following: 1) sense of autonomy, 2) competence, 3) relatedness, and 4) intrinsic motivation. The remainder of this section on student engagement will describe each of these components of student engagement as well as provide sample statements from a student survey designed to assess student engagement during citizen science participation.

Autonomy

Hands-on science inquiry requires a shift in student roles from passive recipient of information to constructivist participant in the creation of learning (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Zion & Slezak, 2005). As students engage in this active type of science learning, they carry more responsibility for their own learning and for decision making during the learning process. Students develop a greater sense of autonomy when they shoulder responsibility for their own learning and are given the opportunities to make choices and solve their own problems as part of their learning experience. Survey statements such as, "I felt I was responsible for my own learning" and "I was able to make choices about my learning" were used to determine autonomy. Autonomous engagement involves the "experience of volition and choice" (Vansteenkiste, Lens, &

Deci, 2006, p. 19). Students experience a sense of autonomy when they identify with the value of an academic task or activity, see personal relevance in the task and identify with the importance of the task or activity. Survey statements such as, “I felt like my decisions were important” and “I had to solve my own problems” were also used to determine a sense of autonomy during citizen science participation.

When student involvement in simple science activities is limited to predetermined procedures and established protocols, the scope of the activity is limited for students. If students are engaged in only simple inquiry activities their ability to be autonomous and engage in meaningful ways with the cognitive processes associated with authentic scientific inquiry may also be limited. For example, if inquiry questions and procedures are generated by students and not solely by the teacher or curriculum then a sense of autonomy for students is deepened.

Students should be encouraged to explore related areas that are of interest to them (Moss, Abrams, & Kull, 1998). In describing student engagement in SSPs, Moss, Abrams and Kull (1998) suggest that “if students could experience a broader notion of research including formulating questions and analyzing data, perhaps they would be more excited about the research itself, and ultimately feel a greater sense of partnership in the SSP” (Moss, Abrams, & Kull, 1998, p. 160).

Students need to feel they are responsible for their own learning and that they are making important choices and decisions as a part of learning. Michael Padilla, NSTA President 2005-2006, defines inquiry as “the ability to think like a scientist; to identify critical questions to study; to carry out complicated procedures; to eliminate all possibilities except the one under study; to discuss share, and argue with colleagues; and to adjust what you know based on that social interaction" (Padilla, 2006, p. 5). For autonomous engagement, students should be given the opportunity to ask their own research questions, design their own research procedures based on those questions, as well as make important decisions about what data are important. They should be challenged to formulate their own explanations based on their data and then communicate as well as justify those explanations before their peers. Vansteenkiste, Simons, Lens, Soenens, Matos, and Lacante (2004) describe the following autonomy-supporting conditions: 1) students solving their own problems, 2) student initiating a task, 3) students choosing what to do and how to do it, and 4) students enjoying the task.

Competence

Student engagement in academic tasks becomes more purposeful as students develop competence by mastering content or skills. Engagement varies as student expectancy for being able to complete the task successfully (given appropriate effort) also varies (Brophy, 2004). Students develop competence when they are given the opportunity to make active responses to other learners and manipulate materials. Survey statements such as, "I liked *CBW* because I like doing science instead of reading about science" and "I feel like I did a good job of observing, identifying and counting birds" were utilized to analyze competence during citizen science.

Task authenticity is also a part of competence (Brophy, 2004). Authentic tasks require using what is being learned for a type of life application that justifies the inclusion of the task in the curriculum in the first place. Two survey statements point toward task authenticity, “I thought like a real scientist during *CBW*” and “Being a part of *CBW* has caused me to think about a future career in science”.

McGinn and Roth (1999) describe a ‘critically engaged citizenship’ as the point where participants view science and scientists in a new light. The type of critically engaged community of citizens where science is created and used provides a foundation for competent participation. Could citizen science participation by students be a type of ‘critically engaged citizenship’ where students gain a foundation of competence?

Relatedness

Schoolwork rarely challenges students to use their minds beyond rote memorization tasks and too often carries no intrinsic value or meaning beyond success in a school context (Newmann & Wehlage, 1993). Student apprenticeships with scientists have been described as one way to help students understand the practice of science, see science as useful and interesting, and see themselves as capable science learners and contributing members of a scientific community (Richmond & Kurth, 1999). This type of relatedness is an important component of student engagement. Out of a desire to be related to others, individuals are inclined to take on the values, beliefs and behaviors that are endorsed by others. Relatedness may refer to the connectedness between students and scientists at Cornell Lab of Ornithology or it may refer to relatedness between students in the class. A single survey statement was used to analyze relatedness to scientists at Cornell Lab of Ornithology, “Because I was participating in *CBW*, I felt connected to the scientists at Cornell Lab of Ornithology”.

Organizing inquiry learning through student collaborative teams offers learners the opportunity to debate their ideas and reflect on one another's approaches (Zohar, 2000). A community consensus of scientific ideas provides an appropriate analog to authentic scientific research practice (Finley & Pocovi, 2000). Four survey statements were used to characterize relatedness within the peer group: 1) "I think teamwork was important during *CBW*", 2) "I used feedback from others to help me do *CBW* and to understand what I was learning", 3) "My group members and I bounced ideas off of each other during *CBW*" and 4) "Working with my team helped me to be successful during *CBW*".

Students need the opportunity for collaborative learning. Truly collaborative learning (not just cooperative grouping) increases awareness and appreciation for reasons why others engage in the academic task. It also gives students the opportunity to share ideas while receiving feedback. This feedback may be in the form of how to overcome difficulties in the task or possibly to introduce new ways of thinking about the task. In this manner, students scaffold learning for each other. As students work in collaborative groups they may be able to access and build upon collective knowledge. In other words, individually, students may not know very much, but as a collective group they know much more. This collective knowledge may be what is needed to motivate them towards more positive engagement with the topic of study.

Intrinsic Motivation

Intrinsically motivated behaviors are those behaviors for which the reward is the satisfaction associated with the activity itself not necessarily an external reward, in other words, engagement in the activity is for its own sake. Intrinsically motivated students find activities inherently interesting and enjoyable. These activities are performed out of interest and do not require external prods, promises or threats. Survey statements such as, “I was able to be creative”, “*CBW* was fun”, “I was interested in *CBW*, my parents or teacher did not have to force me to participate”, and “I was interested in *CBW* because I was curious about birds” aimed at providing an understanding of student intrinsic motivation during citizen science.

Success at challenging tasks (those described as not too easy or too hard) increases student intrinsic motivation (McCaslin & Good, 1996). Therefore, survey statements such as, “*CBW* was not too easy and not too hard” and “I liked *CBW* because I was good at it” were utilized. Table 13 in chapter 3 of this study outlines the survey statements used to analyze these four components of student engagement.

Confounding Issues Associated with Student Engagement

It is possible that students will engage (or not engage) in the citizen science project for other reasons than the components described above. Some students may engage in the task simply because it is a reprieve from the monotony of the daily instructional routine (Blumenfeld, 1992; Miller & Meece, 1999). Participation in the *eBird* citizen science project may be appealing compared to the possible boring repetitive routine of the regular school day. To expose this possible confounding effect I will use the following statement on the student survey: “Doing *CBW* activities gave me the opportunity to think in different ways from my other school subjects”.

An additional confounding effect may be academic level and the ability to employ metacognitive strategies in learning. Low achieving students may lack the necessary cognitive and metacognitive strategies to become engaged with challenging academic tasks. They may find a more challenging task too difficult and become overwhelmed with the greater expectation (Miller & Meece, 1999); however, Miller (2003) reports on research which demonstrates that the lowest achievers in a third grade class did not view high-challenge academic tasks as overwhelming. Students said they preferred high-challenge tasks because the tasks offered an opportunity to be creative, to experience enjoyment, or to expend effort. Low and average achieving students were also more confident about their abilities to successfully complete the tasks when given the opportunity to engage in more challenging tasks (Miller, 2003).

Finally, engagement may be undermined if students are immersed in a classroom or school climate that emphasizes normative rather than self-referent standards of performance (Miller & Meece, 1999). For optimal student engagement of challenging tasks, the classroom climate needs to be positive, encouraging students to take risks, to be willing to make mistakes and to learn from those mistakes. The classroom community needs to support students listening to each other, respecting the ideas of each other at the same time critically examining and questioning those ideas (and not the idea presenter). The nature of the classroom cannot be competitive.

There is no clear-cut distinction among the four components of student engagement used in this study. The boundaries between them are very nebulous. Competence often underlies intrinsic motivation. Students may simply engage in an activity in order to experience a sense of accomplishment, fulfillment and competence (Vansteenkiste, Lens, & Deci, 2006); however, they may do so only as long as free-choice (autonomy) persists. High intrinsic value often leads to higher autonomous motivation which results in greater persistence both in the short term and in the long term.

For students to internalize the norms, standards, habits of mind, and values that are associated with scientific ways of thinking, these need to be presented in a way that facilitates the students' feelings of autonomy, competence, relatedness and intrinsic motivation with respect to science participation. Satisfaction of these basic psychological needs provides the necessary conditions that allow students the freedom to engage in self-determined activity (Brophy, 2004).

Summary

This literature review began with a historical view of the development of citizen science beginning with environmental volunteer monitoring and continuing with SSPs. A definition of citizen science was provided as well as a description of the potential benefits of citizen science participation. A variety of citizen science projects were described beginning with the *Christmas Bird Count* project started in 1900. As citizen science projects evolved, emphasis was shifted to classroom student participation, therefore, several citizen science projects were described that target the K-12 school population. Development of the *Classroom BirdWatch* curriculum and *eBird* citizen science project was provided as important contextual material for this study.

Reasoning tasks associated with the cognitive processes of both simple inquiry and authentic scientific inquiry were defined and explained. Table 9 presented an outline of the coding categories used in this study to identify reasoning tasks utilized by students during citizen science participation.

Finally, student engagement was defined by four components: 1) a sense of autonomy, 2) competence, 3) relatedness and 4) intrinsic motivation. Each component was defined and sample student survey statements were provided to give the reader an introduction to the student engagement survey data collection instrument. The following chapter, Chapter III, will discuss the methodological considerations for this study.

CHAPTER III

METHODOLOGY

"The farther and more deeply we penetrate into matter, by means of
increasingly powerful methods, the more we are confounded by
the interdependence of its parts" (deChardin, 1965).

The purpose of this study was to examine the ways various stakeholders (*CBW* project developer/coordinator, elementary and middle school teachers, and fifth through eighth grade students) envisioned, implemented and engaged in a citizen science project called *eBird/Classroom BirdWatch* which was developed at the Cornell Lab of Ornithology. To what extent did the tasks associated with the *eBird/CBW* citizen science project incorporate (promote) features of authentic scientific inquiry? How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation? How did students describe the scientific inquiry cognitive processes utilized during their participation in the *eBird/CBW* citizen science project? How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/CBW* citizen science project? In order to answer these research questions, I conducted a study of the implementation of the *eBird* citizen science project coupled with the corresponding *CBW* curriculum. In addition to interviews with the project developer/coordinator and document analysis of the *CBW* curriculum materials, I conducted a multiple-case study of three selected teachers and their fifth, seventh or eighth grade students who participated in the *eBird/CBW* project. This study was an interpretative multiple-case study, employing a mixed-methods approach to data collection and analysis of the cognitive processes associated with scientific inquiry and student engagement. A case study was the preferred strategy for this study because “how” questions were posed about a contemporary set of events over which the investigator had little or no control (Yin, 2003). The strength of using a case study approach was the ability to deal with a full variety of evidence (documents, artifacts, surveys and interviews) in a triangulating fashion.

The main unit for analysis of this case study was the cognitive processes associated with science inquiry with an embedded unit of analysis, student engagement. The broad categories of cognitive processes associated with authentic scientific inquiry were: 1) generating a research question, 2) designing a study to address the research question, 3) making observations, 4) explaining results, 5) developing theories, and 6) studying others’ research (Chinn and Malhtora, 2002). Student engagement was measured by a sense of autonomy, competence, relatedness and intrinsic motivation.

The contextual event surrounding the unit of analysis was participation in citizen science. The multiple cases were a fifth grade class, a seventh grade class, and an eighth grade class. The preliminary supposition related to this topic of study was that participation in the *eBird/CBW* citizen science project would engage students in cognitive processes associated with authentic scientific inquiry and that their engagement would demonstrate a sense of autonomy, competence, relatedness and intrinsic motivation.

This study was a multiple-case study because each school was the subject of an individual case study, while the study as a whole covered several schools. The multiple-case study was employed for two reasons. First, analytic conclusions independently arising from two or more cases are more powerful than those coming from a single case alone allowing the overall study to be more robust (Yin, 2003). Second, the contexts of multiple cases are likely to differ to some extent. For this study, the cases demonstrated different grade levels, school types, geographical locations and student demographics. If, under these varied circumstances, common conclusions are generated, the external generalizability of the findings are greatly expanded (Yin, 2003).

Each case was carefully selected so they would demonstrate similar results allowing for literal replication. During data analyses, each case's conclusions were considered to be the information needing replication by the other individual cases. To address research question #2, the three individual cases were combined to facilitate the quantitative analyses of survey data both within each individual case as well as across cases. Table 10 summarizes the design of the research and plan for data analyses per research questions.

Table 10. Summary of Case Studies Utilized by Research Question

Research Questions	Type of Case Study or Research Design	Data Analyses
1 To what extent did the tasks associated with the *eBird/CWB* citizen science project incorporate (promote) features of authentic scientific inquiry?	Document Analysis Interview	Document Analysis Qualitative
2 How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?	Survey design	All survey data combined
3 How did students describe the scientific inquiry cognitive processes utilized during their participation in the *eBird/CBW* citizen science project?	Multiple Case Study	Individual Cases Across Cases
4 How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/CBW* citizen science project?	Multiple Case Study	Individual Cases Across Cases

The *eBird/CBW* citizen science project was chosen for this study because of the prior history of citizen science implementation by the Cornell Lab of Ornithology. The three schools chosen for this study also had a previous history of success with citizen science participation. Prior to this study, identification of barriers to implementation of citizen science have been reported in the literature (Barstow, 2001; Cohen, 1997; Evans, Abrams, Rock, & Spencer, 2001; Moss, Abrams, & Kull, 1998; Rock, Blackwell, Miller, & Hardison, 1997; Trumbull, Bonney, & Grudens-Schuck, 2005). The focus of this study was not to add to this same body of literature but expand on the potential for a different type of student engagement during citizen science; therefore, school sites and teachers were chosen based on their demonstrated ability to implement citizen science in their regular classroom settings.

A case study protocol was developed to guide this investigation in a standardized manner. The study began with an analysis of the *CBW* curriculum and the accompanying website as well as an interview with the curriculum developer/project coordinator. A qualitative data analysis of documents and information was used to describe the cognitive processes and associated reasoning tasks promoted in the *eBird/CBW* citizen science project.

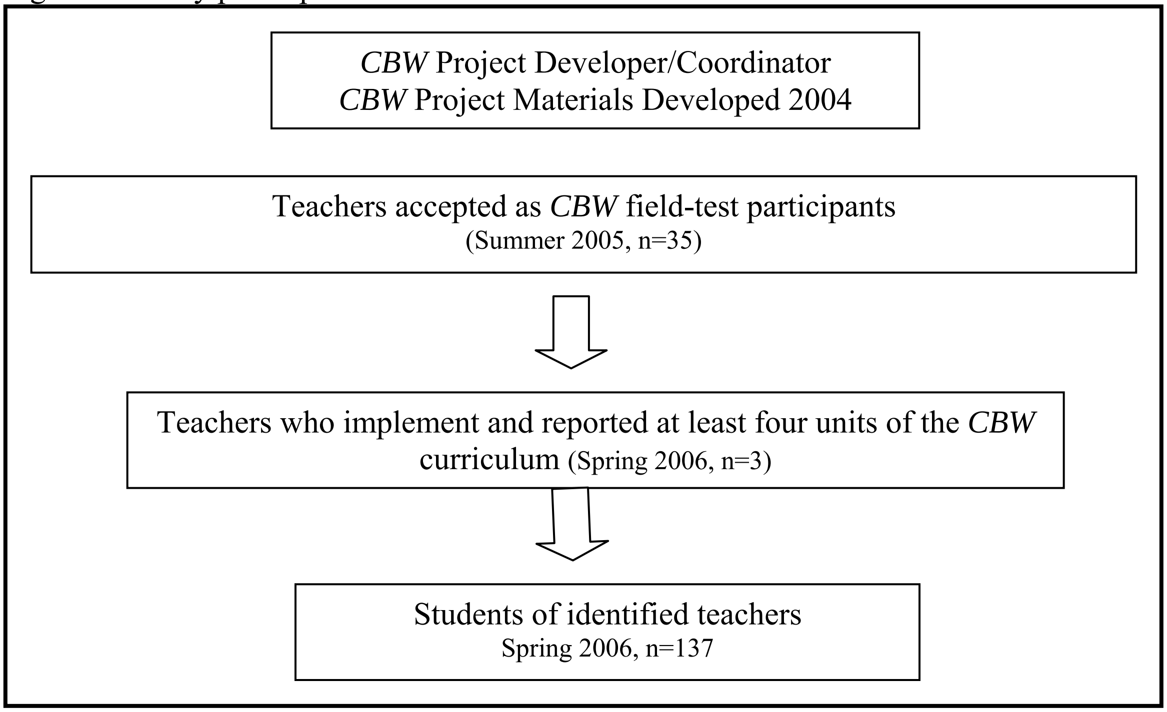
An initial survey was used to identify teachers who had implemented all four units of the *CBW* curriculum to the extent that students were engaged in independent inquiry science practices. Three teachers and their classes were selected to continue with this study. An additional criterion for selection of participants in this study was that these three teachers had a history of strong citizen science participation in previous years.

Qualitative and quantitative data were collected to describe the cognitive processes associated with scientific inquiry that were employed by students as well has student engagement measured by a sense of autonomy, competence, relatedness and intrinsic motivation. The types of qualitative and quantitative data are described in more detail in sub-sections of this chapter.

Participants

Participants in this study included a project developer/coordinator, three classroom teachers, and their students. Figure 3 provides details on the study participants.

Figure 3. Study participants



Project Level

At the project level a single participant, Ms. Smith (pseudonym), was identified based on her involvement in the development of the *CBW* curriculum and implementation of the *eBird* citizen science project utilizing the curriculum. Ms. Smith collaboratively wrote lessons for the *CBW* curriculum with two other Cornell Lab of Ornithology staff members. Ms. Smith took the lead in the writing using feedback from the others to modify the exploration lessons. Ms. Smith was not only involved in the development of the curriculum but she was also the project coordinator during the implementation of the program. Ms. Smith was interviewed to determine the reasoning tasks associated with each of the cognitive processes of scientific inquiry that were intended to be promoted through the *CBW* curriculum.

Teacher Level

Field testing of the *CBW* curriculum occurred during the 2005-2006 school year across North America. Forty-five teachers expressed an interest in field-testing the *CBW* curriculum materials. Thirty-five of the teachers were accepted based on the diverse nature of their classrooms and school settings. The accepted field-test teachers represented fifteen states, had an average of 15 years teaching experience (range 1-33 years), and an average class sizes of 22 students. Most of the teachers were classroom teachers (n=27) with four teachers classifying themselves as science specialists, two teaching only gifted classes and one media specialist. Fourteen of the teachers taught in upper elementary grades (4-5) while twenty teachers taught at the middle school level (6-8). Participating teachers received some 'in-kind' donations like CDs, a copy of the curriculum and Cornell Lab of Ornithology membership. Five of the teachers served on a Teacher Advisory Board for *CBW* curriculum design. The advisory board met twice to discuss curriculum design, revision and implementation. One of the teacher participants from this study served on the Teacher Advisory Board. Twelve of the teachers had previously participated in the Cornell Lab of Ornithology citizen science project *Classroom FeederWatch*. All of the teacher participants from this study had also participated in *Classroom FeederWatch*.

On average, the thirty-five field test teachers rated their bird identification skills as average (3.2) with 1 being novice and 5 being expert. The majority of the teachers described themselves as average (n=13) followed closely by the teachers who described themselves as somewhat above average (n=12). One teacher described herself as a novice. None of the teachers considered themselves experts. Thirty of the thirty-four teachers said they had used some type of bird study in their classrooms prior to *CBW*.

Fifty-six percent of the field test schools were located in rural areas of the country (n=19). Suburban areas were represented by 18% of the schools (n=6) while only four schools were in urban areas (12%).

From the thirty-five teachers who were accepted to field-test the *CBW* curriculum materials, three were chosen for this study. These individuals were selected because they had completed four units in the *CBW* curriculum and had engaged their students in some form of independent inquiry. The teachers taught three different grade levels (fifth, seventh and eighth) in three different states in the Northeastern United States. Two schools were in primarily rural areas while one was in an affluent coastal community. The teachers were not formally trained in the use of the *CBW* curriculum beyond the rudimentary training embedded in the curriculum materials nor did they receive a stipend for participation. Teachers received the curriculum and support materials via the United States Postal Service and the World Wide Web.

Student Level

Participants were fifth, seventh and eighth grade students who were members of the classes taught by the three teachers previously identified. Table 11 displays the demographics for the entire population of student participants. There were a total of 137 student participants: twenty-two fifth graders (16.1%), seventy were seventh graders (51.1%) and forty-five were eighth graders (32.8%). There were seventy-two female (52.6%) and sixty-five male (47.4%) student participants in this study.

Table 11. Student Participant Demographics

	Total Students	**Female**	**Male**
5th grade	22 (16.1%)	12	10
7th grade	70 (51.1%)	36	34
8th grade	45 (32.8%)	24	21
Total	137	72	65

Fifth Grade

Miss Call (pseudonym) taught a self-contained class of fifth graders with an enrollment of twenty-three children (twenty-two students participated in this study). One child in the class was Asian and the remainder of the children were Caucasian with various ethnic backgrounds of Irish, German and Italian. A small percentage of children in the class had learning disabilities. Twelve females and ten males completed independent inquiry projects as part of their regular class work.

The school was a private catholic parochial school located in the Northeastern United States and had a student body of 180 students. There was one class representing every grade level from preschool through eighth grade. The school was located in a small, primarily rural community, with a mix of professional and industrial occupations. The population of the community was approximately 22,000 individuals. The economic status of the area ranged from low to upper class.

At the time of this study, Miss Call had been teaching for a total of twenty-three years with seventeen years at this particular school. She had been teaching fifth grade for ten years. Miss Call holds elementary and early childhood education teaching certifications and a Bachelor of Science degree in early childhood and elementary education. Miss Call rated her bird identification skills at a level of four on a five-point scale (with 5 being expert) or in her own words, “a little bit above average”. She relates, “I can identify more than just the regular bird. I get a lot of people coming in and asking me questions and I can give them information on it. I also bird at home”. Miss Call shared her experience of growing up watching and feeding birds.

There was a bird sanctuary outside of the classroom window that was maintained by the children in her classroom. Binoculars and field guides were always available for getting a close look at the birds as well as checking identifications. The sanctuary was recently renovated by a former student of Miss Call’s as part of an Eagle Scout Project. Miss Call has developed a cross-curricular thematic unit to study birds. Children identify and record information about birds that visit the feeders located in the bird sanctuary. An ongoing project being conducted by the class was to determine the type of food and other materials that were needed in the sanctuary to attract birds and meet their daily needs with the changing seasons. As a class, the students also monitored weather conditions and the affect on birds in the sanctuary.

Miss Call describes her approach to inquiry,

> I develop, for the students, a situation where they are presented with a problem and from that problem figure out what they need to do and

> what tools they will need to help figure out how to answer this problem. In addition, I try to provide insight through research and readings to heighten their curiosity and direct them in ways to help in solving the created problem. The inquiry comes from constantly looking for and asking more questions to gain knowledge, insight, and curiosity. My approach with inquiry is to always have questions and ways to find those answers.

Miss Call has participated with her students in multiple citizen science projects: 1) *Classroom FeederWatch*, 2) *Great Backyard Bird Count*, and 3) *Weather Watching* as well as *Classroom BirdWatch*. She participates in these types of programs for a variety of reasons. Miss Call wants her students to be able to connect with nature in a way that will encourage them to want to preserve the natural environment. She described how students and parents became “fascinated” with birds. “When you get kids involved in something like this [*CBW* citizen science] it helps them to really focus in on the necessity to preserve nature. When kids start to learn to appreciate even something like a bird it will instill in them a sense of preservation of life no matter what”. Miss Call believes that students will find long-term utility in *CBW* participation. “It [Birding] gives them something they can do for the rest of their lives”.

Seventh Grade

Mr. Brown (pseudonym) taught five classes of life science to seventh graders. Seventy of his students participated in this study. Thirty-six were female and 34 were male. Working in pairs, only six student groups completed inquiry projects (n=12). They did so to receive extra credit. As part of an extended day schedule, these students stayed for an additional school period to work on their projects.

The school was a public junior high school located in the Northeastern United States and had a student body of 390 in grades seven and eight. Student body ethnicity was ninety-nine percent Caucasian with less than one percent Hispanic and less than one percent African American. Twenty-five percent of the student body was eligible for the free or reduced-price lunch program. Eighteen percent of students had Individual Education Programs. The population of students in this study was comparable to the population of students in the school. The school is located in a small, primarily rural community. There is a state university located within the same county.

At the time of this study, Mr. Brown had been teaching for a total of eighteen years, seventeen years in his current placement. He holds a Masters of Teaching degree as well as an undergraduate degree in Natural Resources. Mr. Brown rates his bird identification skills at a level of 4.5 on a five-point scale.

There were bird feeders located outside of Mr. Brown's second-story classroom window. Binoculars and a complete set of field guides were always available for getting a close look at the birds as well as checking identifications. Mr. Brown offered extra credit to those students who would conduct independent inquiry projects. The students worked on their projects during an elective period at the end of the school day. Working in pairs, twelve students volunteered to participate in the independent inquiry project.

Mr. Brown has participated with his students in multiple citizen science projects. His classes collaborated with the State Herpetology Connection to conduct a frog and salamander count. They participated with *Classroom FeederWatch* for seven years as well as the *Great Backyard Bird Count*. His overall goal in having his students participate in these citizen science projects was “to get kids to appreciate nature more”. He believes “kids like playing the role of scientist” and as a result of recording data and submitting it to Cornell Lab of Ornithology students learn to “appreciate its worth”, helping them “feel like they are part of the scientific process”. Mr. Brown is attracted to citizen science projects for his students because it is “something different and more meaningful to the kids”.

Eighth Grade

Miss Edwards (pseudonym) taught four classes of eighth graders with an average class size of twenty students (forty-five students participated in this study). Twenty-four of the participating students were female and twenty-one were male.

The school was a public junior high school located in the Northeastern United States and had a student body of 230 students. The school was located in an affluent coastal community. According to Miss Edwards, the student body has “a lot of opportunities… not only in terms of the school support but in terms of family vacations and trips”. There was very little diversity in terms of ethnicity (99% Caucasian) or economic status (< 1% free or reduced lunch).

The school was well-funded by the local school board and community. A community-established foundation holds a million dollar endowment from which teachers can submit annual grant applications for funding. Miss Edwards had been very successful in receiving funding for implementation of her citizen science projects.

At the time of this study, Miss Edwards had been teaching for a total of fourteen years, all at her current placement. She holds an undergraduate degree in Zoology and a

Master's degree in Science Education. She is currently enrolled in a PhD science education program. Miss Edwards rated her bird identification skills at a level of four on a five-point scale or in her own words, "a pretty avid birder".

Over the years, Miss Edwards participated with her students in multiple citizen science projects: 1) *Classroom FeederWatch* (3 years), 2) *Forest Watch* (6 years), and 3) *Pond Probe* (2 years) as well as *Classroom BirdWatch*. Her overall focus with these projects has been ecosystem dynamics over time. She participated in these types of programs for a variety of reasons. Miss Edwards believes student motivation is higher with citizen science. She has noticed a "striking difference with the kids when they have more of their own investment…because their own interests are being pursued". Miss Edwards believes students are more related to their own surroundings during this type of science. While monitoring the health of pine trees in their own town, students "feel like they are doing something that really matters…it is more relevant and hits home better for them". An additional value to the citizen science participation is that students can get "out of the classroom" and have access to different types of scientific tools. Her main goal in *eBird/CBW* participation was for students "to realize that they could come up with questions and really research and come up with the answer themselves and to take part in the process of science so that they get how to solve a question or how to solve a problem rather than me saying first you do this and then you do that".

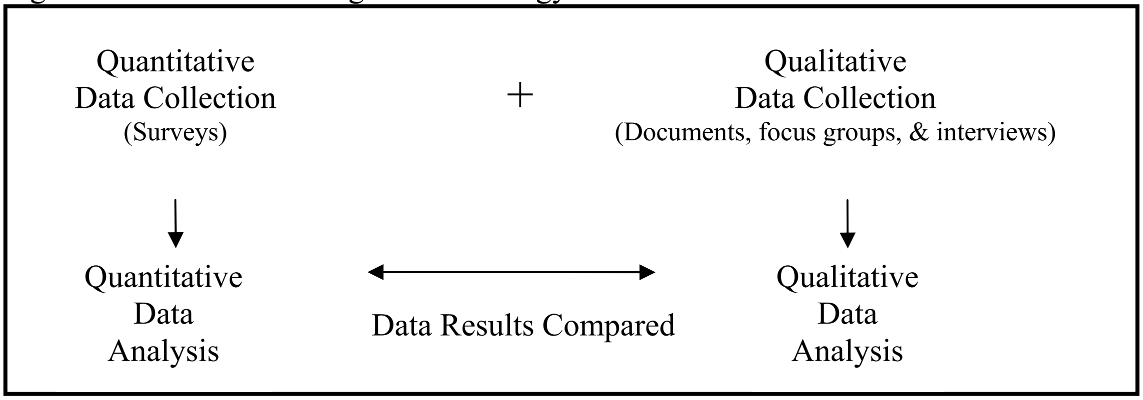
Design of the Study

A goal of this study was to expand on the understanding of classroom-based inquiry science through the investigation of teachers who were participating with their students in a citizen science project. To accomplish this goal, I examined the ways various participants envisioned, implemented and engaged in a citizen science project, *eBird/CBW*. Of importance was the design of the citizen science project materials, the teachers implementing those materials, and the engagement of students. Given the complex nature of the research problem and the focus of the research questions a mixed-methods approach was taken in this study. By mixed methods I mean that I collected and analyzed both quantitative and qualitative data in this multiple-case study. A mixed-methods design allowed me to both explore and explain the cognitive processes associated with scientific inquiry and student engagement by confirming findings from different data sources.

This work was shaped by an interpretive/constructivist paradigm of research. My goal was to identify and interpret the cognitive processes associated with scientific inquiry during citizen science activities as well as student engagement. The basic assumptions of this paradigm are that knowledge is socially constructed by the people active in the research process and that researchers attempt to understand complex lived experience from the point of view of those who live it (Mertens, 1998).

Quantitative and qualitative data were collected using a concurrent triangulation strategy in an attempt to confirm, cross-validate and corroborate findings (Creswell, 2003). Figure 4 depicts a visualization of this strategy. The quantitative data were collected at the same time as the qualitative data (focus groups, interviews, and document analysis). The findings from both types of data were integrated during the analysis and interpretation phase of the study. Validity of findings were supported by multiple sources of data and multiple methods of datum collection. Multiple examples of direct quotations were used to support inferences and interpretations drawn from the data.

Figure 4. Concurrent Triangulation Strategy



The benefits of using this concurrent mixed methods study design has been described by several researchers. First, collecting data from a diverse range of methods (triangulation) reduces the risk that inferences will reflect biases or limitations of any one method (Creswell, 2003; Greene, Caracelli, & Graham, 1989; Maxwell, 1996). Second, contradictions or fresh perspectives may emerge (Greene, Caracelli, & Graham, 1989). Third, this approach can add breadth and scope to a project (Greene, Caracelli, & Graham, 1989).

Conceptual Framework

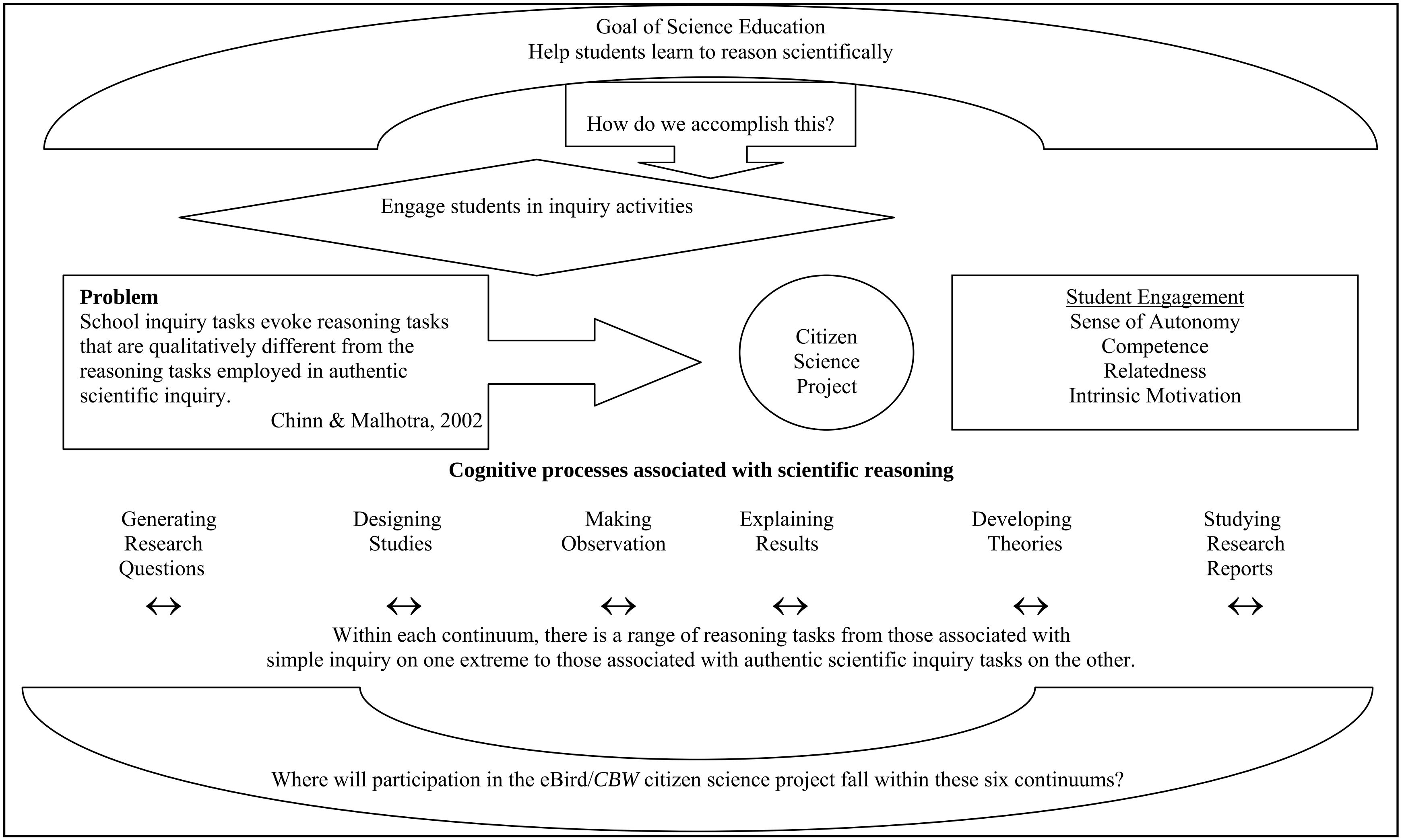
Miles & Huberman (1994) describe a conceptual framework as a diagrammatic representation explaining “the main things to be studied-the key factors, concepts, or variables-and the presumed relationships among them” (p.18). A visual representation of the conceptual framework for this study can be found in figure 5. The overarching premise of this research was that the goal of science education is to help students learn to reason scientifically. To accomplish this, teachers need to engage students in inquiry activities (AAAS, 1993; NRC, 1996). A problem arises in that the inquiry tasks commonly used in schools evoke cognitive processes needed in reasoning that are qualitatively different from the cognitive processes employed in real scientific inquiry (Chinn & Malhotra, 2002). Additionally, this project describes student engagement in citizen science with a focus on student sense of autonomy, competence, relatedness and intrinsic motivation.

Chinn and Malhotra (2002) describe school science tasks as ‘oversimplified forms of inquiry” (p. 177). These researchers present a theoretical framework contrasting authentic scientific inquiry with simple inquiry tasks found in textbook-based science curricula. They suggest that simple inquiry tasks incorporate few if any of the features associated with authentic scientific inquiry. If science inquiry tasks were placed on a continuum, simple inquiry tasks and authentic scientific inquiry would be at the extremes. Chinn and Malhotra suggest that school science inquiry should be redesigned to support and encourage the cognitive processes and reasoning tasks that are associated with authentic scientific inquiry. A gap in the research conducted by Chinn and Malhotra is the consideration of citizen science participation.

Are the inquiry tasks promoted during citizen science more closely aligned with the epistemology and cognitive processes of authentic science? Is citizen science a way to engage students in inquiry that is more qualitatively similar to authentic scientific inquiry? Will citizen science participation encourage different types of student engagement? Several benefits of citizen science participation have been suggested in the literature. Students may gain an appreciation of scientific research as well as the inherent difficulties in gathering quality data (Selover, Dorn, Dorn & Brazel, 2003). The process of science (what is done, how it is done, and why) as well as scientific results may be demystified for the nonscientist (Brewer, 2001 & 2002; Cohen, 1997; Trumbull, Bonney, Bascom, & Cabral, 2000).

The value of this citizen science research notwithstanding, little is known about the parallel between citizen science and authentic scientific inquiry and particularly student engagement in this type of science. Using Chinn & Malhotra's (2002) framework allowed me to look at citizen science with a very specific lens of cognitive processes associated with scientific inquiry. Six cognitive processes that scientists engage in were considered: 1) generating a research question, 2) designing a study to address the research question, 3) making observations, 4) explaining results, 5) developing theories, and 6) studying others' research.

Figure 5. Conceptual Framework



During authentic scientific inquiry scientists generate their own research questions, design their own studies to address a research question by planning procedures and determining variables. They also employ elaborate techniques to guard against observer bias when making observations as well as explain their results by transforming observation data, looking for experimental flaws, following complex chains of inference and employing multiple forms of argument. Scientists coordinate results from multiple studies to construct theories and use a peer-review process for communicating research findings.

In contrast, during simple science inquiry research questions are provided to students. Students follow simple directions on how to implement a procedure. They are usually told what variables to control and what variables to measure as an outcome. The concept of observer bias is not usually addressed in simple science inquiry tasks. Students employ simple contrastive reasoning and seldom examine their own procedures for flaws. Their explanations are often not tied to evidence. Students engaged in simple science inquiry merely uncover empirical regularities instead of determine new knowledge about the natural world.

The theoretical framework described by Chinn and Malhotra (2002) was appropriate for this study for two reasons. First, Chinn and Malhotra analyzed inquiry tasks in textbooks written for upper-elementary and middle schools. The *Classroom BirdWatch* citizen science project curriculum was field-tested with the same population, grades 4 through 8. Second, the systematic nature of this framework allowed for comparisons among text-book inquiry tasks, citizen science inquiry tasks and authentic inquiry tasks.

I compared and contrasted the cognitive processes of authentic scientific inquiry (as defined by Chinn and Malhotra, 2002) with the cognitive processes envisioned, implemented and engaged in during the *eBird/CBW* citizen science project. My goal was to expand the taxonomy of differences between simple inquiry tasks and authentic scientific inquiry to include those types of inquiry tasks associated with participation in a citizen science project and to further describe how students were engaged in this type of science.

Depending on where citizen science falls on this continuum, citizen science may provide the type of science setting that engages students in tasks that are closer to real science. If so, students would have the opportunity to think, act and feel like real scientists. Certain classroom tasks allow students to be more engaged with science than do other tasks leading students to different types of engagement (Vansteenkiste, Lens, & Deci, 2006). To examine student engagement during citizen science I will analyze four facets of engagement: 1) sense of autonomy, 2) competence, 3) relatedness and 4) intrinsic motivation.

Research Procedures

The data-gathering phase of this study was shaped by concurrent analysis, interpretation, and construction of datum collection instruments. Multiple sources of evidence were utilized to support the trustworthiness of this research.

Qualitative datum sources fell into four categories: 1) documents, 2) focus group interviews, 3) individual interviews, and 4) open-ended questions on surveys. Documents included the *CBW* curriculum and *CBW* Website (http://www.birds.cornell.edu/*CBW*) as well as student inquiry project reports. Focus group interviews were conducted with student participants. Individual teacher and project developer/coordinator interviews were conducted on-site and via telephone. Open-ended unit surveys were designed by Cornell Lab of Ornithology and completed by teachers as they finished each unit. All unit surveys were completed by teachers using the electronic datum collection tool, *Survey Monkey*.

Quantitative datum sources included a student engagement survey and a student engagement teacher survey created by the researcher. The student engagement survey was based on the current literature regarding student motivation and engagement. This survey was given to student participants after they completed all units of *CBW*. Those students who conducted independent inquiry projects completed the second survey after their projects were finished. Validity was an important consideration because of interest in whether there was a true correlation between the test instrument (student engagement survey) and the concept of student engagement. The statements on the student engagement survey were reviewed and revised by a full professor and published author with expertise in the area of student engagement and motivation. Appendix A contains the directions and statements used on the student engagement survey.

The student engagement teacher survey was also created by the researcher of this study. The Likert-type statements paralleled those found on the student engagement survey. Teachers completed this survey at the same time that students completed the student engagement survey. The purpose of this survey was to cross-check responses provided by students. The entire survey can be found in Appendix B.

Datum sources varied depending on the research question addressed. Table 12 provides a crosswalk between research questions and datum sources.

Table 12. Crosswalk Between Research Questions and Datum Sources.

Research Question	Datum Sources
1 To what extent did the tasks associated with the *eBird/CWB* citizen science project incorporate (promote) features of authentic scientific inquiry?	*Document Analysis* *CBW* curriculum materials
	Document Analysis *eBird* and *CBW* Website
	Interview *CBW* Project Developer/Coordinator
2 How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?	*Survey* Student Engagement
	Survey Student Engagement Teacher
3 How did students describe the scientific inquiry cognitive processes utilized during their participation in the *eBird/CBW* citizen science project?	*Focus Group Interviews* Student Card Sort
	Document Analysis Student Inquiry Project Reports
4 How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/CBW* citizen science project?	*Survey* Teacher *CBW* Units
	Survey Student Engagement Teacher
	Interview Teacher

Research Question #1

To what extent did the tasks associated with the eBird/CBW citizen science project incorporate (promote) features of authentic scientific inquiry?

Datum sources related to this question were two types of document analyses as well as a project developer/coordinator interview. The *CBW* project curriculum materials originally sent to all field-test teacher participants were analyzed in a qualitative manner. A second document analysis was conducted on the *CBW* website. A final datum source for this question was an interview with the *CBW* project developer/coordinator. I sent the project developer/coordinator the table of cognitive processes and associated reasoning tasks included in chapter two of this study. During a telephone interview, I asked her to describe the reasoning tasks that were promoted in the *eBird/CBW* curriculum. The audio recording for this interview was transcribed and analyzed using NUDIST. The purpose of this type of analysis was to gain the necessary background information needed to understand the dynamics of participation in this project and to describe the science inquiry cognitive processes promoted by this project.

Research Question #2

How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?

Datum sources related to this question were: 1) student engagement surveys completed by students, and 2) student engagement teacher surveys completed by teachers. The student engagement survey was created by the researcher for this study. The survey had twenty-five Likert-type statements related to autonomy, competence, relatedness and intrinsic motivation. The survey, asking students to rate their engagement in *CBW*, was given to all study participants. A second survey asking students to rate their engagement in the independent inquiry project was given to most of the participants from the focus groups. The statements on the two surveys were identical with the exception of the subject of each sentence. For example, the *CBW* survey began with the statement, "I felt like I was responsible for my own learning during CLASSROOM BIRDWATCH" while the independent inquiry survey began with the statement, "I felt like I was responsible for my own learning during MY INQUIRY PROJECT". Both student engagement surveys can be found in Appendix A. Table 13 provides a break down of all student engagement survey statements by student engagement component.

Table 13. Student Engagement Survey by Component

Statement Type	Statements
Autonomy	• I felt like I was responsible for my own learning during CLASSROOM BIRDWATCH. • I felt like my decisions were important during CLASSROOM BIRDWATCH. • Sometimes, I had to solve my own problems during CLASSROOM BIRDWATCH. • I was able to make choices about my learning during CLASSROOM BIRDWATCH.

Competence	• I think about birds and nature in different ways. • Doing CLASSROOM BIRDWATCH activities gave me the opportunity to think in different ways from my other school subjects. • I thought like a real scientist during CLASSROOM BIRDWATCH activities. • I like CLASSROOM BIRDWATCH activities because I like doing science instead of reading about science. • I feel like I did a good job of observing, identifying and counting birds. • I think I can use the ways I have learned to think and solve problems during CLASSROOM BIRDWATCH in my daily life. • As a result of CLASSROOM BIRDWATCH, I want to continue to learn about birds. • Being a part of CLASSROOM BIRDWATCH has caused me to think about a future career in science.
Relatedness	• I think teamwork was important during CLASSROOM BIRDWATCH. • I used feedback from others to help me do and understand CLASSROOM BIRDWATCH activities. • My group members and I bounced ideas off of each other during CLASSROOM BIRDWATCH. • Because I was participating in CLASSROOM BIRDWATCH, I felt connected to the scientists at Cornell Lab of Ornithology. • Working with my team helped me to be successful in CLASSROOM BIRDWATCH.
Intrinsic Motivation	• I liked participating in CLASSROOM BIRDWATCH because I was good at it. • I was able to be creative during CLASSROOM BIRDWATCH. • CLASSROOM BIRDWATCH activities were fun. • I was interested in CLASSROOM BIRDWATCH, my teacher or parents did not have to force me to participate. • I was interested in CLASSROOM BIRDWATCH because I was curious about birds. • I will continue to notice different kinds of birds. • The CLASSROOM BIRDWATCH activities were not too easy and not too hard. • Participating in CLASSROOM BIRDWATCH has helped me to become a better student.

A teacher survey about student engagement was given to the three classroom teachers participating in this study. The purpose of this survey was to compare teacher perceptions of student engagement with student-reported information. Likert-type statements on this survey were fashioned after the statements on the student engagement survey. For example, "Team work helped my students be more successful" and "I think my students felt competent with *CBW* activities". The teacher survey can be found in Appendix B. All teachers completed the survey at the same time as their participation in the interview described in research question number four.

Research Question #3

How did students describe the scientific inquiry cognitive processes utilized during their participation in the eBird/CBW citizen science project?

Student focus group interviews were conducted. The purpose of the interviews was to gain richer and deeper insights into how student participation during the independent inquiry project reflected the reasoning tasks associated with the cognitive processes of authentic scientific inquiry.

Student focus group interviews were conducted with those participants who completed independent inquiry projects. All fifth and seventh grade students who completed inquiry projects participated in focus group interviews (20 and 10, respectively). All eighth grade students completed independent inquiry projects; however, only a sample from the group participated in focus group interviews (n=10). The reason for this was accessibility and time constraints during datum collection. The eighth grade science teacher identified focus group participants to provide a representative sample from the entire eighth grade class. Her identification was based on academic level and motivation as well as ability (parental permission) and willingness to be interviewed.

A card sort was developed by the researcher of this study based on the framework of cognitive processes described by Chinn and Malhotra (2002). The six areas of cognitive processes were designated by six different colors of index cards. Statements reflecting either authentic science reasoning tasks or simple science reasoning tasks were written on the index cards. There was one statement per card. Appendix C lists all of the statements for this card sort. Students were interviewed as a group. They were grouped for the focus interview the same way they had been grouped for their inquiry project. I handed a single student one group of cards and allowed them to read each statement aloud. As a group, students decided if the statement represented something they did or thought about during their independent inquiry project. If they agreed on a statement it was placed in a ‘yes’ pile or if they disagreed with a statement it was placed in a ‘no’ pile. If students were not sure, they placed the statement in a ‘maybe’ pile. During the card sort, I used an audio-recorder to record the dialogue among students. This audio recording was transcribed for analysis.

All students in the fifth grade class completed inquiry projects. There were a total of six student groups and all groups were interviewed for this study. Only six student groups from the seventh grade class completed inquiry projects. They received extra credit for their work. All six groups were interviewed for this study. All students in the eighth grade case completed inquiry projects. The eighth grade teacher selected one group from each class period to participate in the focus group interview (total of four groups). This selection of student groups represented the broad range of students within the entire eighth grade.

Although the cards were intended to examine cognitive processes, there was some overlap with student engagement. Those statements related to research question #2 are listed in Table 14 and are organized by student engagement component.

Table 14. Focus Group Card Sort Statements Related to Student Engagement

Engagement Component	Focus Group Interview Statements
Autonomy	• Our research question was based on something we saw. • Our research question was based on our own curiosity. • Being able to generate our own research question allowed us to be creative. • We made up our own steps. • We decided on our own variables. • We thought about our procedures and wondered if they were any good. • We changed our procedures to make our experiment better. • We figured out the kind of data we needed to collect on our own. • We thought about ways to improve our observations to make them more accurate. • We thought about possible errors we may have made in our data analyses or interpretation. • When we looked at our results we thought of other ideas for what the data might be telling us. • We talked about ways we could check our findings. • We were responsible for deciding how to analyze our data.
Competence	• We felt confident in generating our own research question. • We were happy with the study we designed. • We thought we did a good job of making accurate observations.

Relatedness	• Our research question was based on something another student said or did. • Our research question was based on something we read in the *CBW* materials or some other type of research study. • We designed a good study because we worked together. • We worked together to understand and explain our data. • We used results from other studies to help us explain our data. • We read other studies that had similar results to our investigation. • We read other studies that said something different from what we found in our study. • We looked at other data on *eBird* to add to our learning. • We read other peoples' research to help us develop or understand our research question. • We read other studies to learn about standard steps for collecting certain types of data. • We read other studies to learn about what variables we needed to control and measure. • We read other studies to think about how to fit our study in with the work of other researchers. • Other students read our work and gave us feedback. • We used other student feedback to help us know what to do. • We used other student feedback to help us understand our data. • We reviewed the work of other students & gave them ideas. • We looked at information in the *eBird* database to give us ideas about our research.
Intrinsic Motivation	• We enjoyed identifying and counting birds.

If students completed an inquiry project they had the option of submitting a peer-reviewed research report for consideration for publication in the *Classroom Birdscope* student research journal or *Classroom Birdscope* Webzine. Student research reports submitted to Cornell Lab of Ornithology were also analyzed as part of a document analysis.

Research Question #4

How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the eBird/CBW citizen science project?

Datum sources related to this question were two types of teacher surveys (teacher *CBW* unit surveys and student engagement teacher survey) as well as an individual teacher interviews. The teacher *CBW* unit surveys were created by Cornell Lab of Ornithology and administered through *Survey Monkey*. Most questions were related to curriculum design but several open-ended questions generated teacher responses that were related to this research question. For example, "Please comment on any *BirdTalk* reports and how they contributed to student discussion", " Do you have any suggestions for changes or improvements to this Exploration?, and "How did you use the 'I Wonder' board during this unit?".

The student engagement teacher survey was created by the author of this study. Likert-type statements paralleled the concepts represented in the student focus group interview. For example, teachers were asked to describe student experiences on a scale of 1 (no experience) to 5 (extensive experience) with the cognitive processes associated with scientific inquiry. Teachers were also asked to identify reasoning tasks students generally used in both *CBW* and the independent inquiry. All three teacher participants completed this survey.

Individual teacher interviews were conducted with all three teacher participants. The interviews were audio-recorded and transcribed. Teacher responses to open-ended questions were used to characterize each teacher and their schools as well as shed additional understanding on how students engaged in the citizen science project. For example, "In what ways do you feel students were responsible for their own actions or directed their own learning?", "How would you generally describe the motivation of your students during this project?", and "How many of your children, do you think, will continue to watch birds?".

Pilot Test of Data Collection Instruments

The pilot test was used to refine datum collection plans with respect to both the content of the data and the procedures to be followed. The informants were chosen because they were accessible and the sites were geographically convenient. All informants were of similar age to study participants and had also completed science inquiry projects during the current school year. The student engagement survey and card sort were modified based on feedback from the pilot study.

Data Analyses

Data analysis and interpretation was on-going as data were collected. Findings were generated and systematically determined as successive pieces of data were gathered (Stainback & Stainback, 1988). Cognitive processes and reasoning tasks associated with each cognitive process were defined a priori using the model suggested by Chinn and Malhotra (2002). Some qualitative datum sources (documents, focus group transcriptions, and interview transcriptions) were analyzed using the content analysis software NUDIST (*Non-numerical, Unstructured Data Indexing, Searching, and Theorizing*). Data available in electronic format were analyzed using NUDIST. Data only available in hard copy (*CBW* curriculum and student reports) were analyzed with comparative content analysis. Closed-ended questions and Likert-type questions on surveys produced quantitative data that were analyzed using SPSS (*Statistical Package for the Social Sciences).* Reliability, factor analysis, correlation, frequency, analysis of variance and repeated measures statistical tests were conducted. As part of these analyses, some qualitative data were quantized by counting the frequency of occurrence of events. Table 15 provides a summation of the data analyses procedures that were performed on each of the datum sources.

Table 15. Summation of Data Analyses Procedures

Question	Datum Sources	Analysis
1	*Document Analysis* *CBW* project curriculum materials	Content Analysis
	Document Analysis *CBW* Website	
	Interview Project Developer/Coordinator	Content analysis performed with NUDIST
2	*Survey* Student Engagement	SPSS • Reliability analysis • Factor analysis • Correlation analysis • Frequency analysis • Repeated Measures analysis
	Survey Student Engagement Teacher	SPSS • Frequency analysis
3	*Focus Group Interview* Student Card Sort	SPSS • Frequency analysis • Analysis of variance
	Document Analysis Student Inquiry Project Reports	Content Analysis
4	*Survey* Teacher *CBW* Units	Content Analysis
	Survey Student Engagement Teacher	SPSS Frequency analysis
	Interview Teacher	Content analysis performed with NUDIST

Trustworthiness

Lincoln and Guba (1985) define trustworthiness as the quality of an investigation and its findings that make it noteworthy to an audience. Four criteria for trustworthiness were used to evaluate the quality of this research design: construct validity, external validity, reliability and credibility.

Construct validity refers to establishing correct operational measures for the concepts being studied. Multiple sources of evidence were gathered during the datum collection phase (artifacts, surveys, interviews) while a chain of evidence was established during the data analyses phase. Key informants reviewed draft reports of the findings from this study (teachers and *CBW* project coordinator).

External validity deals with the problem of knowing whether a study's findings are generalizable beyond the immediate case study. Case studies are only generalizable to theoretical propositions and not to populations (Yin, 2003). Since this was a multiple case study, analytic generalizations were described. An a priori theory was used as a template with which to compare the empirical results of each case. Replication was claimed since two or more cases were shown to support the same theory. Generalization to other types of citizen science projects (direct replications) should be tested in future studies to determine if similar results will be found. It is only after these direction replications have been made that the results can be accepted as providing strong support for the initial theory. Internal validity was not addressed since this study was descriptive in nature and not concerned with making causal claims.

The goal of reliability tests is to minimize errors and biases in a study. The procedures for this study have been thoroughly documented with a case study protocol as described earlier in this chapter (Yin, 2003).

Credibility reflects the fit between the actual responses of the participants involved in this study and my reconstruction and interpretation of their responses. Multiple datum collection techniques were used as a reliability check for consistent patterns of theme development (Creswell, 2003). Interviews were audio-recorded and transcribed. Excerpts from these transcriptions were used to provide evidence for the assertions made in this report (Weiss, 1994). Quotations used were representative of the perceptions and views held by all participants. Various participants in this project conducted a member check by reading the discussion section of the final report, specifically, evaluating my representation of their responses (Creswell, 2003).

Given the interpretative nature of this work, it is important that I make my bias transparent. I hold a Master of Arts degree in secondary science instruction and a Master of Science degree in Biology. My specialization was aquatic ecology. I was a seventh grade science teacher before beginning my doctoral studies. During that time, my students participated in the GLOBE student-scientist partnership. Based on my experiences with the GLOBE project, I felt citizen science participation could be a means to engage students in more authentic scientific practices. Since leaving the seventh grade classroom, I have continued to work with various age-groups of children, exposing them to authentic scientific practices in ecological studies. For example, I installed a herpetology monitoring station at a local environmental education center and have lead children through the process of collecting, identifying and releasing reptile and amphibian species for the purpose of determining local species diversity. Although I have an extensive background with aquatic macroinvertebrates, my experience with birds is limited to armature status.

CHAPTER IV

FINDINGS

"When we try to pick out anything by itself,
we find it hitched to everything else in the universe."
John Muir

The purpose of this study was to examine and describe the ways various stakeholders (*CBW* project developer/coordinator, elementary and middle school teachers, and fifth through eighth grade students) envisioned, implemented and engaged in a citizen science project called *eBird/Classroom BirdWatch*. The study examined the cognitive processes of science inquiry associated with the tasks undertaken during citizen science participation. It also described student engagement during citizen science through measures of a sense of autonomy, competence, relatedness and intrinsic motivation.

This study was conducted and the data analyzed using an interpretative multiple-case study, mixed-methods approach which included document analysis, surveys, focus group interviews and individual interviews. This chapter details the findings of the study and is organized by research question: 1) To what extent did the tasks associated with the *eBird/Classroom BirdWatch* citizen science project incorporate (promote) features of authentic scientific inquiry?, 2) How did student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?, 3) How did students describe the scientific inquiry cognitive processes utilized during their participation in the *eBird/Classroom BirdWatch* citizen science project?, and 4) How did classroom teachers describe student engagement in the cognitive processes associated with scientific inquiry during the *eBird/Classroom BirdWatch* citizen science project? Both quantitative and qualitative data analyses are presented.

Research Question #1

To what extent did the tasks associated with the eBird/Classroom BirdWatch citizen science project incorporate (promote) features of authentic scientific inquiry?

Three different datum sources were used to answer this research question: 1) *CBW* curriculum materials (document analysis), 2) *CBW* Website (document analysis), and 3) *CBW* project developer/coordinator interview. Content analysis was used to determine the cognitive processes represented in the curriculum materials. The qualitative analysis software NUDIST was used to analyze the interview transcript of the *CBW* project developer/coordinator.

I first coded the tasks described in the *CBW* curriculum (Exploration lessons, student journal and teacher resource guide) with the six cognitive processes: 1) *generating research questions*, 2) *designing studies*, 3) *making observations*, 4) *explaining results*, 5) *developing theories*, and 6) *studying others' research*. Under each cognitive process there were subcategories that represented either simple or authentic scientific reasoning tasks. Table 16 provides an outline of the cognitive processes associated with authentic science represented in all units of the *CBW* curriculum. Only those exploration lessons that provide students with opportunities to engage in cognitive processes associated with authentic science are discussed.

Table 16. Authentic Science Cognitive Processes Found in *CBW* Curriculum

Exploration/Exploration Number	**Cognitive Process Associated with Scientific Inquiry**	**Authentic Science**
Unit 1/Exploration 1 What is That Sound?	Generating research questions	▪ Develop own questions based on others' work ▪ Develop own questions based on curiosity
Unit 1/Exploration 2 Schoolyard Silhouettes	Making observations	Technique to guard against perceptual bias
Unit 1/Exploration 3	None	
Unit 1/Exploration 4	None	
Unit 1/Exploration 5 Students as Citizen Scientists	Developing theories	Coordinate results from multiple studies
	Studying others' research	• Reading research of others • Building on work of others
	Making observations	Technique to guard against perceptual bias
Unit 1 Capstone	Designing a study	▪ Determine multiple controlled situations ▪ Critical reflection on methods
	Explaining results	Indirect reasoning
	Developing theories	▪ Constructing theories based on evidence ▪ Study at level of observable regularity
Unit 2/Exploration 6	None	
Unit 2/Exploration 7 Bird Reproduction	Explaining results	Data transformation: mapping
	Studying others' research	Reading research of others
Unit 2/Exploration 8	None	
Unit 2/Exploration 9 Bird Life Cycles	Making observations	Technique to guard against perceptual bias
	Developing theories	Coordinate results from multiple studies
	Studying Other's Research	Reading research of others
Unit 2/Exploration 10	None	

Unit 3/Exploration 11 How Do Scientists Study Animals?	Generating research questions’	Develop questions based on curiosity
	Explaining results	Using evidence to support explanations
	Developing theories	Coordinate results from multiple studies
	Studying others’ research	Reading research of others
Unit 3/Exploration 12 Interpreting Data	Generating research questions’	Develop questions based on curiosity
	Studying others’ research	Peer review of findings
Unit 3/Exploration 13	None	
Unit 3/Exploration 14 What’s in a Report?	Generating research questions	• Questions based on observations • Questions based on curiosity
	Designing a study	Critical reflection on methods
	Developing theories	Constructed theories based on evidence
	Studying others’ research	Reading research of others
Unit 3/Exploration 15	None	
Unit 4/Exploration 16 Fair Test	Generating research questions	• Developing questions based on observations • Developing questions based on others’ work
Unit 4/Exploration 17 What Kind of Question is That?	Generating research questions	• Questions based on observations • Questions based on curiosity
	Designing a study	• Steps designed by researcher • Variable determined by researcher
Unit 4/Exploration 18	None	
Unit 4/Exploration 19 Preparing a Report	Studying others’ research	Peer review of findings
Unit4/Exploration 20	None	

I examined the *CBW* and *eBird* websites using the same coding procedures described above. Table 17 provides an outline of the cognitive processes associated with authentic science represented on the two websites.

Table 17. Authentic Science Cognitive Processes Found on Websites

Website	**Cognitive Process associated with Scientific Inquiry**	**Authentic Science**
CBW	Generating a Research Question	Develop own questions based on observations
eBird	Developing theories	Coordinating results from multiple studies
	Study Others' Research	Building on work of others

To triangulate my findings, I conducted an interview with the *CBW* Project Developer/Coordinator. The interview was audio-recorded and transcribed. Data were analyzed using the same coding for the curriculum and websites.

Unit 1- Exploration Lessons 1-5

During unit one, students learn to identify birds by sound and sight. There are five explorations in this unit. The focus of the first exploration is how birds use sound to communicate. Students begin to learn how to identify birds first by silhouette (exploration two) and then by field markings (exploration three). Students used field guides in exploration four and learned how to enter their data into the *eBird* database in exploration five. The unit culminates in a capstone experience where students are invited to conduct regular stationary or traveling bird counts and enter their data into the *eBird* database.

Exploration One: What is That Sound?

After brainstorming reasons why birds might sing or call, students are instructed to read a variety of studies about bird communication with the purpose of evaluating their own ideas about why birds sing or call. The class is divided into groups of 3-4 students and each group is given a different copy of a *Bird Talk* report. Each group of students shares with all students what has been learned from the report. As a class, students re-evaluate their previously constructed list of why birds might sing or call, adding any additional ideas to the list or removing any ideas that no longer seem valid. Students are then encouraged to begin generating questions to be posted on an "I Wonder" board as well as in their student journals.

During this exploration, students engage in a single cognitive process: *generating research questions*. Within this cognitive process two aspects of authentic scientific inquiry are noted: 1) developing their own questions based on others' work and 2) developing their own questions based on curiosity.

During simple science tasks students usually read about topics from science texts or trade books. The texts or trade books may imply that science is a static body of knowledge whereas the research reports may be viewed as science is a work in progress. The format of the *Bird Talk* reports is similar to that of topics in a trade book. Each report consists of two or three paragraphs that shares information about a type of bird communication. If these reports were reformatted to look more like scientific research reports then their use would be more aligned with authentic science. With simple changes in formatting, students would have the opportunity to engage in two additional aspects of authentic inquiry: 1) reading the research of others and 2) building on the work of others. Scientists study the research findings and reports of others to inform their own developing ideas and to help shape their future research plans.

Using the *Bird Talk* reports, students are encouraged to generate potential research questions. Building on the work of others as well as basing questions on their own curiosity, students post their potential research ideas on an "I Wonder" board and/or on a similar page in their student journal. Developing their own research questions based on others' work or based on their own curiosity are two aspects of authentic science. During exploration one, students are encouraged to develop their own questions based on the *Bird Talk* reports, their class (group) discussions and their own curiosity. During simple science, questions are often provided by the teacher or the curriculum.

Exploration Two: Schoolyard Silhouettes

During Exploration Two, students are taken outside to look for birds. Working in groups of two or three, students identify and count the birds they may already be familiar with and make sketches of birds with which they are unfamiliar. Students are encouraged to corroborate their species identification with other members of the group and then record the data in their student journals. Students are encouraged to evaluate their process of identifying and counting birds with the following suggested questions:

- Was it harder or easier to identify birds than you thought it would be?
- Do you think we accurately identified the birds we named?
- Where were the birds on our walk? What were they doing?
- How could we try to identify the birds we drew?

- Why is it important that we count accurately?

Students are engaging in the cognitive process of scientific inquiry *making observations*. Not only do students identify and count birds but they also are encouraged to check their identifications with others, critically consider the validity of their observations as well as methods to improve observations, and consider the value of accurate observations. These are all techniques to guard against perceptual bias that is an important part of making observations during authentic science. During simple science, students make observations and maybe measurements but they often do not consider ways to guard against the perceptual bias that is inevitable during any human endeavor.

Exploration Five: Students as Citizen Scientists

During this exploration students watch the *Urban Bird Studies-Citizens Helping Scientists* video, read a letter from a Cornell Lab of Ornithology scientist inviting students to participate in the citizen science project, and learn how to enter bird count data on the *eBird* website, http://www.eBird.org. Three cognitive processes associated with authentic scientific inquiry are represented in this exploration: 1) *making observations*, 2) *developing theories*, and 3) *studying others' research*.

The video, *Urban Bird Studies-Citizens Helping Scientists,* demonstrates several cognitive processes associated with simple science. During one segment, a variety of scientists talk about their research questions related to various bird studies. During the early stages of citizen science participation, research questions are provided to students in the hopes that students will begin to develop their own questions. The video depicts students making observations and conducting bird counts; however, no reference is made to ways in which students could guard against perceptual bias. Students in the video appear to participate in direct observations that are not connected to any theory.

Studying others' research is a cognitive process associated with authentic science that is represented in the video. Students are encouraged to send their data to the Cornell Lab of Ornithology so that "scientists can tabulate and study the data…and publish the results". This building on the work of others is important in authentic scientific work.

The letter shared with students written by a Cornell Lab of Ornithology scientist suggests two cognitive processes associated with authentic scientific inquiry. Students are encouraged to coordinate results from multiple studies (*developing theories*) and read research of others (*studying others' research*). Brian Sullivan, *eBird* Project Leader, invites students to "not only enter data, but also retrieve data to learn more about the birds in your neighborhood or state". When students do this they are considering multiple studies and coordinating results of those studies to consider questions related to either a larger geographic area or longer period of time. In doing so, students have the opportunity to see their work as 'part of a whole'. Scientists often coordinate results from multiple studies to answer research questions that could not necessarily be answered with a single data set.

Also, students are invited to look at data that are submitted by other eBirders. Reading the research of others is important during authentic scientific inquiry and is often missing from simple inquiry tasks. From the Cornell Lab of Ornithology letter, "After you have submitted data to *eBird*, you can look at it by itself or with all of the other data reported by *eBird* users". Given the electronic nature of the *eBird* database, students have the ability to access both historical and real-time data. The dynamic nature of this datum set is much more like that of authentic science than traditional textbook school science. Access to the *eBird* datum set allows students the opportunity to query data, combine data from multiple studies to ask a larger variety of research questions and to generate additional research questions of their own.

On a student journal page that corresponds with this exploration (page 18), students are asked to consider why it is important to accurately record count information, and why scientists find repeated counts from the same site especially useful ("Why is it important to accurately record location information?" and "Why do you think scientists prefer to receive repeated counts from the same location?", *CBW* Student Journal, page 18). Since science is a human endeavor, scientists must constantly develop techniques to guard against perceptual bias. During simple science tasks, students rarely consider perceptual bias or validity issues related to datum collection. Repeated species identification and counts from the same site lend validity to the data being collected.

Capstone Experience

Students begin by creating a class plan for datum collection including making decisions about: 1) what kind of count to do (i.e. casual observation, stationary, traveling, exhaustive area), 2) where counts will take place, 3) how long each count will last, 4) how often counts will be conducted, and 5) who will enter data. A *CBW* tally sheet is provided in the student journal which asks students to record various physical and group parameters (i.e. date, start time, total birding time, weather, number of people in the group, whether they are reporting all birds seen, habitat, bird species, and bird counts).

As students develop their *eBird/CBW* study they are given the opportunity to determine multiple controlled situations such as deciding on: where bird counts will take place, frequency of count, and length of counting period. These types of variables are important controls for field studies that involve species surveys. During simple science, students often do not consider controlled conditions.

The specific protocols for each type of count method (causal, stationary, traveling, and exhaustive) are provided by project scientists. These standard protocols are developed by scientists and are followed during scientific bird studies. Prescribed steps for a study is associated with simple science (i.e. students following the steps of a laboratory activity). This is not the same as following scientific protocols. All types of field scientists investigate accepted protocols for species counts when conducting species diversity studies. For example, to describe water quality, field biologists follow standard protocols to determine the relative abundance of certain benthic macroinvertebrates in streams. They identify specific stream areas based on flow, substrate composition and water depth. Different protocols are used for different types of streams or rivers. In a headwater stream, a standard size collection device (Surbur sampler) is used to collect all benthic organisms. The Surbur sampler is placed in the stream and substrate materials, organisms and water are collected, preserved and returned to the laboratory for macroinvertebrate identification. In larger streams a rivers different types of protocols will be used depending on flow, substrate composition and water depth.

Students are encouraged to critically reflect on their methods when they are asked to brainstorm ideas about ways to minimize counting the same bird twice. Critical reflection on methods used during a scientific study is an important task during authentic science. Scientists think about the methods they plan to use in their study and look for potential sources of error in datum collection. During simple science, students follow prescribed steps usually with no thought as to whether or not the methods may generate errors.

During these initial stages of the citizen science participation I have identified several tasks that have features similar to authentic inquiry. There are, however, several features of simple science present too. Students are often led to consider only direct reasoning with no datum transformation. For example, several questions from the capstone experience ask students, “What is the most commonly seen species in our count area(s)?, What is the least common?, and Which species do we see in the largest groups?”. Data are not transformed in any way: it remains numbers of birds. Students would use direct reasoning to look at number of birds to answer these types of questions. Students could be encouraged to use more indirect reasoning (authentic science) if they were lead to consider possible relationships between number of certain bird species and parameters such as weather conditions, site designation or time of count.

At this point in the citizen science participation, students are just making direct observations not connected to any type of theory. This is an additional feature of simple science. During authentic science, scientists construct theories based on the evidence that they gather. It is possible that students may initially start to make predictions or draw conclusions about what they observe. For example: ‘more chickadees visit when it is snowing’ or ‘birds seem to visit less when it is raining’. Students are encouraged to collect additional data that will help them determine if their ideas are valid. This can be seen as beginning steps to constructing theories based on evidence and a type of study at the level of observable regularity (authentic science).

Unit Two- Exploration Lessons 6 - 10

During this unit students are introduced to various aspects of bird biology. During exploration six, students identify basic needs for bird survival and consider how their schoolyard habitat may or may not provide for the basic needs of birds. Bird adaptations to habitat are also introduced. Bird reproduction, migration and life cycle are the topics covered in explorations seven, eight and nine respectively. During exploration ten, students learn about an environmental issue that currently affects birds. Through role-play and research, they come to a class consensus about what action(s) should be taken to help resolve the problem.

Exploration 6: What Do Birds Need to Survive?

Students are encouraged to make observations but in a manner reflective of simple science. Students also are encouraged to explain ideas but in a way that demonstrates direct reasoning (simple science).

Exploration 7**:** Bird Reproduction

During this lesson students are given the opportunity to examine bird sighting reports that were derived from the Cornell online *eBird* database. Students use the data from the reports to plot points on a map found in their student journals. Two cognitive processes associated with authentic science are demonstrated: 1) e*xplaining results* and 2) *studying others' research*. Within the cognitive process, *explaining results*, students are engaged in datum transformation. Students transform bird sightings to geospatial points on a map. By using data from the *eBird* online database, students are studying the research of others. The *eBird* database is made up of bird sightings from all over the United States. These data are submitted by a variety of individuals.

Exploration 9: Bird Life Cycles

During this lesson students watch a power point presentation titled, *A Story of Hope*. The slide-show is about the plight of the Ivory-billed Woodpecker and the efforts by scientists to record its presence (or absence). Three cognitive processes associated with authentic science are suggested within this presentation: 1) m*aking observations*, d*eveloping theories* and 3) s*tudying others' research*. The story shares how scientists use recording equipment as a technique to guard against perceptual bias (m*aking observations*). Results from multiple studies are coordinated (d*eveloping theories*) from several different scientists, working at different times and places. Exposure to this power point presentation is another opportunity for students to become aware of the research of others (*studying others' research*).

Unit Three – Exploration Lessons 11 - 15

During this unit, students have the opportunity to learn about the scientific process. Students read about scientists who are conducting animal studies. They learn specific skills such as creating and interpreting graphs as well as generating tentative explanations for patterns represented by the data. Students learn about the important aspects of a scientific research report and consider the importance of methodology within a scientific study.

Exploration 11: How Do Scientists Study Animals?

During this activity, students read a *Meet a Scientist* report. There are six different reports that are about a half page each. Each report describes a different Cornell Scientist and their research interests. The simple descriptions provide students with a basic understanding of how each scientist learns about different types of animals. Four of the six reports discuss how the scientists publish their research in “scientific journals, magazines, and newspaper articles”. As students read these reports they are engaging in the cognitive process *studying others’ research* (reading research of others). Specifically students are instructed to look for the researcher’s question, what kind of data were collected and how they were collected, as well as what conclusions the researcher made. Students are encouraged to notice several other cognitive processes associated with authentic science: 1) g*enerating research questions* – Scientists develop questions based on curiosity, 2) d*eveloping theories* – Scientists coordinate results from multiple studies, and 3) e*xplaining results* - Scientists use evidence to support their explanations.

Exploration 12: Interpreting Data

During this lesson, students are introduced to the application of graphing as a means to visually represent data. In a handout titled, *Black-capped Chickadee Study Report* one cognitive process associated with authentic science is noted. The statement, “A few small studies done by researchers made Lab scientists curious about how much flock size varied across North America” suggests to students that scientists generate research questions based on curiosity. On the Student Journal page 51, students are given the opportunity to work with data collected by *CBW* students from Oregon. Students participate in cognitive processes: 1) e*xplaining results* and 2) s*tudying others' research*. Students are instructed to create a graph from the data which is a simple science form of explaining data. Students then are told to exchange their graph with a student partner and to give each other feedback. This is an important part of *studying others' research* (peer review of findings).

Exploration 14: What's in a Report?

During this activity, students learn about the elements of a scientific paper while reading a paper written by a 10th grade *CBW* student for the *BirdScope* publication (*Annalisa's Report*). This is an opportunity for students to read the research of others (s*tudying others' research*). From reading the report students may come to see that research questions can be developed based on observations (g*enerating research questions*) and that theories are constructed based on evidence (d*eveloping theories*).

After reading this student-generated scientific paper, students participate in a game where they are given statements from other student-generated reports and decide which part of a report each statement represents. From these statements, students are given examples of how research questions are based on curiosity (g*enerating research questions*) and suggestions about how to critically reflect on research methods (d*esigning a study*).

Unit Four – Exploration Lessons 16 - 20

This unit is the independent inquiry portion of the *CBW* curriculum. Due to the nature of independent inquiry, this unit is much more open-ended than the other units. Students learn about designing a fair test, controlling variables, planning a study, preparing a report and representing findings. Students are given the opportunity to design an original project in order to answer a question that interests them. They are given guidance in how to create and implement their plan for datum collection, analysis and presentation. In exploration nineteen, students learn how to organize their data into tables and graphs as well as how to analyze their data and draw conclusions. They are encouraged to participate in a peer review process before revising their report.

Exploration 16: Fair Test

This lesson is about developing research questions. Two authentic science reasoning tasks for g*enerating research questions* are represented in this lesson: 1) developing questions based on observations (descriptive or experimental studies) and 2) developing questions based on others' work (examining and analyzing data collected by other scientists available in a database).

Exploration 17: What Kind of Question Is That?

During this lesson students read through a second *CBW* student-generated report (*Amy's Experiment*) to identify components of an experiment as well as types of variables. G*enerating research questions* is the only cognitive process associated with authentic science demonstrated in the initial stages of this lesson (questions based on observations and questions based on curiosity).

During the second part of the lesson, the class decides on at least one research question to discuss in more detail. They are encouraged to develop a hypothesis and plan an experiment to test their hypothesis. Students are given the opportunity to design their own steps and determine their own variables (*designing a study*).

Exploration 19: Preparing a Report

An important part of writing a scientific paper is the peer review process (s*tudying others' research*). During lesson 19, students are encouraged to seek peer review of their work. A "Peer Review Contract" and "Peer Review Form" in the student journal help to guide this process for students (pages 81 & Appendix, Student Journal).

Website Analysis

The *CBW* website, http://www.birds.cornell.edu/*CBW*, includes information to help teachers implement the *CBW* curriculum. On the page titled, *About Classroom BirdWatch*, it is stated that students engage in inquiry by making careful observations of birds, and asking questions based on their observations (*generating research questions*). Two assumptions regarding participation in this program are also noted: 1) students "make important contributions to science by collecting data about their local birds and sending the information to scientists" and 2) "students typically find this aspect of helping scientists and birds especially rewarding and motivating". On the page titled, *Data Entry*, utility for the *eBird* data are suggested, "Scientists use the data submitted to *eBird* in reports and conservation plans"; however, no cognitive processes are noted on this page.

The *eBird* website, http://www.eBird.org, describes the *eBird* citizen science project with information about how to submit observations as well as links for viewing and exploring data. On the first page, *About eBird*, the cognitive process d*eveloping theories* is noted. "You can also access the entire historical database to find out what other *eBird*ers are reporting from across North America. In addition, the cumulative *eBird* database is used by birdwatchers, scientists, and conservationists who want to know more about the distributions and movement patterns of birds across the continent". This is an example of coordinating results from multiple studies. The electronic database could also be used by students to build on the work of others (s*tudying others' research*).

Project Coordinator Interview

I sent the project developer/coordinator (Ms. Smith-pseudonym) the table of cognitive processes and associated reasoning tasks included in chapter two of this study. During a telephone interview, I asked her to describe the reasoning tasks that were promoted in the *eBird/CBW* curriculum. The conversation was audio-taped and transcribed. The narrative was analyzed using the NUDIST qualitative analysis software.

Ms. Smith reports that the *CBW* curriculum was designed to afford students the opportunity to engage in the cognitive processes associated with science to differing degrees. Developing research questions based on student observations and curiosity was an authentic manner in which students could *generate research questions*. She felt that developing questions based on the work of others happened less frequently, but did occasionally occur. She points to the use of the "I Wonder Board" as an important part of the curriculum where students record their research questions.

Of the six cognitive processes, Ms. Smith felt like d*esigning a study* was represented the most in the *CBW* curriculum. She identified five reasoning tasks within this cognitive process associated with authentic science that were represented in the curriculum: 1) variables determined by the researcher, 2) controls selected based on causal models, 3) multiple controlled situations, 4) critical reflection on methods, and 5) steps designed by the researcher.

When thinking about the cognitive process, *making observations*, Ms. Smith felt like the only method of guarding against perceptual bias promoted in the curriculum was that children are encouraged to double check their observations/identifications with other children. The curriculum does not promote the use of various types of equipment to validate datum collection.

Ms. Smith reported that most aspects of the cognitive process, *explaining results*, aligned better with simple science. For example, students are asked to draw birds, graph data, conduct simple error analysis and use direct reasoning; however, she feels the complexity of the reasoning tasks associated with this cognitive process may be too much for adolescents. “Some students do statistics, but what I am coming to realize is that the things in the authentic science column are probably beyond the scope of what most middle-schoolers can do”.

For the cognitive process, *developing theories*, Ms. Smith identified only one reasoning task, coordinate results from multiple studies, that is promoted in the *CBW* curriculum. She recalled events when students read through past student research in *Classroom BirdScope* magazines to either spur their own projects, support their current work or provide an alternative viewpoint to a similar idea.

Reading the research of others, building on the work of others, and peer review were three reasoning tasks associated with *studying others’ research* that Ms. Smith identified as being promoted in the *CBW* curriculum. The Cornell Lab of Ornithology publication, *Classroom BirdScope*, was the main vehicle used to provide students with bird research that was on their academic level. This annual publication contains submissions from *Classroom FeederWatch* or *Classroom BirdWatch* students who have conducted projects during the previous school year.

Data Across Sources: eBird/CBW Curriculum, Website, and Developer/Coordinator Interview

In answering research question #1, I found it necessary to first analyze data qualitatively and then to quantify the coded categories. I collated the reasoning tasks related to each of the cognitive processes of authentic scientific inquiry and determined the frequency of occurrence of those reasoning tasks. Table 18 demonstrates this collation of information across datum sources. Three datum sources were used: 1) *CBW* Curriculum, 2) *eBird/CBW* Website, and 3) *CBW* Project Developer/Coordinator interview.

Table 18. Frequency of Reasoning Tasks Represented in *eBird/CBW* Curriculum, Website and Developer/Coordinator Interview.

Cognitive Process	Reasoning Task Associated with Authentic Science	Frequency of Occurrence *CBW* Curriculum	Frequency of Occurrence *eBird/CBW* Website	Occurrence in Developer/ Coordinator Interview
Generating Research Questions	Develop own questions based on observations	3	1	yes
	Develop own questions based on others' work	2		less directly
	Develop own questions based on curiosity	5		yes

Designing Studies	Variable determined by researcher	1		yes
	Determine multiple controlled situations	1		yes
	Steps designed by researcher	1		yes
	Critical reflection on methods	2		yes
Making Observations	Techniques to guard against perceptual bias	3		no
Explaining Results	Data transformation, statistics	1		no
	Data transformation, other	1		no
	Indirect reasoning	1		no
	Using evidence to support explanations	1		yes
Developing Theories	Construct theories based on evidence	2		maybe
	Study at level of observable regularity	1		no
	Coordinate results from multiple studies	3	1	yes
Studying Research Reports	Reading research of others	5		yes
	Building on work of others	1	1	yes
	Peer review of findings	2		yes

These findings show that a range of authentic inquiry reasoning tasks were promoted during the *eBird/CBW* citizen science project. There was a higher frequency of incidents where students were encouraged to generate their own research questions either based on their own observations, others' work or their own curiosity (Explorations 1, 11, 12, 14, 16, and 17). On a single occasion the website promoted student development of their own research questions based on their own observations. The interview with the project developer/coordinator confirmed this interpretation.

Students were encouraged to design their own studies during the Unit 1 Capstone experience and again during Unit Three (Explorations 14 and 17). Specific reasoning tasks identified were: determining variables, determining multiple controls, designing steps for investigation and critical reflection on experimental methods. It was not surprising that the cognitive process of *designing a study* fell later in the flow of the curriculum. Before planning a study, students must first have some background knowledge and prior experience with the topic. No reference to this cognitive process was made on either the *eBird* or *CBW* website; however, the project developer/coordinator confirmed that all four of these reasoning tasks were promoted during citizen science participation.

An important precursor to designing a study is for students/scientists to study the research of others for the purpose of determining what is already known in the field. Throughout the citizen science experience, students were encouraged to read the research of others, building on the work of others, and participate in peer review of findings (explorations 5, 7, 9, 11, 14, and 19). The interview with the *CBW* curriculum developer/coordinator confirmed these findings. During simple science experiences the reasoning task of reading the research of others is typically reduced to reading about science topics in science trade books.

Throughout the citizen science participation students were making observations. During the first two units of the *CBW* curriculum (explorations 2, 5, and 9), students were encouraged to consider techniques to guard against perceptual bias in their observations: 1) check observations with others, 2) critically consider the validity of observations, 3) determine methods to improve observations, and 4) consider the value of accurate observations. The *CBW* developer/coordinator suggested these same types of bias reduction techniques. Science is a human endeavor and bias is inevitable. During authentic science, scientists recognize this and consciously strive to find ways to guard against their own perceptual bias.

On three occasions in the *CBW* curriculum, students were encouraged to explain their results in ways that were consistent with authentic science (Unit 1 Capstone, Explorations 7 and 11). The *CBW* developer/coordinator described this cognitive process promoted in the curriculum as more like simple science; however, she did feel that the curriculum promoted using evidence to support explanations. Students were encouraged to transform their data but typically in a simple fashion like drawing or graphing. Basic statistical procedures (mean, median and mode) are introduced in exploration 17, but the project developer/coordinator does not believe that most students at the fifth through eighth grade level are developmentally ready for this practice.

During simple science students either gather direct observations not connected to theory or they make observations simply to illustrate a stated theory. During *CBW* citizen science three authentic inquiry reasoning tasks associated with *developing theories* were promoted: 1) constructed theories based on evidence, 2) study at the level of observable regularity, and 3) coordinating results from multiple studies. These reasoning tasks can be found throughout the four units (exploration 5, unit 1 capstone, explorations 9, 11, and 14). As with the cognitive process of *explaining results*, the project developer/coordinator felt that the area of *developing theories* was promoted more like simple science. She identified a single reasoning task associated with authentic science: coordinate results from multiple studies.

Research Question #2

How does student engagement in citizen science influence a sense of autonomy, competence, relatedness and intrinsic motivation?

Quantitative Analysis: Data Description, Administration and Management for the Student Engagement Survey

Data for this portion of this study were collected from 137 students in three schools. Data on the schools participating in the study are included in Table 11 of chapter three. Students completed a student engagement survey developed and administered by the author of this study. Each student was given the survey (Appendix A) and a standard set of instructions was read to each class. For the fifth grade class, the author read each survey item aloud as students read along on their own copies of the survey. For the seventh and eighth grade classes, students read the statements silently to themselves. Those students who completed an independent inquiry project took a second student engagement survey. All fifth grade students completed an independent inquiry project and were given two surveys. The independent inquiry project was optional for seventh graders; therefore, only those students who completed the independent inquiry project were given a second survey (n=12). Even though all eighth grade students completed independent inquiry projects they only completed the first student engagement survey due to time restrictions and limited accessibility.

All survey data were entered into SPSS spreadsheets. Descriptive statistics were determined and reliability, factor, correlation, and repeated measures analyses were conducted.

Descriptive Statistics

Table 11 in chapter three provides student participant demographics. Fifth (n=22), seventh (n=70) and eighth grade (n=45) students were included in this study. The 137 students participating in this study came from three schools located in three different states in the Northeastern United States. Almost fifty-three percent of the students were female (n=72).

Validity and Reliability

The accuracy and consistency of the student engagement survey data collection instrument was important in this study. Validity refers to the extent to which an instrument measures what it is intended to measure while reliability refers to the extent to which an instrument measures a variable consistently.

Datum collection instruments have validity when they are appropriate for the specific purpose and population under study. The student engagement survey was developed according to the well documented self-determination theory described by Edward Deci and Richard Ryan (2000). The survey was constructed to address the psychological needs of autonomy, competence, and relatedness described in this theory. A fourth category, intrinsic motivation, was included as a cross check to the three psychological needs. If the needs of autonomy, competence and relatedness are fulfilled, then students will be more intrinsically motivated (Brophy, 2004). Because this data collection instrument represents a supportable theory it has construct validity.

Content validity of the student engagement survey was addressed by seeking expert opinion on whether the data collection instrument was measuring the specific body of knowledge related to student engagement. The statements on the Student Engagement Survey were reviewed and revised by a full professor and published author with expertise in the area of student engagement and motivation.

Data collection instruments are said to have internal consistent reliability when individual statements are determined to statistically measure the same construct. The internal consistency for the Student Engagement Survey using Cronbach's alpha (computed with SPSS) yielded a value of .894 (n=137). According to Glasnapp and Poggio (1985), a reliability coefficient of .6 to .8 can be considered indicative of a moderate to high relationship. The high reliability statistic for this survey indicates the extent to which the items in the survey are related to each other. The reliability of this instrument was acceptable.

Factor Analysis

A factor analysis was conducted on the student engagement survey (n=137), a researcher constructed instrument, in order to examine the underlying dimensions of the survey instrument. A factor analysis with a principal components extraction was used to reduce the size of the data file from twenty-five variables to six components. Relationships were defined using a rotated component matrix. The benefits to this method were to reduce the data file and to be able to use uncorrelated predictors.

The extraction communalities range from 0.410 to 0.756 for the twenty-five items on the survey. These values estimate the variance in each variable accounted for by the components. Six principal components were identified and extracted with eigenvalues greater than one. The eigenvalue represents the amount of variance in the original variable accounted for by each component. Nearly fifty-nine percent of the variability within the original twenty-five variables was accounted for by these six principal components. I was able to reduce the complexity of the datum set by using these six components with a forty-one percent loss of information. Using the six components is preferable to using separate variables because the components are representative of all twenty-five of the original variables, and the components are not correlated with each other.

Using a rotation sums of square loading maintained the cumulative percentage of variation explained by the extracted components, but spread the variation more evenly over the components. The rotation method was Varimax with Kaiser normalization. The percent of variance within the six principal components was 5.534 to 14.396. Component one had a much higher percent of variance than any of the other components (see table 19).

Table 19. Rotation Sums of Squared Loadings

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	3.599	14.396	14.396
2	2.464	9.856	24.252
3	2.442	9.769	34.021
4	2.402	9.610	43.631
5	2.278	9.113	52.744
6	1.384	5.534	58.278

A value of 0.400 or greater was used to identify those survey statements that were associated with each component. All twenty-five survey statements were identified with at least one principal component. Three survey statements were identified with two components (statement 11, 12, 23). Statements were listed with the strongest correlated component. Only one statement was identified with a negative value (statement 24). Results of the factor analysis can be found in Table 19. A purpose of this study was to describe student engagement in citizen science with regards to a sense of autonomy, competence, relatedness and intrinsic motivation. The third column in Table 20 shows the frequency of response of students who agreed (A) or strongly agreed (SA) with the statements on the Student Engagement Survey. The frequency of agreement for each overall component was determined by computing the mean for all statements within that component.

Table 20. Six Principal Components of the Student Engagement Survey

Correlation Value	Item	Frequency of Agreement (%) n=137
Component 1: Competence		(A + SA) 35.7
.683	I think I can use the ways I have learned to think and solve problems during *Classroom BirdWatch* activities in my daily life.	30.7
.654	Conducting *Classroom BirdWatch* activities has helped me to become a better student.	43.1
.639	Doing *Classroom BirdWatch* activities gave me the opportunity to think in different ways from my other school subjects.	51.8
.588	Because I was participating in *Classroom BirdWatch* Activities, I felt connected to the scientists at Cornell Lab of Ornithology.	36.5
.565	Being a part of *Classroom BirdWatch* has caused me to think about a future career in science. *(6)	24.1
.550	I thought like a real scientist during *Classroom BirdWatch* activities.	27.7
Component 2: Intrinsic Motivation		(A + SA) 60.4
.806	I liked *Classroom BirdWatch* because I like doing science instead of reading about science.	84.7
.683	*Classroom BirdWatch* activities were fun.	60.6
.598	I was interested in *Classroom BirdWatch* activities my teacher or parents did not have to force me to do the activities.	62.0
.414	I liked participating in *Classroom BirdWatch* activities because I was good at it.	34.3
Component 3: Interest in Birds		(A + SA) 40.9
.677	I think about birds and nature in different ways.	38.7
.658	I was interested in *Classroom BirdWatch* activities because I was curious about birds.	38.7
.625	As a result of *Classroom BirdWatch* activities, I want to continue to learn about birds. *(1)	35.8
.588	I will continue to notice different kinds of birds. *(1)	50.4

Component 4: Autonomy		(A + SA) 61.9
.689	Sometimes, I had to solve my own problems during *Classroom BirdWatch* activities.	62.8
.659	I feel like I did a good job of observing, identifying and counting birds during *Classroom BirdWatch* activities.	64.2
.531	I felt like my decisions were important during *Classroom BirdWatch* activities.	62.8
.484	I was able to be creative during *Classroom BirdWatch* activities.	57.7
.468	I was able to make choices about my learning during *Classroom BirdWatch* activities.	62.0
Component 5: Relatedness		(A + SA) 67.5
.742	Working with my team helped me to be successful in *Classroom BirdWatch* activities.	70.8
.718	I used feedback from others to help me do *Classroom BirdWatch* activities and to understand what I was learning.	51.8
.588	I think teamwork was important during *Classroom BirdWatch* activities.	81.8
.576	My group members and I bounced ideas off of each other during *Classroom BirdWatch* activities.	65.7
Component 6: Outliers		(A + SA) 58.1
.598	During *Classroom BirdWatch* activities, I felt like I was responsible for my own learning.	46.0
-.578	*Classroom BirdWatch* activities were not too easy and not too hard. (This was the only item to have a negative correlation greater than .400)	70.1

* Indicates a lower correlation with a second component which is given in parentheses

Component 1 - Competence

Five of the six statements in this component have to do with competence. In the short-term, participation in citizen science may give students the opportunity to think in different ways, specifically, to think like a real scientist. More than half of the students said that *CBW* activities gave them an opportunity to think in different ways from other school subjects (51.8%); however, only about twenty-eight percent of the students said that they thought like a real scientist (27.7%).

In the long-term, this new way of thinking may be seen as valuable for solving problems in one's daily life, helping students become better students, and leading students to consider future careers in science. Forty-three percent of the students felt that *CBW* activities helped them to become better students; however, fewer students (30.7%) felt that the ways of thinking and solving problems during *CBW* could be transferred to situations in their daily life. Less than twenty-five percent of the students felt that *CBW* activities caused them to consider future careers in science (24.1%).

The final statement in this component asked students how they viewed their connections to the scientists at Cornell Lab of Ornithology. Almost thirty-seven percent of the students (36.5%) said that participating in the *CBW* activities helped them to feel more connected with this group of scientists. Overall, only thirty-six percent of the students surveyed (35.7%) felt competent in their *CBW* activities.

Component 2 – Intrinsic Motivation

All of the statements in this component deal with intrinsic motivation. Students may like citizen science activities because the activities may be active and enjoyable. They may choose to participate out of interest (as opposed to being forced) and may feel like they were good at the types of activities associated with this particular citizen science project. Free choice is important in intrinsic motivation (Schraw, Flowerday, & Lehman, 2001).

An overwhelming eighty-five percent of students said that they liked *CBW* activities because they enjoyed the active nature of their participation. A majority of students said that *CBW* activities were fun (60.6%) and that they were self-motivated in their participation. Students reported that teachers or parents did not have to force them to participate (62.0%). However, only thirty-four percent of students felt like they were good at the *CBW* activities. This lower value may relate to the overall lower level of competence discussed previously. Overall, sixty percent of the students surveyed were intrinsically motivated to participate in *CBW* activities.

Component 3 – Interest in Birds

The common element in component three is an interest in birds. Past or present curiosity about birds may generate initial student interest. Student engagement may affect the way students think about birds as well as their future interests in birds. Student curiosity about birds may be connected to their persistence to continue to watch and learn about birds.

Approximately half of the students (50.4%) said that they would continue to notice different kinds of birds; however, a smaller number of students (35.8%) said they wanted to continue to learn about birds. Almost thirty-nine percent of the students said that their interest in *CBW* activities stemmed from a curiosity about birds and that they had come to think about birds and nature in different ways (38.7% for both). Just over forty percent of all students demonstrated an interest in birds (40.9%).

Component 4 – Autonomy

All of the statements correlated in this component deal with student autonomy. The ability to be creative and make choices is important for student autonomy. As students have the opportunity to solve their own problems, make important decisions and acquire the skills that allow them to see themselves as proficient in science they will become more autonomous.

More than half of all students agreed with every statement correlated with autonomy. Students said they felt like they could be creative (57.7%) and make choices (62.0%) during *CBW* activities. Almost sixty-three percent of students felt like their decisions were important during *CBW* activities. Most students felt responsible for solving their own problems (62.8%). Approximately sixty-four percent of students said they felt like they did a good job of observing, identifying and counting birds during *CBW* activities. This measurement is of interest in light of other statements in which students indicated contradictory feelings. For example, only thirty-six percent of the students surveyed (35.7%) felt competent in their *CBW* activities and thirty-four percent of students felt like they were good at the *CBW* activities. Almost sixty-two percent of all students felt autonomous during *CBW* activities (61.9%).

Component 5 - Relatedness

All of the statements correlated in this component deal with relatedness. Of the six components described, the component of relatedness shows the highest total percentage of student agreement (67.5%). Teamwork is important in student engagement both for feedback as well as generation of ideas.

Students strongly described teamwork as important during *CBW* activities (81.8%) and attributed their success as a by-product of their team work (70.8%). Students reported that they used teamwork to bounce ideas off of each other (65.7%). They said they used feedback from others to help them do *CBW* activities as well as understand what they were learning (51.8%).

Component 6 – Outliers

Two survey statements did not fall into the pre-defined student engagement categories. Forty-six percent of the students surveyed said they felt responsible for their own learning during *CBW* activities. Over seventy-percent of students (70.1%) said that *CBW* activities were not too easy and not too hard. Task challenge is defined as those tasks that are not too easy or not too hard. Almost three-fourths of the students felt that *CBW* activities were challenging.

Table 21 shows five identified components of student engagement ordered by frequency of agreement. The sixth component, with two statements, was eliminated from further analysis. The factor analysis demonstrates that the student engagement survey is indeed an instrument that measures students' engagement during citizen science based on a sense of autonomy, competence, relatedness and intrinsic motivation.

Table 21. Components of Student Engagement

Component	**Frequency of Agreement (%)**
Relatedness	67.5
Autonomy	61.9
Intrinsic Motivation	60.4
Interest in Birds	40.9
Competence	35.7

Correlation Analysis

A correlation analysis was conducted for each component. Effect size is generally thought of as the degree to which observed relationships differ from zero. The correlation indicator, Spearman's rho, was obtained to demonstrate effect size because the variables were ordinal measures.

All statements within the following components positively correlated with each other: (1) competence (Spearman $r_s(136) = .284 - .500$, $p< .01$ two-tailed), (2) intrinsic motivation (Spearman $r_s(136) = .350 - .537$, $p< .01$ two-tailed), (3)interest in birds (Spearman $r_s(136) = .235 - .729$, $p< .01$ two-tailed), and (5) relatedness (Spearman $r_s(136) = .272 - .494$, $p< .01$ two-tailed). Not all statements in component 4 (autonomy) correlated positively with each other. See Table 22 for a summary of the Spearman rho values.

Table 22. Correlations within Component 4 (Autonomy)

Statement Number	Correlations Spearman $r_s(136)$ respectively	Significance
2	Statements 3, 4, & 9 .257, .246, .278	$p < .01$ two-tailed
	Statement 19 .206	$p < .05$ two-tailed
3	Statements 2, 9, & 19 .257, .279, .249	$p < .01$ two-tailed
4	Statements 2 and 9 .246 and .303	$p < .01$ two-tailed
9	All statements (2, 3, 4, 19) .278, .279, .303, .316	$p < .01$ two-tailed
19	Statement 2 .206	$p < .05$ two-tailed
	Statements 3 and 9 .249 and .316	$p < .01$ two-tailed

Student rankings for statements within each component were averaged to determine a single component score for each student. A nonparametric correlation analysis was conducted for these composite component values. Removing the two statements from component six, all other components positively corresponded with all other components (Spearman $r_s(136) = .244 - .605$, $p < .01$ two-tailed).

Frequency of Agreement and Repeated Measures Statistical Comparisons Between CBW and Independent Inquiry Surveys

All fifth grade students conducted the independent inquiry as part of unit four of the e*Bird/CBW* project. Twenty of the students completed student engagement surveys about their independent inquiry participation. Not all seventh grade students completed the independent inquiry portion of the *eBird/CBW* project but those students who did participate (n=10) also completed student engagement surveys about their independent inquiry participation. All eighth grade students completed independent inquiries but no student engagement surveys were completed by this group of students because of time limitations and accessibility. Table 22 shows a comparison of frequency of agreement between *CBW* student engagement and independent inquiry student engagement for only those students completing both surveys (n=30). The statement items in the table have been modified to reflect the language on both surveys. An average frequency of agreement of all statements is provided for each component (competence, intrinsic motivation, interest in birds, autonomy, and relatedness).

Table 23. Frequency of Agreement Comparisons Between Student Engagement *CBW* and Independent Inquiry Surveys

Item	Frequency of Agreement on *CBW* n=30	Frequency of Agreement on Independent Inquiry n=30	Difference between the two frequencies of agreement
	(%)		Percentage points
Component 1: Competence	(A + SA) 46.7	(A + SA) 48.3	↑ 1.6
I think I can use the ways I have learned to think and solve problems during *CBW/* Inquiry activities in my daily life.	33.3	30.0	↓ 3.3
Conducting *CBW/* Inquiry activities has helped me to become a better student.	70.0	73.3	↑ 3.3
Doing *CBW/* Inquiry activities gave me the opportunity to think in different ways from my other school subjects.	53.3	53.3	---
Because I was participating in *CBW/* Inquiry activities, I felt connected to the scientists at Cornell Lab of Ornithology.	53.3	46.7	↓ 6.6
Being a part of *CBW/* Inquiry has caused me to think about a future career in science. *(6)	36.7	30.0	↓ 6.7
I thought like a real scientist during *CBW/* Inquiry activities.	33.3	56.7	↑ 23.4
Component 2: Intrinsic Motivation	(A + SA) 69.2	(A + SA) 83.3	↑ 14.1
I liked *CBW/* Inquiry because I like doing science instead of reading about science.	93.3	93.3	---
CBW/ Inquiry activities were fun.	63.3	86.7	↑ 23.4
I was interested in *CBW/* Inquiry activities, my teacher or parents did not have to force me to do the activities.	70.0	93.3	↑ 23.3
I liked participating in *CBW/* Inquiry activities because I was good at it.	50.0	60.0	↑ 10

Component 3: Interest in Birds	(A + SA) 55.9	(A + SA) 60.0	↑ 4.1
I think about birds and nature in different ways.	46.7	43.3	↓ 3.4
I was interested in *CBW/* Inquiry activities because I was curious about birds.	60.0	66.7	↑ 6.7
As a result of *CBW/* Inquiry activities, I want to continue to learn about birds. *(1)	46.7	53.3	↑ 6.6
I will continue to notice different kinds of birds. *(1)	70.0	76.7	↑ 6.7
Component 4: Autonomy	(A + SA) 70.7	(A + SA) 76.7	↑ 6.0
Sometimes, I had to solve my own problems during *CBW/* Inquiry activities.	73.3	73.3	---
I feel like I did a good job of observing, identifying and counting birds during *CBW/* Inquiry activities.	76.7	83.3	↑ 6.6
I felt like my decisions were important during *CBW/* Inquiry activities.	76.7	76.7	---
I was able to be creative during *CBW/* Inquiry activities.	63.3	83.3	↑ 20.0
I was able to make choices about my learning during *CBW/* Inquiry activities.	63.3	66.7	↑ 3.4
Component 5: Relatedness	(A + SA) 80.9	(A + SA) 85.0	↑ 4.1
Working with my team helped me to be successful in *CBW/* Inquiry activities.	90.0	93.3	↑ 3.3
I used feedback from others to help me do *CBW/* Inquiry activities and to understand what I was learning.	50.0	63.3	↑ 13.3
I think teamwork was important during *CBW/* Inquiry activities.	96.7	100.0	↑ 3.3
My group members and I bounced ideas off of each other during *CBW/* Inquiry activities.	86.7	83.3	↓ 3.4

A repeated measures statistical test was used to analyze the overall main effects and interactions between the two surveys and between subject groups (fifth and seventh grade students, males and females). The null hypothesis for this test was that there was no difference between the mean Likert-score (*CBW* or independent inquiry) for each component of student engagement as measured by the student engagement survey, no difference between males and females and no difference between fifth and seventh grade students. A repeated measures test was used because the same subjects took both surveys; therefore, dependency and correlation were expected. The repeated measures test makes an adjustment for the lack of independence.

A repeated measures test was run for each component of student engagement identified in this study (competence, intrinsic motivation, interest in birds, autonomy, relatedness, and all statements combined). The Greenhouse-Geisser analysis was utilized because sphericity could not be assumed. Eta-squared, the percent reduction in error gained by examining group membership, is reported as well as power, the probability of correctly rejecting a false null hypothesis.

There were no significant main effects or interactions among subjects (fifth and seventh graders or between males and females). An increase in intrinsic motivation during the independent inquiry was the only significant difference between *CBW* and independent inquiry, $F(1,1)= 4.82$, $p = .037$, $eta^2 = .156$. Generally, the observed power was low. This is a reflection of the small sample size for this test. To increase power, thus bringing potential main effects or interactions to light, a larger sample size is needed.

Table 24 shows the descriptive statistics for the repeated measures test providing the mean Likert-scale scores and standard deviation for each group of participants. Scores are broken down by component of student engagement and are compared between *CBW* and independent inquiry surveys. Higher standard of deviation was seen for the interest in birds component, especially among seventh graders. When compared to the fifth graders, seventh graders generally had higher standard deviations for the competence component as well.

Table 25 shows the tests of within-subjects effects from the repeated measures analysis. Table 26 shows the tests of between-subject effects from the repeated measures analysis.

Table 24. Mean and Standard Deviation Values for Student Engagement Ratings Organized by Component

	5th Grade Female n=10	5th Grade Male n=10	5th Grade Total n=20	7th Grade Female n=6	7th Grade Male n=4	7th Grade Total n=10
	Mean Likert-scale scores Standard Deviation					
Competence						
CBW	3.13 .689	3.17 .619	3.15 .637	3.47 .833	3.17 .981	3.35 .855
Independent Inquiry	3.33 .689	2.93 .446	3.13 .601	3.67 .823	3.42 .674	3.57 .738
Intrinsic Motivation						
CBW	3.98 .671	3.70 .904	3.84 .788	4.29 .485	4.44 .515	4.35 .474
Independent Inquiry	4.63 .358	4.08 .578	4.35 .547	4.58 .303	4.31 .591	4.48 .432
Interest in Birds						
CBW	3.75 .745	3.58 .825	3.66 .771	3.71 1.16	3.25 1.37	3.53 1.19
Independent Inquiry	3.75 .697	3.83 .698	3.79 .680	3.54 .843	3.31 1.13	3.45 .911
Autonomy						
CBW	4.14 .490	3.76 .645	3.95 .591	4.27 .797	3.75 .526	4.06 .718
Independent Inquiry	4.22 .751	3.90 .598	4.06 .681	4.43 .463	3.90 .808	4.22 .643
Relatedness						
CBW	4.48 .432	4.08 .501	4.27 .499	4.50 .354	4.44 .515	4.48 .399
Independent Inquiry	4.65 .474	4.25 .514	4.45 .523	4.33 .585	4.44 .239	4.38 .460
All statements						
CBW	3.86 .278	3.63 .434	3.74 .374	3.99 .614	3.77 .714	3.90 .627
Independent Inquiry	4.06 .311	3.73 .329	3.90 .355	4.08 .540	3.88 .682	4.00 .572

Table 25. Greenhouse-Geisser Repeated Measures Tests of Within-Subjects Effects

	Sig.	Partial Eta Squared	Observed Power
Competence	.274	.046	.189
Competence X Grade	.206	.061	.239
Competence X Gender	.314	.039	.167
Comp. X Grade X Gender	.196	.063	.248
Intrinsic Motivation	**.037***	.156	.561
Int. Mot. X Grade	.126	.088	.331
Int. Mot. X Gender	.214	.059	.233
Int. Mot. X Grade X Gender	.796	.003	.057
Interest in Birds	.758	.004	.060
Int. in Birds X Grade	.456	.022	.113
Int. in Birds X Gender	.316	.039	.166
Int. in Birds X Grade X Gender	.965	.000	.050
Autonomy	.159	.075	.288
Autonomy X Grade	.796	.003	.057
Autonomy X Gender	.908	.001	.051
Autonomy X Grade X Gender	.837	.002	.055
Relatedness	.627	.009	.076
Relatedness X Grade	.177	.069	.267
Relatedness X Gender	.658	.008	.072
Relatedness X Grade X Gender	.658	.008	.072
All Statements	**.034***	.162	.579
All Statements X Grade	.625	.009	.076
All Statements X Gender	.736	.004	.062
All X Grade X Gender	.588	.011	.083

***p < .05 indicates significance**

Table 26. Greenhouse-Geisser Repeated Measures Tests of Between-Subjects Effects

	Sig.	Partial Eta Squared	Observed Power
Competence			
Grade	.269	.047	.193
Gender	.375	.030	.140
Grade X Gender	.855	.001	.054
Intrinsic Motivation			
Grade	.121	.090	.339
Gender	.234	.054	.216
Grade X Gender	.378	.030	.139
Interest in Birds			
Grade	.406	.027	.129
Gender	.546	.014	.091
Grade X Gender	.652	.008	.072
Autonomy			
Grade	.726	.005	.063
Gender	.072	.119	.439
Grade X Gender	.711	.005	.065
Relatedness			
Grade	.691	.006	.067
Gender	.249	.051	.206
Grade X Gender	.202	.062	.243
All Statements			
Grade	.517	.016	.097
Gender	.152	.077	.296
Grade X Gender	.835	.002	.055

Component 1- Competence

Less than seven percent difference in frequency of agreement occurred between five of the six statements related to competence; however, one statement, “I thought like a real scientist during my inquiry project”, showed a 23.4% increase in frequency of agreement during the independent inquiry project compared to the *CBW* portion of the project. The mean competence frequency of agreement for the *CBW* survey was 46.7%

while the independent survey mean was 48.3%. There were no significant main effects or interactions between subjects.

Component 2- Intrinsic Motivation

This component was the only one to show a significant difference between *CBW* and independent inquiry surveys. Overall, intrinsic motivation showed an increase of frequency of agreement of 14.1 percentage points during the independent inquiry portion of the *CBW* citizen science project, $F(1,1) = 4.82$, $p = .037$, $eta^2 = .156$. The observed power was .561. There were no significant effects between grade levels or gender with a low eta squared value of .156. By examining these two groups, the percent reduction in error is 15.6%.

Of particular interest are two statements within this component that showed higher percent agreement frequencies, "My independent inquiry activities were fun" (23.4% increase) and "I liked participating in my independent inquiry, my teacher or parents did not have to force me to do the activities" (23.3% increase). Overall, intrinsic motivation frequency of agreement during *CBW* was 69.2% and during the independent inquiry was 83.3% (increase of 14.1%).

Component 3 – Interest in Birds

Only small differences were seen between statements referring to interest in birds (3.4% – 6.7%). As with *CBW*, the highest frequency of agreement was with the statement, "I will continue to notice different kinds of birds" (76.7%). Overall, interest in birds frequency of agreement during *CBW* was 55.9% and during the independent inquiry was 60.0% (increase of 4.1%). There were no significant main effects or interactions.

Component 4 – Autonomy

Autonomy frequency of agreement during *CBW* was 70.7% and during the independent inquiry was 76.7% . There were no significant main effects or interactions between subjects. With the exception of one statement, difference between individual statements ranged from 0% to 6.6%. Student frequency of agreement with the statement, "I was able to be creative during my independent inquiry project" increased by 20.0 percentage points from *CBW* participation to the independent inquiry participation.

Component 5 – Relatedness

During *CBW*, relatedness showed the highest frequency of agreement for all components (80.9%). The same was true during the independent inquiry (85.0%). There were no significant main effects or interactions between subjects. Large percentage of agreement increases were not demonstrated in this component due to the fact that frequencies for *CBW* statements were already very high (90.0, 50.0, 96.7, 86.7%). The lowest percent agreement on the *CBW* survey was, "I used feedback from others to help me do my inquiry activities and to understand what I was learning" (50.0%). During the independent inquiry, this value increased by 13.3 percentage points (63.3%). There was one hundred percent agreement among all students that teamwork was important during their independent inquiry.

All Statements

When Likert-scale scores for all statements were compared in the repeated measures analysis, a significant difference between *CBW* and independent inquiry student engagement surveys was indicated, $F(1,1) = 5.028$, $p = .034$, $eta^2 = .162$. The observed power was .579. There were no significant main effects or interactions between subjects.

Quantitative Analysis: Student Engagement Teacher Survey

Data for this portion of this study were collected from the three teachers of the students who took the student engagement survey described earlier. Descriptive data on the schools and teachers participating in the study are included in chapter three. The student engagement teacher survey (Appendix B) had statements that mirrored the statements from the student engagement survey. The purpose of the survey was to compare teacher perceptions of student engagement with student-reported information. All teachers completed the survey at the same time that they participated in the interview described in research question number four.

Table 27 shows the frequency of agreement for both students and teachers on each survey instrument. The differences between the two frequencies were also provided.

Table 27. Comparison Between Student and Teacher-Reported Student Engagement

	Student Frequency of agreement n=137	Teacher Frequency of agreement n=3	Difference	Student Frequency of agreement n=30	Teacher Frequency of agreement n=3	Difference
Competence	35.70	83.30	↑ 47.6	48.30	100.0	↑ 51.7
Intrinsic Motivation	60.40	91.70	↑ 31.3	83.30	100.0	↑ 16.7
Interest in Birds	40.90	100.0	↑ 59.1	60.00	100.0	↑ 40.0
Autonomy	61.90	83.3	↑ 21.4	76.70	100.0	↑ 23.3
Relatedness	67.50	66.70	↓ .80	85.00	100.0	↑ 15.0

For both *CBW* and independent inquiry surveys, frequency of agreement means for the teachers were higher than for the students (with the exception of relatedness during *CBW*). Generally, teachers perceived students to be more competent, intrinsically motivated, interested in birds and autonomous than what was actually reported by students.

Research Questions #3 and #4

3. *How do students report the types of scientific inquiry cognitive processes utilized during their participation in the eBird/Classroom BirdWatch citizen science project?*
4. *How did classroom teachers report student engagement in the cognitive processes associated with scientific inquiry during the eBird/Classroom BirdWatch citizen science project?*

Data Description, Administration and Management

A card sort interview procedure was used with student focus groups. Students who conducted independent inquiry projects together participated in the focus group together. The card sort was used to determine the reasoning tasks students used during their independent inquiry projects. Six different colored cards represented the six cognitive processes associated with science. Statements representing either authentic or simple science reasoning tasks were printed on the cards. There were eight statements for *generating research questions*, eleven for *designing a study*, ten for *making observations*, sixteen for *explaining results*, seven for *developing theories* and nine for *study others' research*. Students were reminded that the cards were about only their inquiry project, not any other part of *CBW*. Students were instructed to sort the cards into one of three piles: 1) those statements they agreed would definitely describe what they did or thought about during their project, 2) those statements they agreed might describe what they did or thought about during their project, and 3) those statements that they agreed would not describe what they did or thought during their project. As a group, students decided which pile was most appropriate for each statement.

Appendix C contains the data collection instrument used as well as coding for student responses (whether they were authentic science or simple science). A score of one (1) indicated students answered in a manner that reflected authentic science, a score of two (2) indicated students answered in a manner that reflected simple science and a score of three (3) was used for all 'maybe' answers. Data were entered into an SPSS spreadsheet.

Descriptive Statistics

Data for this portion of this study were collected from forty students in three schools. Data on the schools participating in the study are included in Chapter III, Table 11. Twenty of the students were fifth graders, ten were seventh graders and ten were eighth graders. Fifty percent of the students were female (n=20). There were fifteen groups of students with seven groups being all male, seven groups all female and one group half male and half female.

Frequency Analysis

Yes, no and maybe statements were counted for each grade level and a frequency of agreement for each statement was determined by dividing the number of yes statements by the number of total groups (n=15). Table 28 shows the statements from the card sort that related to specific reasoning tasks. Some statements were phrased negatively. For example, the first statement was, "Our research question was suggested to us by our teacher or another adult". If students answered yes for this statement then simple inquiry would be indicated. For clarity, all statements in Table 28 are worded in the positive for authentic science (rephrased statements have NOT). Frequency of agreement values were adjusted for negative statements. Additional qualitative data were collected as student conversations were audio-recorded during the focus group interview session.

Table 28. Frequency of Student Responses on the Card Sort

Cognitive Process and Reasoning Tasks	Frequency of Agreement with Statement			
	5th n=6	7th n=5	8th n=4	All groups n=15
Generate Research Questions				
Our research question was NOT suggested to us by our teacher or another adult.	50.0	40.0	100.0	60.0
Our research question was based on something we saw.	50.0	20.0	25.0	33.3
Our research question was based on something another student said or did.	0	20.0	25.0	13.3
Our research question was based on something we read in the *Classroom BirdWatch* materials or some other type of research study.	33.3	20.0	25.0	26.7
Our research question was based on our own curiosity.	83.3	80.0	100.0	86.7
Designing a study				
We DID NOT follow steps in the *Classroom BirdWatch* materials or from our teacher.	33.3	20.0	0	20.0
We made up our own steps.	66.7	20.0	0	33.3
We decided on our own variables.	66.7	40.0	50.0	53.3

Our teacher DID NOT tell us what variables to use.	66.7	40.0	100.0	66.7
We did not have any variables, we only observed birds.	83.3	100.0	100.0	93.3
We thought about our procedures and wondered if they were any good.	50.0	100.0	100.0	80.0
We changed our procedures to make our experiment better.	83.3	80.0	50.0	73.3
We figured out the kind of data we needed to collect on our own.	50.0	20.0	75	46.7
Our teacher DID NOT tell us what kind of data to collect.	83.3	40.0	100.0	73.3
Making observations				
We looked at and counted birds.	66.7	80.0	75.0	73.3
We DID NOT only look at birds.	83.3	100.0	100.0	93.3
We checked each others observations or counts.	66.7	60.0	100.0	73.3
We thought about whether our bird identifications were accurate.	33.3	60.0	25.0	40.0
We thought about ways to improve our observations to make them more accurate.	83.3	40.0	50.0	60.0
We used cameras or electronic sound recording devices to check our observations.	0	0	0	0
The purpose of our experiment was NOT to describe something through careful data collection.	50.0	60.0	75.0	60.0
The purpose of our experiment was to test our thinking through careful data collection.	50.0	60.0	75.0	60.0
Explaining results				
We DID NOT make graphs of our data.	0	0	0	0
We submitted our data to *eBird*.	0	0	0	0
We found mean (average), median and mode with our data.	33.3	100.0	75.0	66.7
We used statistics to help us understand our data.	0	0	100.0	26.7
Our teacher or the *CBW* materials DID NOT show us how to organize our data.	50.0	20.0	25.0	33.3
We sometimes got unexpected results from our data.	50.0	80.0	75.0	66.7
We DID NOT think our unexpected results were because we did something wrong.	83.3	60.0	100.0	80.0

We DID NOT think our unexpected results were because we did not understand the data very well.	83.3	100.0	100.0	93.3
We think our unexpected results just shows that our hypothesis was wrong (not supported).	16.7	60.0	50.0	40.0
We think uncertainty is just a natural part of the scientific process.	83.3	100.0	75.0	86.7
Even though we got the results we expected, we wondered if our procedures were good.	33.3	40.0	75.0	46.7
We thought about possible errors we may have made in our data analysis or interpretation.	50.0	100.0	100.0	80.0
When we looked at our results we thought of other ideas for what the data might be telling us.	33.3	40.0	100.0	53.3
We talked about ways we could check our findings.	50.0	60.0	25.0	46.7
We were responsible for deciding how to analyze our data.	100.0	100.0	75.0	93.3
We worked together to understand and explain our data.	83.3	100.0	100.0	93.3
Developing theories				
We used evidence to support our explanations.	83.3	100.0	100.0	93.3
We used results from other studies to help us explain our data.	33.3	60.0	0	33.3
We read other studies that had similar results to our investigation.	0	60.0	25.0	26.7
We read other studies that said something different from what we found in our study.	16.7	0	25.0	13.3
We looked at other data on *eBird* to add to our learning.	0	20.0	0	6.7
Our purpose in this investigation was NOT to find out something that scientists already knew.	33.3	40.0	50.0	40.0
Our purpose in this investigation was to find out something that scientists DID NOT already know.	16.7	40.0	50.0	33.3
Studying others' research				
We read other peoples research to help us develop or understand our research question.	50.0	60.0	25.0	46.7
We read other studies to learn about standard steps for collecting certain types of data.	66.7	100.0	100.0	86.7

We read other studies to learn about what variables we needed to control and measure.	16.7	40.0	100.0	46.7
We read other studies to think about how to fit our study in with the work of other researchers.	0	40.0	25.0	20.0
Other students read our work and gave us feedback (peer review).	50.0	60.0	100.0	66.7
We used other student feedback to help us know what to do.	16.7	40.0	50.0	33.3
We used other student feedback to help us understand our data.	0	0	25.0	6.7
We reviewed the work of other students & gave them ideas (peer review).	66.7	60.0	75.0	66.7
We looked at information in the *eBird* database to give us ideas about our research.	0	20.0	0	6.7

The majority of students (86.7%) reported that their *research questions* were based on their own curiosity. Smaller numbers of students said their research questions were based on something another person said or did (13.3%), some other type of research (26.7%), or something they saw (33.3%). A majority of students said their research question was NOT suggested by a teacher or another adult (60.0%). Students reported they had observed birds both at school and at home and in some cases this helped to shape their research questions. When talking about how their research questions were generated students said, “We had seen the birds come at different times throughout the school year, and active at certain times” (seventh grade research question: Does the presence of crows affect other bird visitation to our school feeders?), “We saw birds coming to the fly-through feeders” (fifth grade research question: Do flythrough feeders affect the number of birds that come to our sanctuary?) or “I have a bird feeder at home and I watch birds” (Eighth grade research question: Will the type of berry affect how much of the berries bird eat?). Students suggested their research questions were generated based on several types of reading materials such as classroom bird tally sheets, student journals, the *Classroom BirdScope* journal or from teacher discussions of previous student projects. One student's statement sums up the general belief of most students, "Some of our questions were based on prior knowledge about what we already knew about birds. Sometimes we didn't really even know it was a question, we just asked it".

Within the cognitive process, *designing a study*, students most often said they thought about their procedures and wondered if they were any good (80%) and they changed their procedures to make their experiments better (73.3%). However, as students described their 'changes' for me, they often talked about making changes to accommodate their own schedules or needs instead of making changes to improve experimental conditions for the experiment's sake.

Only about a third of the students said they made up their own steps (33.3%). The remainder said they followed steps that were provided by either their teacher or the *CBW* materials (66.7%). Students indicated their teachers were often very instrumental in helping them to develop their study. Only about one-half of the students said they decided on their own variables (53.3%) or figured out the kind of data they needed to collect on their own (46.7%). In general, students had trouble identifying the variables of their project for me during the focus group interview. The following is an excerpt from one of the focus group interviews. It is characteristic of many of the comments made my students on this subject.

Students: “We decided on our own variables. Maybe.”

Researcher: “What were your variables?”

Students: “We don’t know, we didn’t think about it.”

Researcher: “Did you have an independent variable? The independent variable is the thing that you change.”

Students: “Humidity”

Researcher: “What was your dependent variable? The dependent variable is the outcome, the thing you measured or counted?”

Students: “The number of bird?”

Researcher: “Did you have any controlled variables. Did you hold anything constant, keep it the same?”

Students: “Not really.”

As students thought about the cognitive process, *making observations*, only sixty percent of the groups reported they considered ways to improve their observations to make them more accurate. Students reported using field guides, charts, the computer, and their teacher to substantiate bird identifications. Students described their experiment as testing their thinking through careful data collection (60%) as opposed to simply describing something through careful data collection (40%). Almost three-fourths of the groups said they checked each others observations or counts (73.3%).

For the cognitive process, *explaining results*, the highest frequency of agreement was with the statements, “We were responsible for deciding how to analyze our data” and “We worked together to understand and explain our data” (93.3% for each). A number of groups described their uncertainty about their results as a natural part of the scientific process (86.7%). Half of the fifth grade groups and all of the seventh and eighth grade groups said they thought about possible errors made in data analyses or interpretations. All groups said they transformed their data into graphs but only the eighth grade groups said they used statistics to transform and understand their data. The majority of students did not discuss ways they could validate their findings (46.7%) and just over half of the students considered alternative explanations during data interpretation (53.3%).

A large majority of students (93.3%) said they used evidence to support their explanations. All other statements within the cognitive process, *developing theories*, had lower percentages of agreement (6.7 - 33.3%). Generally, students did not coordinate results from other studies to contribute to or inform their understanding of their own investigation. No student groups could identify theories that were constructed from their evidence.

Students reported they *read other studies* to learn about standard steps for collecting certain types of data (86.7%) but they did not use other studies to think about how their study would fit in with existing work (20.0%). Just under fifty-percent of the student groups said they use others' research to help them develop or understand their research question or learn about what variables they needed to control or measure (46.7% each). *Classroom BirdScope* and the *CBW* curriculum were publications most often cited by students as the source of the "others' research". Students reported they participated in a peer review process by both having their work reviewed and reviewing the work of others (66.7%); however, on probing, most peer review was in the form of editing suggestions for final papers or posters. Students described the peer review process, “We used peer review when we were done with the project and finished writing the report. Other kids circled words to tell us what did not make sense. We did not get any feedback during the project; we kept to ourselves and did not tell others what we were doing”.

Simple or Authentic Science

For this analysis, I coded each statement with a ‘one’ or ‘two’. If the students responded to the statement in a manner that reflected authentic science a code of ‘one’ was given. If the student group responded in a manner that reflected simple science a code of ‘two’ was given. I then determined the percent of statements within each cognitive process that students responded to in an authentic science manner.

Students responded in the authentic science manner for fifty-seven percent of the statements under the cognitive process *generating research questions*. Authentic science *designing a study* statements were indicated eighty-two percent of the time, *making observations* statements eighty percent of the time, and *explaining results* sixty-nine percent of the time. *Developing theories* had the lowest percent of occurrence with only twenty-five percent of the student responses reflecting authentic science. Students responded according to authentic science for fifty-six percent of the statements under the cognitive process *studying others’ research*. Table 29 shows these percentages in descending order.

Table 29. Frequency of Agreement with Authentic Science Statements for each Cognitive Process Category

Cognitive Process	**Frequency of Agreement with Authentic Science Statements**
Designing a study	82%
Making observations	80%
Explaining results	69%
Generating research questions	57%
Studying others' research	56%
Developing theories	25%

Analysis of Variance

An analysis of variance was conducted using SPSS, *Statistical Package for the Social Sciences*. The following hypotheses were developed and tested at the alpha less than .05 level of significance.

Hypothesis One: There are no significant differences in cognitive process scores between males and females.

Hypothesis Two: There are no significant differences in cognitive process scores among fifth, seventh and eighth grade students.

Tables 30 and 31 contain the results of the ANOVA test used to analyze the data and test the hypotheses. The only significant difference between males and females was for the cognitive process *making observations*, F(2,12)=5.252, *p*=.023, eta^2=.467. The cognitive process, *explaining results*, showed the only significant statistical difference among the three grade levels, F(2,12)=6.098, *p*=.015, eta^2=.504 .

Table 30. ANOVA Cognitive Processes for Gender (n=15)

Cognitive Process	Female Mean (Std. Dev.)	Male Mean (Std. Dev.)	Statistical Difference $p < .05$*	Eta Squared
Generating research questions	1.6 (.129)	1.6 (.327)	.981	.003
Designing a study	1.4 (.209)	1.6 (.187)	.303	.181
Making observations	1.3 (.163)	1.6 (.276)	**.023***	.467
Explaining results	1.5 (.171)	1.6 (.212)	.208	.230
Developing theories	1.7 (.373)	1.9 (.216)	.327	.170
Studying others' research	1.7 (.301)	1.7 (.239)	.802	.036

***p < .05 indicates significance**

Table 31. ANOVA Cognitive Processes for Grade Level (n=15)

Cognitive Process	5th grade Mean (Std. Dev.)	7th grade Mean (Std. Dev.)	8th grade Mean (Std. Dev.)	Statistical Difference $p < .05$*	Eta Squared
Generating research questions	1.7 (.195)	1.6 (.313)	1.5 (.137)	.403	.141
Designing a study	1.5 (.280)	1.6 (.144)	1.4 (.155)	.724	.052
Making observations	1.5 (.223)	1.5 (.404)	1.4 (.275)	.856	.025
Explaining results	1.7 (.166)	1.5 (.151)	1.3 (.139)	**.015***	.504
Developing theories	1.9 (.202)	1.8 (.447)	1.7 (.309)	.790	.039
Studying others' research	1.8 (.136)	1.7 (.328)	1.5 (.256)	.082	.341

*** p < .05 indicates significance**

Student Research Reports

While analyzing fifth, seventh and eighth grade student research reports, I found the following reasoning tasks most frequently:

- Single prescribed outcome measured,
- Counting,
- No controlled conditions,
- Data transformation, graphing,
- Direct reasoning, and
- Direct observations not connected to theory.

Other reasoning tasks were seen less frequently:

- Observing prescribed features,
- Considering alternative mechanisms to explain results,
- Reading research of others,
- Building on the work of others,
- Simple contrastive/causal reasoning, and
- Single controlled conditions or multiple controlled conditions.

Cognitive Processes and Student Engagement

Some card sort statements reflected student engagement as defined by a sense of autonomy, competence, relatedness and intrinsic motivation. The qualitative data were converted to quantitative data by assigning frequency counts to agreed upon statements.

Table 32 provides a list of the statements related to this research question with corresponding frequency of agreement by grade level and total.

Table 32. Frequency of Agreement with Student Engagement Statements

Student Engagement Component	Abbreviated Statement	5th grade	7th grade	8th grade	total
		Frequency of agreement (%)			
Autonomy	Generating our own research question allowed us to be creative.	66.7	80	100	80
	We made up our own steps.	66.7	20	0	33.3
	We figured out the kind of data we needed to collect on our own.	50	20	75	46.7
	We were responsible for deciding how to analyze our data.	100	100	75	93.3
Competence	We felt confident in generating our own research question.	83.3	100	75	86.7
	We were happy with the study we designed.	83.3	100	100	93.3
	We thought we did a good job of making accurate observations.	83.3	80	75	80
Relatedness	We designed a good study because we worked together.	83.3	100	100	93.3
	We worked together to understand and explain our data.	83.3	100	100	93.3
	Other students read our work and gave us feedback.	50	60	100	66.7
	We used other student feedback to help us know what to do.	16.7	40	50	33.3
	We used other student feedback to help us understand our data.	0	0	25	6.7
	We reviewed the work of other students & gave them ideas	66.7	60	75	66.7
Intrinsic Motivation	We enjoyed identifying and counting birds.	83.3	60	100	80

Students said generating their own research question allowed them to be creative (80%); however, few student groups reported they made up their own steps (33.3%) or figured out the kind of data they needed to collect (46.7%). Students felt they were responsible for deciding how to analyze their data (93.3%). Students reported they thought they did a good job of making accurate observations (80%), felt confident in generating their own research questions (86.7%) and were happy with the study they designed (93.3%). Most student groups said they worked together to understand and explain their data and attributed their success in designing a good study to working together (93.3% for each). However, students did not feel they used feedback from other groups of students to extend their learning or receive help on their project (6.7% - 66.7%). Eighty percent of the student groups agreed they enjoyed identifying and counting birds.

Teacher Perspectives

Qualitative data were collected from teachers in three forms: 1) unit surveys, 2) teacher version of the student engagement survey and 3) teacher interviews. Teacher interviews were audio-recorded and transcribed. The narratives were coded using the content analysis software NUDIST. After initial review of the data, coding categories were established. I will describe the perspectives of each teacher and then provide a brief combined analysis.

Miss Call wants her students to be able to connect with nature in a way that will encourage them to want to preserve the natural environment. She described how students and parents became “fascinated” with birds. “When you get kids involved in something like this [*CBW* citizen science] it helps them to really focus in on the necessity to preserve nature. When kids start to learn to appreciate even something like a bird it will instill in them a sense of preservation of life no matter what". Miss Call believes that students will find long-term utility in *CBW* participation. "It [Birding] gives them something they can do for the rest of their lives".

Miss Call works to generate student interest by inviting a local naturalist to visit the classroom to guide children in their developing understandings about birds. She found that students progressed in their observation abilities but not in their abilities to develop and design experiments to find out answers for questions that were being raised. After examining the *CBW* explorations she reports, "I felt that these explorations might be the very thing to help us accomplish our next goal of putting our birding skills to work and experiment and answer the questions that arise as we complete our daily observations throughout the year".

Miss Calls describes her students' participation, "They really feel like scientists and they take their counts and submitting of information very seriously. They are also very serious about maintaining the stationary feeders at the school and developing an understanding of their responsibility in this program". As students begin to "feel like scientists", Miss Call sees the need for students to "take field trips to visit scientists at work and to research and interview scientists in their various fields." During the *CBW* portion of the project, students read *Meet the Scientist* reports. Miss Call felt like the reports allowed her students to better understand the process of science. The reports helped students to generate questions about scientists and their specific studies. Miss Call realizes the importance of a strong student-scientist connection to improve the overall citizen science participation. "I wish it would have been possible to provide other instances for meeting and talking with scientists in person".

Mr. Brown's overall goal in having his students participate in this citizen science project was "to get kids to appreciate nature more". He believes "kids like playing the role of scientist" and as a result of recording data and submitting it to Cornell Lab of Ornithology students learn to "appreciate it's worth", helping them "feel like they are part of the scientific process". Mr. Brown is attracted to citizen science projects for his students because it is "something different and more meaningful to the kids".

Miss Edwards believes student motivation is higher with citizen science. She has noticed a "striking difference with the kids when they have more of their own investment…because their own interests are being pursued". Miss Edwards believes students related more to their own surroundings during this type of science. While monitoring the health of pine trees in their own town, students "feel like they are doing something that really matters…it is more relevant and hits home better for them". An additional value to the citizen science participation is that students can get "out of the classroom" and have access to different types of scientific tools. Her main goal in *eBird/CBW* participation was for students "to realize that they could come up with questions and really research and come up with the answer themselves and to take part in the process of science so that they get how to solve a question or how to solve a problem rather than me saying first you do this and then you do that".

When referring to student participation in *CBW*, Miss Edwards said activities or class discussions often took longer than planned because "kids were interested and had a lot to say". She felt that students became more "motivated" as their skills in bird identification improved.

On the teacher version of the student engagement survey, teachers were asked to rate student experience for the cognitive processes associated with scientific inquiry. Table 33 shows average teacher responses. A rating of "1" indicated no experience while a rating of "5" indicated extensive experience. Teachers described that students gained more experience with the following cognitive process during the independent inquiry: *generating research questions, designing a study, explaining results*, and *developing theories*.

Table 33. Teacher Ratings of Student Experience with Cognitive Processes

Cognitive Process	Average Rating for *CBW*	Average Rating for Independent Inquiry
Generating research questions	3.6	4.3
Designing research studies	3.6	4.7
Making observations	4.7	4.7
Analyzing data	4.3	4.3
Explaining results	3.6	4.3
Developing theories	3.6	4.3
Communicating ideas	4.3	4.7
Studying other's work	4.3	4.3
Peer review of classmate work	4.3	4.3

All teachers agreed that during *CBW* units 1-3, student research questions were provided by the teacher or curriculum materials, inquiry steps were prescribed and students were observing specified features. To explain results, simple datum transformation was employed, specifically, drawing. All of these reasoning tasks are associated with simple inquiry.

During the independent inquiry (unit 4), teachers agreed that students developed their own research questions based on observations or their own curiosity. Both inquiry steps and variables were determined by the student researchers and students critically reflected on their methods. Students not only made observations but they also took measurements and transformed data using graphing and statistics. Students utilized indirect reasoning to explain results. Additionally, teachers reported that students studied others' research by reading research of others, building on work of others, and conducting peer review of findings. All of these reasoning tasks are associated with authentic inquiry science. The only simple inquiry reasoning tasks identified by teachers were: single controlled conditions, drawing as a form of datum transformation, and direct reasoning that involved straight forward inferences.

Summary

The purpose of this chapter has been to present evidence of student engagement in the cognitive processes of inquiry science from three perspectives: 1) the viewpoint of the citizen science project developer, 2) the viewpoint of students engaged in citizen science, and 3) the viewpoint of teachers. Results for this study have been presented and organized by research question.

The findings in this chapter show that a range of authentic inquiry reasoning tasks were promoted and practiced during the *eBird/CBW* citizen science project. Students and teachers agreed that during the independent inquiry portion of the project students were able to generate their own research questions based on their own curiosity. Student relied on their teachers to help them design their inquiry studies. Teachers helped students to develop research procedures, decide on paired independent and dependent variables, and to figure out the kind of data to collect. Students said that they thought about their procedures and wondered if they were any good. Students used field guides, charts, the computer, each other and their teachers to confirm observations and guard against perceptual bias. The majority of students viewed their work as “testing their thinking through careful datum collection” as opposed to “simply describing something through careful datum collection”.

Student transformation of data were more frequently done with drawing and graphs. Most students said they were responsible for organizing and analyzing their own data. Students considered experimental flaws in data analyses and interpretation and more frequently attributed this to uncertainty being a natural part of the research process. Some students considered alternative explanations during data interpretation as well as ways to validate their finings.

Evidence for student engagement in the cognitive process, *developing theories*, was limited. Students reported that they used evidence to support explanations but they did not attempt to construct any underlying theory, perform multiple studies on the same topic, or coordinate results from multiple studies. In general, students were directly observing empirical phenomena to gather facts about the natural world. Students did read the research of others to help them learn about standard steps. Some students said that the research of others helped them to develop or understand their research question and procedures. The research of others' most often cited by students and teachers was the *Classroom BirdScope* journal or *CBW* curriculum materials.

Students more frequently agreed with authentic science inquiry reasoning tasks associated with the cognitive processes *designing a study*, *making observations*, *explaining results*, *generating research questions,* and *studying others' research*. Students, teachers and *CBW* project developer/coordinator all suggested that *developing theories* was one cognitive process where students participated in more simple inquiry manner. The cognitive process, *making observations*, was the only one to have a statistical difference between males and females. *Explaining results* was the only cognitive process to show a statistical difference between grade levels.

Student engagement was described by the psychological needs of a sense of autonomy, competence and relatedness as well as intrinsic motivation. During both the teacher-guided part of *eBird/CBW* (units 1-3) and the independent inquiry (unit 4), students felt related, autonomous and intrinsically motivated. All three of these components had higher frequency of agreement ratings during the independent inquiry portion of the citizen science project. The difference for intrinsic motivation was statistically significant. Students said the independent inquiry was more interesting and fun, allowed them to be more creative and encouraged them to think more like a real scientist than the teacher-guided units of *CBW*. All survey statements being considered, there was a statistical significant difference between *CBW* ratings and independent inquiry ratings.

There was little difference between the two parts of the citizen science project with respect to the student engagement component, competence. The student engagement survey instrument did not measure high frequency of agreement on competence related statements. Students did not feel that *CBW* or inquiry activities connected to their daily life or caused them to think about future careers in science but they did feel that the activities helped them to be better students.

Chapter V provides a discussion and interpretation of these differences as well as offers a line of reasoning for implications of these findings for science education. The chapter will begin with a discussion of the cognitive processes promoted and practiced during *eBird/CBW* citizen science participation. Student engagement as part of citizen science will be described. Implications for these findings and suggestions for citizen science program modifications will be provided.

CHAPTER V

DISCUSSION & CONCLUSIONS

"The objective is to teach the student to see the land,
to understand what he sees, and enjoy what he understands."
Aldo Leopold

Research Overview

The purpose of this study was to expand the taxonomy of differences between authentic scientific inquiry and simple inquiry tasks to include those inquiry tasks associated with participation in citizen science and to further describe how students engaged in this type of science. This research has shown that *eBird/CBW* citizen science engages students in reasoning tasks associated with both simple and authentic scientific inquiry. Using the continuum of reasoning tasks offered by Chinn & Malhotra (2002), citizen science is more like authentic science than textbook science for some cognitive processes. Additionally, students generally demonstrated a sense of relatedness, autonomy and intrinsic motivation but did not demonstrate a sense of competence while participating in *eBird/CBW* citizen science.

This chapter begins with a discussion and interpretation of the results presented in chapter IV. Reflections on these findings in light of studies discussed in Chapter II will also be included. Data analyzed consisted of responses to student and teacher surveys, interviews (both individual and focus groups) as well as various document analyses.

Implications of these findings for implementation of citizen science in the classroom as well as future areas of research suggested by this study will also be offered.

Discussion, Interpretations and Suggestions

Cognitive Processes Promoted and Practiced Promoted and Practiced Promoted and Practiced During eBird/CBW Citizen Science and Suggestions for Citizen Science Modifications

My research goal was to determine the types of cognitive processes associated with scientific inquiry that were promoted during the *eBird/CBW* citizen science project and to establish the extent to which those identified processes reflected authentic scientific inquiry. I was particularly interested in which features of authentic inquiry were incorporated regularly into the existing tasks and which were incorporated only rarely. With this background, the next part of this project was to describe the ways that students participated in citizen science, identifying the cognitive processes they engaged in and whether their reasoning tasks were more like simple inquiry or authentic scientific inquiry. I chose to examine this from two perspectives: 1) the students' self-reported perspective and 2) the teachers' perspective.

Chinn & Malhotra (2002) characterized and compared inquiry tasks in fifth through eighth grade school textbooks (n=9 textbooks, 468 tasks) as well as inquiry tasks developed by psychologists and educational researchers (n=26 tasks) with the cognitive processes associated with authentic scientific inquiry. Throughout this discussion section, reference will be made to how citizen science compares to both of these with reference to the reasoning tasks associated with the cognitive processes of scientific inquiry as described in chapter II. This focus is important because school science is often perceived as a form of science that is very different from the science that real scientists do (Rahm, Miller, Harley, & Moore, 2003). A proposition of this study was that citizen science is more like authentic science than school textbook science and provides a more scaffolded approach to the more complex aspects of authentic science inquiry.

Generating Research Questions, Studying Others' Research, and Making Observations

A range of authentic inquiry reasoning tasks were promoted during the *eBird/CBW* citizen science project. Students were encouraged to generate their own research questions based on observations, other's work and their own curiosity. They were encouraged to read the research of others for the purpose of building upon others' work and to review the work of their peers. Making accurate observations was promoted as being important but no suggestions were made for developing techniques to guard against perceptual bias.

Students reported they generated their own research questions. This type of reasoning task is often missing in simple science learning where students are typically provided a research question by the teacher or curriculum materials (Chinn & Malhotra, 2002). Chinn & Malhotra (2002) reported that no textbook activities allowed students to generate their own research questions. This practice was also uncommon for researcher-generated inquiry tasks.

During the *eBird/CBW* citizen science project students were given the opportunity to develop their own research questions based on their observations, curiosity and the work of others. Students reported their research questions were most often based on their own curiosity as opposed to research questions presented by the teacher or curriculum materials. Students said, “We had seen the birds come at different times throughout the school year, and active at certain times”. Student curiosity was encouraged as children noticed and became more familiar with birds. Participation in the *eBird/CBW* citizen science project may have been a type of ‘question engine’. Question engines are activities that engage students in making observations and developing inferences as a precursor to generation of student research questions (Saul, Dieckman, Pearce, & Neutze, 2005). Developing research questions is an important part of scientific inquiry because it organizes and gives meaning to the inquiry process (Lehrer, Schauble, & Petrosino, 2001). Teachers agreed that students developed their own research questions based on observations or their own curiosity. All three teachers related how students developed questions from “watching the birds over the course of a period of time”.

An important precursor to research question generation and designing a study is for students/scientists to study the research of others for the purpose of determining what is already known in the field. Throughout the citizen science experience, students were encouraged to read the research of others, build on the work of others and participate in peer review of findings. Students and teachers said they read other studies but mostly for the purpose of learning about standard steps for collecting certain types of data. Scientists read research literature for a variety of reasons: 1) to learn about standard protocols for collection of data, 2) to learn what variables need to be controlled and measured, and 3) to determine how to ground their research in the theoretical and empirical work of other scientists (Chinn & Malhotra, 2002). Students used several types of reading materials to help them: 1) classroom bird tally sheets, student journals and the *Classroom BirdScope* journal. One teacher described how students generated research questions after examining the *Classroom BirdScope* journal and the *Christmas Bird Count* Database.

None of the textbook inquiry tasks analyzed by Chinn & Malhotra (2002) provided students with an opportunity to study expert research reports. A limited number of researcher-developed inquiry tasks (12%) provided for learners to read abbreviated magazine-style research reports (Chinn & Malhotra, 2002). During *eBird/CBW* citizen science, students had several opportunities to read abbreviated research reports by Cornell Lab of Ornithology scientists as well as peer-reviewed research reports written by other students in *Classroom BirdScope*. Although peer review is promoted throughout the citizen science program, students more frequently used the peer review process for editing help on final papers or presentations and not for critical analyses of data or methods. The ways that students engaged in the cognitive processes, *generating research questions* and *studying other's research*, during *eBird/CBW* citizen science have many similarities to authentic inquiry science because student questions were generated based on curiosity, their own observations and the research of others. Students also used their study of other's research to learn about standard steps for collection of data.

Throughout the citizen science participation, students were making observations. Students checked peer observations and considered ways to improve their observations but did not use any other techniques to guard against perceptual bias. Chinn & Malhotra (2002) did not report on either textbook tasks or researcher-developed tasks with reference to developing techniques to guard against perceptual bias in observations.

Leach (1998) suggests that school science does not encourage students to evaluate knowledge claims and data but instead promotes science as a process of description through careful data collection. Students participating in *eBird/CBW* citizen science however, described the purpose of their experiment as testing their own thinking. This epistemological viewpoint is important in authentic scientific inquiry. In the area of *making observations*, citizen science participation is more like authentic scientific inquiry than simple inquiry when compared to school textbooks.

To promote additional reasoning tasks associated with authentic scientific inquiry, citizen science projects and/or the teachers implementing those projects should encourage the use of peer review during all aspects of the inquiry process from research question generation to communication of results. Working in collaborative groups, students can experiment with ideas in a 'critical friends' setting, mold and shape those ideas as a result of feedback from others and provide the same type of critical feedback and suggestions to their peers. This type of collaborative, peer review process does not come naturally for students who have learned to value only right and wrong answers in the school setting. Intellectual risk-taking must be promoted, encouraged and valued by the classroom teacher. As part of their citizen science participation, students should be encouraged to use peer review in all parts of the inquiry process to help in: 1) developing a good research question, 2) designing appropriate experimental procedures to answer the research question, 3) examining and interpreting evidence, 4) developing theories, and 5) communicating findings and conclusions.

Students participating in citizen science should read the research of others to help them develop good research questions by: 1) identifying what is already known about a topic, and 2) determining what still needs to learned as a result of a gap in the literature. This step is important in authentic scientific inquiry to help students/scientists to ground their research in the theoretical and empirical work of other scientists. Finding research of others that is appropriate for the reading level of fifth through eighth grade children can be problematic. The *eBird/CBW* citizen science project has addressed this need with the publication of the *Classroom BirdScope* student research journal and with smaller case studies of scientists in the *CBW* curriculum (*Meet the Scientist Reports*). An additional approach to reading the research of other is for students to analyze raw data. During *eBird/CBW* citizen science this is possible with the Internet *eBird* database. I found limited use of the *eBird* database among students involved in this project and would recommend more access to this resource as a way for students to study the research of others.

Although students made multiple and frequent observations over long periods of time, they were not encouraged to specifically consider techniques to guard against perceptual bias. This is an additional area where the citizen science participation might be refined. For example, if students were encouraged to use electronic recording equipment (video or audio) to collect bird observation data, this could be used to confirm observations and identifications thus reducing perceptual bias.

Designing a Study, Explaining Results, and Developing Theories

The *eBird/CBW* curriculum materials encouraged students to design their own experiments to test their research questions. The *eBird/CBW* materials prompted students to design their own experimental studies including determining variables and critically reflecting on methods. Students were encouraged to use evidence to support their explanations and coordinate results from multiple studies but other reasoning tasks associated with *explaining results* or *developing theories* were more like simple science.

Students reported they did not develop their own experimental procedures; instead, they followed steps provided by their teacher. In most cases, students used a single paired independent and dependent variable. The three teachers however, agreed that students developed their own steps during the independent inquiry and that they also determined their own variables and critically reflected on their methods. This difference of perception is important when considering students' sense of autonomy. Although teachers believed students were determining their own steps, students did not believe this. Student engagement in a learning task requires that students feel a sense of ownership and responsibility as well as have the power to make decisions in their learning. To participate in authentic scientific inquiry, students must see themselves in the role of experiment designer.

The majority of both fifth and eighth grade students reported that they determined the kind of data to collect on their own. When students decide on the type of data to collect, they are more likely to engage in the types of thinking and reasoning that are required to evaluate the appropriateness of the type of data compared to the research question (Chinn & Malhotra, 2002). Students also agreed they thought about flaws in their own procedures. Students selecting their own variables, developing simple controls, and considering possibilities of methodological flaws were three areas where Chinn & Malhotra (2002) found that textbook science inquiry tasks were lacking (2%, 4% and 2% of textbook inquiry tasks, respectively). The textbook science inquiry tasks they evaluated provided procedures for students and did not encouraged them to consider methodological flaws.

In general, authentic scientific inquiry is complex in nature. Although students did not appear to develop their own experimental procedures during their citizen science participation, they did feel they made decisions about the types of data to collect and they considered methodological flaws in their procedures. Overall, this area of *designing a study* had more reasoning tasks associated with simple inquiry than with authentic scientific inquiry.

Authentic inquiry science reasoning tasks associated with *explaining results* and *developing theories* appeared less frequently in both student and teacher reports. Students reported they were responsible for deciding how to analyze their data but did not consider ways to validate their findings or consider alternative explanations during data interpretation. For the most part, data transformation was simple drawing or graphing. Teachers said that students used indirect reasoning to explain their results but an analysis of student research reports showed only direct reasoning. No student groups could identify theories that were constructed from their evidence.

The limited nature of representation of these cognitive processes (*explaining results* and *developing theories*) may be due to the target level of students for the *eBird/CBW* citizen science project. Upper elementary and middle school students are just beginning to experience higher-order thinking in independent ways. Such higher-order reasoning tasks as complex error analysis, indirect reasoning, developing a complex chain of inferences and manipulating variables different from theoretical variables may be reasoning tasks that are beyond the capabilities of most pre-adolescent learners. It is not implied however, that these higher-order thinking skills should not be promoted at the fifth through eighth grade levels. Miller and Meece (1999) suggest that exposing students to challenging academic tasks with instructional supports will help them to be more likely to develop cognitive and motivational abilities that characterize independent learners.

Chinn & Malhotra (2002) found that 2% of the textbook inquiry tasks reflected simple transformation of observations in the form of averaging data or graphing results. They also report that no textbook tasks provided students with the opportunity to develop theories about mechanisms; however, more than one-third of the tasks developed by researchers asked learners to develop theories. This was promoted minimally during *eBird/CBW* citizen science. *Explaining results* and *developing theories* are two additional areas where citizen science might be refined to provide the types of instructional supports that will help students develop the higher-order reasoning skills that are needed to explain results in an authentic science fashion.

To promote more authentic reasoning tasks in the area of *designing a study*, *explaining results* and *developing theories*, citizen science projects and/or classroom teachers should provide more opportunities for students to engage in independent inquiry. When independent inquiry evolves out of citizen science participation, students may be more intrinsically motivated due to greater interest. As students gain experience in designing their own studies, they may become more confident in developing their own steps, determining their own variables and making important decisions about what types of data to collect, how to organize the data and how to interpret the data. Students should be encouraged to critically examine their experimental procedures and to evaluate their findings in light of the uncertainty that is a natural part of the scientific process. As discussed previously, peer feedback and collaborative brain-storming could be used to help students refine their experimental design skills and to encourage critical reflection of methodology.

As they begin to explain their results, students should be encouraged to take error analysis beyond the focus of 'following steps appropriately' by considering flaws in methods, analyses and inferences. Students should be encouraged to look for ways to verify the validity of their methods. Although statistical analyzes may be beyond the developmental level of most upper elementary and middle-schoolers, students should be encouraged to transform their raw data in ways that will allow them to see patterns in the data, describe trends and use evidence to support their explanations.

Citizen science participation has the potential to allow students to develop their own theories because, in most cases, teachers do not already know the outcome of the experiment. The unpredictable nature of the natural world allows citizen science inquiry to be more open-ended than planned textbook experiments. From the beginning, students must be aware that citizen science is not about confirming stated theories in the textbook. Instead, citizen science is about contributing information so that students and scientists can answer important research questions that do not already have answers. Students should be encouraged to coordinate results and resolve inconsistencies from many different types of studies. This could be conducted across groups in a single classroom, across different class periods or across geographic space using the World Wide Web. Citizen science project designers and classroom teachers should consider ways to scaffold higher-order thinking processes such as: error analysis, indirect reasoning, complex chain of inferences, manipulated variables different from theoretical variables, responses to anomalous data, and generalizations to new situations.

Student Engagement During Citizen Science

Student engagement was defined by sense of autonomy, competence, relatedness and intrinsic motivation. Citizen science participation and independent inquiry participation were compared. Data collection and analyses came from student engagement surveys, student engagement teacher surveys, student focus group interviews and teacher interviews. For analyses, data were combined across all cases (fifth, seventh and eighth grades). Students responded to two student engagement surveys. The first survey was related to *eBird/CBW* citizen science as part of units 1-3 in the *CBW* curriculum. The second student survey was related to unit four of the *CBW* curriculum where students completed an independent inquiry project. The remainder of this section will refer to the first survey as *CBW* and the second survey as independent inquiry.

For both *CBW* activities and independent inquiry, students and teachers held different perceptions of student engagement. In only one area, relatedness during *CBW*, did students and teachers have similar frequencies of agreement. Overall, teachers more frequently agreed that students had a sense of autonomy, competence, interest in birds and intrinsic motivation than did students. This difference in perception emphasizes the importance of gathering student input regarding their own engagement in learning activities.

Teachers described "playing the role of scientist" as important in helping students to feel a part of the scientific process. The "role of scientist" was defined as "sending in data, collecting data and valuing data". One teacher emphasized to students that they were the "eyes and ears of the best lab in the world in terms of bird biology". Even though teachers believed that the student connection to scientists was strong, only about one-third of students said they felt connected to the scientists at Cornell Lab of Ornithology. Student-scientists feeling connected to scientists is a critical factor contributing to student perceptions of scientific research (Moss, Abrams, & Kull, 1998).

During *CBW*, students reported higher frequency of agreement on relatedness statements than any other student engagement component. Students strongly described teamwork as important during *CBW* activities and attributed their success as a by-product of their team work. Students reported they used teamwork to bounce ideas off of each other. Allowing students to work in collaborative teams offers them the opportunity to debate their ideas and reflect on one another's approaches. This community consensus of scientific ideas is an important part of the peer review process associated with authentic scientific research practice.

Students need the opportunity for collaborative learning. Collaborative learning increases awareness and appreciation for reasons why others engage in an academic task. It also gives students the opportunity to share ideas while receiving feedback. Just over half of the students reported they used feedback from others to help them do *CBW* activities as well as understand what they were learning. This feedback may be in the form of how to overcome difficulties in the task or possibly to introduce new ways of thinking about the task. In this manner, students scaffold learning for each other. As students work in collaborative groups they may be able to access and build upon collective knowledge. In other words, individually, students may not know very much, but as a collective group they know much more. This collective knowledge may be what is needed to motivate them towards more positive engagement with the topic of study.

More than half of the students agreed with statements that reflected a sense of autonomy and intrinsic motivation. Students felt they could be creative during their *CBW* participation. Not only did they feel they could make choices during *CBW* but they also felt those choices were important. Students experiencing a sense of control over their participation are more intrinsically motivated (Pintrich & Schunk, 2002). Students reported they were responsible for their own learning in that they often had to solve their own problems. Students develop a greater sense of autonomy when they shoulder responsibility for their own learning and are given the opportunities to make choices and solve their own problems as a part of their learning experience.

Student involvement in simple science activities is often limited to predetermined procedures and established protocols (Chinn & Malhotra, 2002). This limits the scope of the activity for students and does not allow them to engage in meaningful ways. If students are engaged in only simple science activities their ability to experience a sense of autonomy is reduced. When students are given the opportunity to decide on phenomena to investigate and research questions to answer they demonstrate more interest and enhanced motivations (McGinn & Roth, 1999).

Students reported they enjoyed the active nature of their *CBW* participation; more than half of them described the experience as “fun”. Teachers also suggested students enjoyed the citizen science participation, giving students the “ability to be, not only successful, but to have a more enjoyable experience with school”. It has been suggested that excitement and enthusiasm for authentic science may be generated as a result of citizen science research experiences (Barstow, 2001).

Intrinsically motivated behaviors are those behaviors for which the reward is the satisfaction associated with the activity itself, not necessarily an external reward, in other words, engagement in the activity is for its own sake. Intrinsically motivated students find activities inherently interesting and enjoyable. These activities are performed out of interest and do not require external prods, promises or threats. Students reported that they participated in *CBW* without being forced by teachers or parents. Participation in the *eBird/CBW* citizen science project provided students with the opportunity to satisfy their interests and curiosity rather than please a teacher or parent.

Teachers reported that *eBird/CBW* citizen science allowed students to experience more relevant learning and be successful even when unsuccessful with other school subjects or topics. The nature of the field experience associated with citizen science participation may additionally reinforce the intrinsic value of learning (Brophy, 2004). All teachers discussed the value of citizen science participation, particularly for their lower level students.

> I do see in my lower level students that this is an area [*eBird/CBW* citizen science] for them to shine a lot of times whereas they don't necessarily have that opportunity in other areas… I had one mother who came to me and said, 'my daughter was never interested in anything, she did not even want to go to school. I struggled to get her to school. She has come into your room and she has started to work with those birds, she is up, she is out, she wants to go [to school]'. She was a lower level student. It was something that she could relate to, something she felt she could succeed at.

Miller (2003) reports that low and average achieving students were more confident about their abilities to successfully complete tasks when given the opportunity to engage in more challenging tasks.

Comparing Student Engagement Within a Citizen Science Project

The *eBird/CBW* citizen science project was analyzed in two parts. The first part has simply been referred to as *CBW* (units 1-3). The second part has been referred to as the independent inquiry (unit 4). As students thought about their participation in *CBW* and their participation in the independent inquiry, students reported that the independent inquiry allowed them to think more like a real scientist. The independent inquiry activities had a higher element of 'fun' and engaged them in ways that promoted their intrinsic interest. Students reported they were able to be more creative during their independent inquiry than during *CBW*. There was one hundred percent agreement among all students that teamwork was important during their independent inquiry. Grade level or gender showed no main effects; therefore, effects were attributed to differences between *CBW* and independent inquiry.

During *CBW*, approximately thirty-three percent of the students agreed they thought like real scientists; however, during the independent inquiry, almost fifty-seven percent of the students agreed that they thought like real scientists. When data are considered in light of the cognitive processes discussed earlier, it is important to consider the value of independent inquiry in helping students to develop a sense of what it means to 'think like a scientist'. Referring back to the conceptual framework of this study (chapter III), the overarching premise was that the goal of science education is to help students learn to reason scientifically. To accomplish this, teachers need to engage students in science inquiry activities (AAAS, 1993; NRC, 1996). Since many of the reasoning tasks associated with the cognitive processes of authentic science are promoted and practiced during the independent inquiry, students are able to 'practice' thinking like a scientist. Although many of the reasoning tasks are promoted in the *CBW* portion of the project, students do not feel like they are actually thinking like a scientist until they conduct the independent inquiry. Teachers reported that students had the greatest amount of responsibility for their own actions during the independent inquiry project.

There was a significant difference between intrinsic motivation during *CBW* and intrinsic motivation during independent inquiry. Given the reported overall decline in intrinsic motivation of children from elementary through junior high school (Pintrich & Schunk, 2002), these findings are encouraging. Teachers reported that more choices and opportunities to express creativity were offered to students during the independent inquiry portion of the project. One teacher described her students in the following manner,

> They are much more invested, when it is their question and their project, they are much more motivated and invested in figuring it out. Whereas in the early activities [*CBW*] they were invested in doing it, they had fun, but it was 'we have to do this, it is part of what we are doing and I am going to get graded on it', so there was little more, I don't think it was as intrinsically motivating as with the earlier units. With unit 4 [independent inquiry], I had kids going all over town chasing 'turkeys' around, they had a great time with it.

In both *CBW* and the independent inquiry, students reported a strong frequency of agreement with the statement, "I liked *CBW*/Inquiry because I like doing science instead of reading about science" (93.3% for each). Active physical and mental engagement is important in science learning (NRC, 2000). Even though the independent inquiry was required for fifth and eighth graders (but optional for seventh graders), there was high student agreement about interest in the independent inquiry to the extent that students' participation did not require teacher or parent prodding.

Competence was the lowest component of student engagement with reference to frequency of agreement on survey statements for both *CBW* (46.7%) and the independent inquiry (48.3%). Engagement in *CBW* citizen science did not appear to allow students to generate a belief in mastery of content or skills. Students did not appear to develop competence even though they had the opportunity to make active responses to other learners and to participate in active learning. Jere Brophy (2004) suggests that task authenticity is a part of competence. Authentic tasks are those that require students to use what is being learned for a type of life application. Lower frequency of agreement on the statement, “I thought like a real scientist during *CBW*” (33.3%) may indicate that students did not see the tasks involved in *CBW* as being authentic; the chain of logic being if students don’t develop competence they may not see the task as authentic. Students reported a higher percentage of agreement on this same statement with regards to the independent inquiry project (56.7%) which may indicate students viewed the independent inquiry tasks as more authentic but they still did not allow students to develop competence. Additionally, the research literature reports that intrinsic motivation relates positively to perceived competence and internal control (Pintrich & Schunk, 2002). The results of this study do not reflect this assertion. Although intrinsic motivation and internal control appear to be related, perceived competence does not positively correlate. It is possible that a lack of perceived task authenticity may be contributing to lower competence.

Students felt like citizen science participation helped them to be better students but not necessarily better people in terms of ways of thinking and problem-solving. For both *CBW* and independent inquiry, frequency of agreement for the statements, “I think I can use the ways I have learned to think and solve problems during *CBW*/Inquiry activities in my daily life” and “Conducing *CBW*/Inquiry activities has helped me to become a better student” were very different (about 30% and 70% respectively). It would appear, from this study, students did not see the relevance of their participation to their everyday lives. As discussed in Chapter II, citizen science experiences, in theory, have the potential to provide a link between the 'real world' and school learning (Barstow, 2001; Moss, Abrams, & Kull, 1998). The findings from this study do not support this assumption.

It is possible there were factors positively affecting intrinsic motivation and internal control but negatively affecting perceived competence. In all cases participation in *CBW* was mandatory as a part of the regular school class. For fifth and eighth grade students, the independent inquiry was required as a part of course work. For seventh grade students, the independent inquiry was rewarded with extra credit. Mean scale scores for competence statements for fifth and seventh grade students were similar; however, seventh grade students had much higher standard of deviation values. The appearance of intrinsic motivation may be overshadowing the extrinsic motivation produced by school assignments or the promise of extra credit. Grades and extra credit rewards may be negatively affecting perceived competence. Engaging in an intrinsically interesting activity to obtain an extrinsic reward can undermine intrinsic motivation (Pintrich & Schunk, 2002).

When a child has the opportunity to 'self-determine' their own behavior they develop a sense of autonomy. Students reported an increased frequency of agreement during independent inquiry on the statement, "I was able to be creative during *CBW*/Inquiry activities" (63.3% and 83.3%, respectively). As students are given the opportunity to generate their own research questions, design their own studies and make decisions about gathering, organizing and interpreting data, they exercise creative thought and develop a greater sense of autonomy (Vansteenkiste, Simons, Lens, Soenens, Matos & Lacante, 2004).

Autonomy often promotes connectedness with others (Brophy, 2004). In both *CBW* and the independent inquiry, students reported high frequency of agreement on statements referring to relatedness. The greatest increase of frequency in this component was for the statement, "I used feedback from others to help me do *CBW*/Inquiry activities and to understand what I was learning" (50.0% and 63.3%, respectively). The social constructivist model of learning suggests that students must construct their own meaning during social interaction, trying out ideas, evaluating the ideas of others, exposing misconceptions and considering new ideas (NRC, 2005). More so than *CBW*, the independent inquiry appeared to allow students to socially construct knowledge to a greater extent. Feedback and peer review was promoted and practiced during *eBird/CBW* citizen science, but as has been previously discussed, the nature of this peer review was limited.

Generally, students reported that being a part of *CBW* and/or participating in the independent inquiry did not cause them to think about a future career in science. Self-perceptions of ability are related to an individual's expectancy beliefs which are reflected in choice behavior (Pintrich & Schunk, 2002). Although, generating 'little scientists' is not a main goal of science education, the need for future scientists is great. A goal of science education is that students develop habits of mind for making informed decisions that relate to the natural world (AAAS, 1990; NRC, 2000). The survey statement about ‘future careers in science’ was not worded in a way that could measure if students were developing the habits of mind needed to make informed decisions about the natural world as part of participation in *CBW* or the independent inquiry.

Citizen Science Participation

When coupled with independent inquiry, citizen science participation engages students in ways that contribute to their sense of autonomy, intrinsic motivation and relatedness. Students were developing important background from which they could generate their own research questions during the initial *eBird/CBW* citizen science activities (units 1-3). For student engagement in the cognitive processes associated with scientific inquiry, the independent inquiry project was an important part of the *eBird/CBW* citizen science project. Statements related to intrinsic motivation, autonomy and relatedness components of student engagement had higher frequencies of agreement during the independent inquiry. Other researchers have also suggested the value of independent inquiry as part of student-scientists partnerships (Moss, Abrams, & Kull, 1998; Penuel, Shear, Korbak, & Sparrow, 2005). When students are encouraged to develop their own research questions and determine the direction of their project they experience the creative and explorative nature of science. Students in the pre-adolescent age range develop science inquiry skills when they are provided with sustained engagement with situations that require the use of those inquiry skills over long periods of time (Kuhn & Dean, Jr., 2005).

A large majority of students reported they liked *CBW* activities and that extrinsic pressure from parents or teachers was not necessary to ensure their participation. Even though they liked their citizen science participation; they did feel they were good at *CBW*. Competence is but one psychological need related to student engagement. During this citizen science participation, autonomy and relatedness needs were being met to a much higher degree than competence. Citizen science project designers/coordinators as well as teachers need to find ways to increase student feelings of competence to further nurture increased student engagement.

Participation in citizen science may give students the opportunity to think in different ways from other school subjects, however, less than one third of the students felt the ways of thinking and solving problems they encountered during citizen science could be transferred to situations in their daily life. It would appear, from these data, that citizen science participation did not help students to perceive relevance in this type of science learning. Citizen science project developers and teachers need to make explicit the transferability of citizen science thinking and process skills to the daily lives of students. Making science learning relevant in the lives of students is important to student engagement. This could be done by helping students to see the value in scientific research for resource management, conservation, or human health reasons. Beginning any citizen science project with the environmental problem driving the research is important. For example, certain woodland birds (thrushes and some raptors) have specific habitat requirements. Forest fragmentation may be detrimental to these birds. Citizen science students discover how science connects to their lives when they are taught about the use of scientific data to guide resource management decisions tied to zoning and regional planning of vacant land next to their school grounds. As they collect data and ask their own research questions about local species of woodland birds, students can contribute in very real ways to the resource decisions being made in their own communities. This type of learning may not lead more students to think about future careers in science, but it may help them to develop the habits of mind needed to make informed citizenry decisions about the natural world and may help students develop task authenticity. For authenticity, from the students' perspective, science should be grounded in the students' daily life experiences (Radinsky, Bouillion, Lento, & Gomez, 2001). Students need to attribute meaningfulness, relevance and value to the practices promoted and practiced during the citizen science project for student task authenticity to emerge; doing so, will promote autonomous engagement. Helping students to see the relevance of science to their daily lives may facilitate student development of competence.

During *CBW*, students agreed less frequently in the competence component (36.5 – 27.7) with statements that referred to scientists ("Because I was participating in *CBW* activities, I felt connected to the scientists at Cornell Lab of Ornithology"; "Being a part of *CBW* has caused me to think about a future career in science"; "I thought like a real scientist during *CBW* activities"). The nature of this study was to describe the similarities between citizen science participation and authentic science. In general, the results show that citizen science inquiry is more like authentic science inquiry than school science textbook inquiry activities. However, it would appear students did not feel like scientists. I am left to wonder if this is because 1) students have come to believe that the way school science has been taught traditionally is authentic science, or 2) if they just do not know how real scientists think or 3) if they just do not believe that they are competent enough to think like a real scientist? The myth that scientists are an elite community made up of only smart people is prevalent in today's school society (McComas, 1996).

Citizen science project designers and teachers could promote competence in citizen science participants by: 1) promoting better connections between students and scientists, and 2) nurturing science task authenticity for students. Scientists establishing relationships with all citizen science students may not be practical given time and geographical constraints. Regional partnerships may be the second best approach. Regional partners are groups or individuals who act on behalf of the scientist(s) to communicate with citizen science students and teachers. High levels of *eBird* participation in the state of Texas have been contributed to regional partners. Regional partners can assist teachers with their own understandings of the content and scientific processes involved in the project and with different approaches to inquiry instruction (Penuel, Shear, Korbak, & Sparrow, 2005). Regional partners could also help teachers to identify local issues of concern to engage students in relevant inquiry. The regional partners may be seen as a 'more experienced other' to scaffold scientific inquiry and inquiry teaching for teachers. Students need to experience the collaborative nature of this partnership. They should feel they are true partners with scientists, contributing valuable information as opposed to just working for the scientists as collectors of data (Moss, Abrams, & Kull, 1998).

Truly collaborative partnerships between students and citizen science scientists or regional partners may help students develop task authenticity. Rahm, Miller, Hartley, & Moore (2003) suggest that project ownership is an important feature that mediates the emergence of authenticity. Increased ownership might allow students to exercise their competence by questioning certain components of the scientists' practice and challenging scientists as they provide feedback on student work and/or presentations. Better connections to scientists (with or without regional partners) would help in this area. Students need more exposure to the kinds of scientists currently working in multiple areas of science and to inquiry practices that are common to each. Access to experts related to specific scientific research has already been recommended as a vital component for citizen science participation (Evans, Abrams, Rock, & Spencer, 2001). A sense of ownership in the research under study sets the stage for active participation in citizen science (Moss, Abrams, & Kull, 1998). Such access and association may contribute to increased student competence.

Based on Deci & Ryan's (2000) self-determination theory, individuals need to feel and to be competent in their interactions with others, with tasks and activities and the larger context. In this study, relatedness (interactions with others) had the highest frequency of agreement among students; however, competence with tasks and connections with the larger context of the project had much lower frequency of agreement results. It is important for citizen science project coordinators to emphasize the relationship between students and scientists. Previous research literature has pointed to the importance of close contact between 'nonscientist' and scientist to help participants feel like they are an important part of the research process (Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005; Rahm, Miller, Hartley, & Moore, 2003). It is suggested that emphasizing student/scientists relationships and connections may contribute to student competence in science as well as students' increased engagement.

Summary

Trumbull and colleagues (2005) examined student participation in the citizen science project, *Classroom FeederWatch*, and reported that students' understanding of inquiry and their ability to plan and conduct inquiry showed little increase after participation in the project. Three specific recommendations were made in their report: 1) align student practices in citizen science to the work of ornithologists, 2) scaffold the inquiry process for students with emphasis on helping students make the transition from science as a body of knowledge to science as an inquiry process, and 3) provide students and teachers with models of how scientists link content (birds) to inquiry (bird studies).

Based on this study, *eBird/CBW* citizen science participation may scaffold student experiences with scientific inquiry providing them with the opportunity to engage in more authentic scientific inquiry. The areas of *generating their own research question*, *reading the research of others* and *making observations* have been identified as cognitive processes where citizen science participation was more like authentic scientific inquiry than like simple inquiry when compared to textbook science. In the cognitive areas of *designing a study*, *explaining results*, and *developing theories* citizen science participation needs to be refined to promote more authentic reasoning tasks associated with authentic scientific inquiry. Suggestions have been offered to promote additional reasoning tasks associated with each of these cognitive processes. Chinn & Malhotra (2002) admit their "analysis leaves open the question of how similar textbook inquiry tasks are to other inquiry tasks in science education" (p. 205). This research has attempted to address this gap by comparing how similar citizen science is with either simple inquiry or authentic scientific inquiry.

More than in science textbooks, students were encouraged to generate their own research questions based on their own curiosity or observations as well as based on the work of others. Citizen science students were given the opportunity to read the research of others, build on that research and participate in the peer review process. Students made observations and operated from the important epistemological framework that the purpose of the experiment was to test thinking. The first three units of the *eBird/CBW* curriculum were important to help students develop background knowledge, generate curiosity, and experience components of inquiry used in ornithological work. Participation in units 1-3 of the *eBird/CBW* curriculum was the springboard from which students could jump into independent inquiry which provided them with the opportunity to engage in more authentic scientific inquiry.

Moss and colleagues (1998) examined high school student conceptions of scientific inquiry associated with engagement in the citizen science project, *Forest Watch*. The outcome of their study was that student conceptual understandings of scientific research rarely evolved over the course of the school year. Insufficient exposure, a lack of sense of partnership with scientists and the design of the project were reasons suggested by the researchers for this situation. Although this study did not measure conceptual understanding, students did engage in all six of the cognitive processes associated with scientific inquiry. For three of those processes, *generating a research question*, *studying research of others'* and *making observations*, students engaged in some reasoning tasks associated with authentic scientific inquiry. The design of the *eBird/CBW* citizen science project and extended exposure to bird studies may be contributing critical factors for more authentic participation. Evans and colleagues (2001) identified support materials and clearly defined research protocols as essential features of student-scientist partnerships (SSP).

Lawless and Rock (1998) suggest that the primary benefit of a SSP to a scientist is the generation of scientific knowledge while that of the student is generation of the knowledge of science. In reference to citizen science participation, I disagree. Citizen science students have the opportunity to work with the same purpose as scientists, to generate scientific knowledge. In doing so, students participate in more authentic science inquiry. It is important however, for project designers and teachers to ensure that students clearly understand the research question under investigation and the environmental problem(s) associated with the project. If promoted by teachers, student contributions of their independent inquiry projects to the *Classroom Birdscope* student research journal may be one way students can feel as if they are contributing to scientific knowledge and therefore a true partner with Cornell scientists. As previously stated, a greater sense of partnership between students and *eBird/CBW* scientists may possibly contribute to greater student engagement.

Future Areas of Research

McGinn and Roth (1999) describe a ‘critically engaged citizenship’ as participants viewing science and scientists in a new light. They suggest that a community, in which science is created and used, provides a foundation for competent participation. The type of citizen science participation described in this research did not help students gain a foundation of competence. Why?

As an entire component, competence only had a frequency of agreement of 35.7%. This means that only about one-third of the students felt like they were good at citizen science activities. McGinn & Roth (1999) view scientific knowledge as competence in scientific discourse rather than bodies of collected facts and theories. Students in this study did not feel competent in their citizen science participation. Did students perceive their lack of competence as a lack of 'bodies of collected facts and theories' or 'limited accessibility to scientific discourse' or a combination of both? As in learning any language, competence is acquired through participation in ongoing practice (Lave and Wenger, 1991); therefore it would follow that, participation in the ongoing practice of science fosters the development of robust understandings and discourse (McGinn & Roth, 1999). However, participation in this 'ongoing practice of science' did not appear to facilitate student acquisition of appropriate discourse in the scientific community of practice enough to contribute to competence. McGinn, Roth, Boutonne & Woszczyna (1995) suggest that with increased competence and participation, student science discourse increasingly comes to resemble the discourse adopted by working scientists. This study did not examine discourse, but this may be a future area of research to examine components of competence within citizen science participation.

Student development of habits of mind for making informed decisions that relate to the natural world is an important science education goal (AAAS, 1990; NRC, 2000). Does participation in citizen science offer students the opportunity to develop these types of habits of mind? All of the teachers involved in this study shared that one of their goals in having their students participate in *eBird/CBW* was that students would develop a greater appreciation for birds as a part of the natural world. Does this happen and does a greater appreciate lead to a habit of mind that would help students make informed decisions? Findings from this study would suggest that students did not see relevance in their citizen science participation to everyday life.

As discussed in Chapter II, other student benefits have been suggested by various researchers. Many of these benefits were not examined in this study. Future research may explore some of these potential benefits:

- Improved student relationships with nature (Riquarts & Hansen, 1998), environmental attitudes (Bogner, 1998), or appreciation for local ecosystems and species (Brossard, Lewenstein, & Bonney, 2005; Evans, Abrams, Reitsma, Roux, Salmonsen, & Marra, 2005).
- Demystification of the process of science (Brewer, 2001; Trumbull, Bonney, Bascom & Cabral, 2000).
- Understanding of real problems of local community significance (Serman, Rudenjak-Lukenda, & Perkovic, 2000).

Limitations of This Study

The limitations of this study relate to the fact that this project was conducted with a single citizen science project. Further studies need to be conducted with other citizen science projects to compare the results of this study before generalizations can be made about citizen science participation in general.

Additionally, there was little diversity among student participants with regard to race and socioeconomic status. The majority of participants were Caucasian, middle to upper middle class students. Future studies need to consider whether similar results would be obtained with populations of differing types.

More Questions Than Answers

As with most research projects, this study has generated more questions than answers. It appears that citizen science is more closely aligned with authentic science than textbook inquiry tasks. It would also appear that student needs of autonomy and relatedness are strongly met during citizen science.

It would appear that citizen science participation did not help students see themselves as ‘little scientists’ but could it help students become members of a scientifically literate society that understands and appreciates the way science knowledge is generated as well as the nature of science knowledge itself? Does it provide students with the opportunity to develop an increasing understanding of and appreciation for the positive and negative sides of science as well as the fallible and contingent character of science and scientists?

McGinn and Roth (1999) suggest that appropriating scientific discourse and culture allows a person to construct their own credibility as participants in science. In other words, using the language of science helps students to make their own ‘niche’ in the scientific community. We often have to ‘talk the talk’ to get the attention of members of a community of interest. I wonder if participation in citizen science would help students to ‘appropriate the scientific discourse and culture’ in a way that allows them to construct their own credibility as participants in science and to enable them to come to see themselves as science-type people. Would this type of participation enable a wider range of students to understand and communicate about scientific issues? Could it be argued that citizen science forms of participation are valid in scientific practice? How would citizen science discourse compare to authentic science discourse? How do students learn about the culture and practice of science and/or develop a sense of themselves as scientists during citizen science participation? What resources and/or discourse do students use for identity building?

Research has shown that stimulated situational interest promotes learning and often leads to development of individual interest (Schraw, Flowerday, & Lehman, 2001). Interest is an important component of student motivation and engagement (Brophy, 2004). Could participation in citizen science be an activity that stimulates situational interest in science in such a way as to increase student engagement in the discipline? How can citizen science participation help to support the emergence of science authenticity for a broad range of students in a manner that leads them towards an understanding of science that is meaningful to them?

Conclusion

The *National Science Education Standards* (AAAS, 1993; NRC, 1996) set the main goal of science education to provide a context in which students can learn to reason scientifically, helping them grasp essential science concepts, to understand the nature of science, and to connect the relevance of science and technology with their lives (NRC, 1996). In an effort to expand the vision of inquiry science in the K-12 classroom, this study explored citizen science as a type of reform-based classroom inquiry. Using the framework of cognitive processes established by Chinn and Malhotra (2002), I have argued that citizen science provides opportunities for fifth through eighth grade students to participate in more reasoning tasks associated with authentic science inquiry that textbook science. I agree with Chinn and Malhotra that school science is qualitatively different from authentic science and suggest that citizen science participation is a way to scaffold the more complicated aspects of authentic science inquiry for middle level students. I have outlined how citizen science participation has contributed to student sense of autonomy, relatedness and intrinsic motivation as indicators of student engagement. I have also highlighted components of the *eBird/CBW* citizen science project that encouraged students to engage in the reasoning tasks related to the cognitive processes associated with authentic scientific inquiry and I have suggested additional components of citizen science that would further promote authentic science participation.

The goal of this study was to expand the vision of what it meant to participate in authentic science at the elementary and middle-school level. School science may, by its very nature, always be different from what real scientists do; however, citizen science can provide an intermediate step towards authentic inquiry science.

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APPENDIX A

STUDENT ENGAGEMENT SURVEY

Survey Likert-type Statements
Student Engagement during *CBW*

Please think about the times that you spent doing Classroom BirdWatch or *eBird* activities. Read each statement carefully and rate how the statement describes you on a scale of 1 to 5. If you think the statement DOES NOT describe you at all, please rate it a 1. If you think the statement describes you very much, please rate it a 5. If you are somewhere in the middle, you can rate the statement a 3 or you could rate yourself a 2 or 4 if you feel closer to one end or the other. Remember, there are no right or wrong answers, we are just interested in your honest opinions. Thank you!

The statement describes me…

1 _________ 2 _________ 3 _________ 4 _________ 5

Not at all Just so-so Very much

_____ I felt like I was responsible for my own learning during CLASSROOM BIRDWATCH.

_____ I felt like my decisions were important during CLASSROOM BIRDWATCH.

_____ Sometimes, I had to solve my own problems during CLASSROOM BIRDWATCH.

_____ I was able to make choices about my learning during CLASSROOM BIRDWATCH.

_____ I think about birds and nature in different ways.

_____ Doing CLASSROOM BIRDWATCH activities gave me the opportunity to think in different ways from my other school subjects.

_____ I thought like a real scientist during CLASSROOM BIRDWATCH activities.

_____ I like CLASSROOM BIRDWATCH activities because I like doing science instead of reading about science.

_____ I feel like I did a good job of observing, identifying and counting birds.

_____ I think I can use the ways I have learned to think and solve problems during CLASSROOM BIRDWATCH in my daily life.

_____ As a result of CLASSROOM BIRDWATCH, I want to continue to learn about birds.

_____ Being a part of CLASSROOM BIRDWATCH has caused me to think about a future career in science.

_____ I think teamwork was important during CLASSROOM BIRDWATCH.

_____ I used feedback from others to help me do and understand CLASSROOM BIRDWATCH activities.

_____ My group members and I bounced ideas off of each other during CLASSROOM BIRDWATCH.

_____ Because I was participating in CLASSROOM BIRDWATCH, I felt connected to the scientists at Cornell Lab of Ornithology.

_____ Working with my team helped me to be successful in CLASSROOM BIRDWATCH.

_____ I liked participating in CLASSROOM BIRDWATCH because I was good at it.

_____ I was able to be creative during CLASSROOM BIRDWATCH.

_____ CLASSROOM BIRDWATCH activities were fun.

_____ I was interested in CLASSROOM BIRDWATCH, my teacher or parents did not have to force me to participate.

_____ I was interested in CLASSROOM BIRDWATCH because I was curious about birds.

_____ I will continue to notice different kinds of birds.

_____ The CLASSROOM BIRDWATCH activities were not too easy and not too hard.

_____ Participating in CLASSROOM BIRDWATCH has helped me to become a better student.

Survey Likert-type Statements
Student Engagement during Independent Inquiry

Please think about the times that you spent doing **your independent inquiry project** for Classroom BirdWatch. Read each statement carefully and rate how the statement describes you on a scale of 1 to 5. If you think the statement DOES NOT describe you at all, please rate it a 1. If you think the statement describes you very much, please rate it a 5. If you are somewhere in the middle, you can rate the statement a 3 or you could rate yourself a 2 or 4 if you feel closer to one end or the other. Remember, there are no right or wrong answers, we are just interested in your honest opinions. Thank you!

The statement describes me…

1 ________ 2 ________ 3 ________ 4 ________ 5

Not at all — Just so-so — Very much

_____ I felt like I was responsible for my own learning during MY INQUIRY PROJECT.

_____ I felt like my decisions were important during MY INQUIRY PROJECT.

_____ Sometimes, I had to solve my own problems during MY INQUIRY PROJECT.

_____ I was able to make choices about my learning during MY INQUIRY PROJECT.

_____ I think about birds and nature in different ways.

_____ Doing MY INQUIRY PROJECT gave me the opportunity to think in different ways from my other school subjects.

_____ I thought like a real scientist during MY INQUIRY PROJECT.

_____ I liked MY INQUIRY PROJECT because I like doing science instead of reading about science.

_____ I feel like I did a good job of observing, identifying and counting birds during MY INQUIRY PROJECT.

_____ I think I can use the ways I have learned to think and solve problems during MY INQUIRY PROJECT in my daily life.

_____ As a result of MY INQUIRY PROJECT, I want to continue to learn about birds.

_____ Being a part of MY INQUIRY PROJECT has caused me to think about a future career in science.

_____ I think teamwork was important during MY INQUIRY PROJECT.

_____ I used feedback from others to help me do MY INQUIRY PROJECT and to understand what I was learning.

_____ My group members and I bounced ideas off of each other during MY INQUIRY PROJECT.

_____ Because I was participating in MY INQUIRY PROJECT, I felt connected to the scientists at Cornell Lab of Ornithology.

_____ Working with my team helped me to be successful in MY INQUIRY PROJECT.

_____ I liked participating in MY INQUIRY PROJECT because I was good at it.

_____ I was able to be creative during MY INQUIRY PROJECT.

_____ MY INQUIRY PROJECT was fun.

_____ I was interested in MY INQUIRY PROJECT, my teacher or parents did not have to force me to do the project.

_____ I was interested in MY INQUIRY PROJECT because I was curious about birds.

_____ I will continue to notice different kinds of birds.

_____ MY INQUIRY PROJECT was not too easy and not too hard.

_____ Participating in MY INQUIRY PROJECT has helped me to become a better student.

APPENDIX B

STUDENT ENGAGEMENT TEACHER SURVEY

Teacher Survey related to student engagement and cognitive processes

Please indicate your agreement with each of the following statements. Please rate Units 1-3 together in the left hand column and unit 4 (the independent inquiry) in the right hand column. Thank you!!

1	2	3	4	5
Strongly disagree	Disagree	Unsure	Agree	Strongly agree

Student Engagement

Units 1-3	Statement	Independent Inquiry (Unit 4)
	The Classroom BirdWatch activities allowed my students to take responsibility for their own learning.	
	I think my students felt like they were an important part of the bird studies at Cornell Lab of Ornithology.	
	Students had to solve their own problems during Classroom BirdWatch activities.	
	Students were able to make their own choices during Classroom BirdWatch.	

Units 1-3	Statement	Independent Inquiry (Unit 4)
	The Classroom BirdWatch curriculum helped my students to think about science in new ways.	
	I think my students felt successful with the Classroom BirdWatch activities.	
	The ways of thinking that my students learned during Classroom BirdWatch will help them in their future.	
	My students talk more about birds or science in general after participating in Classroom BirdWatch.	
	My students ask more questions and demonstrate a greater sense of wonder about the natural world.	

Units 1-3	Statement	Independent Inquiry (Unit 4)
	Team work helped my students be more successful.	
	Students gave constructive feedback to each other.	
	Students felt connected to the scientists at Cornell Lab of Ornithology.	

Units 1-3	Statement	Independent Inquiry (Unit 4)
	I think my students felt competent with Classroom BirdWatch activities.	
	The Classroom BirdWatch activities allowed my students to be creative.	
	Students enjoyed Classroom BirdWatch activities.	
	Students were interested in Classroom BirdWatch activities without much prompting or prodding by me or parents.	
	Students were curious about birds.	
	I think students will continue to notice birds.	
	Participating in Classroom BirdWatch has helped my students to become better students.	
	Students have an increased appreciation for inquiry.	
	Students have an increased interest in the scientific process.	
	Students have an increased understanding of scientific habits of mind.	

Which components of inquiry do you feel your students have gained experience with because of Classroom BirdWatch?

1	2	3	4	5
No Experience		Some experience		Extensive experience

Units 1-3	Component of Inquiry	Independent Inquiry (Unit 4)
	Generating research questions	
	Designing research studies	
	Making observations	
	Analyzing data	
	Explaining results	
	Developing theories	

	Communicating ideas	
	Studying other's work	
	Peer review of classmate work	

How do you think your students would describe the various units of Classroom BirdWatch?

	Too easy	challenging, but not too difficult	Too challenging
Unit 1			
Unit 2			
Unit 3			
Unit 4			

How would you describe the **value** of your class's participation in this project? [Please fill in the blanks if you have other ideas besides those listed]

	1 Strongly Disagree	2 Disagree	3 Unsure	4 Agree	5 Strongly Agree
Something for every student to do					
Meeting national science standards					
Meeting school/district standards					
Getting students outside					
Providing information to scientists					
Students learning more about birds (structure, diversity, behavior, ecology)					
Becoming more aware of what is in our community					
Gaining experience with science processes					
Gaining experience with science habits of mind					
Providing the community with information for natural resource management					
A means for acquiring funding for supplies					

Recognizing the complex nature of the classroom, and schools in general, we were wondering about the potential structural supports or resources that may have contributed to your ability (or inability) to implement most aspects of Classroom BirdWatch.

Can you name someone (or organization) who has:

- Supported/ encouraged your use of *CBW*?
- assisted you with the use of *CBW* or provided you with additional resources as you implemented *CBW*?
- taken an active part in removing constraints that my have potentially hindered you from the use of *CBW*?

Please read each student task and place an X in the *CBW* and/or independent inquiry column if you feel the majority of your students attempted the task.

Cognitive Processes	**Student Tasks**	***CBW*** **Units 1-3**	**Independent Inquiry**
Generating Research Questions	Questions provided by teacher		
	Questions provided by curriculum		
	Develop own questions based on observations		
	Develop own questions based on others' work		
	Develop own questions based on curiosity		
Designing a Study	Prescribed steps		
	Steps designed by researcher		
	Single pre-defined independent and dependent variable		
	Variable determined by researcher		
	Observing prescribed		

	features		
	No controlled condition		
	Single controlled condition		
	Multiple controlled situations		
	External controls verifying procedures or equipment		
	Single prescribed outcome measure		
	Intervening and multiple outcomes		
	Critical reflection on methods		
Making Observations	Making measurements		
	Technique to guard against perceptual bias		
Explaining Results	No data transformation		
	Data transformation, drawing		
	Data transformation, graphing		
	Data transformation, statistics		
	Complex error analysis (methodological flaws)		
	Simple error analysis		
	Direct reasoning (straight forward inference)		
	Indirect reasoning		
	Complex chain of inferences		
	Manipulated variables different from theoretical variables		
	Manipulated variables same as theoretical variables		
	Complex reasoning, responses to anomalous data: ❖ consider alternative		

	mechanism to explain results ❖ ignore, reject or express uncertainty about data		
	Complex reasoning, consider ways to verify validity of new methods		
	Generalizations to new situations		
Developing Theories	Construct theories based on evidence		
	Direct observations not connected to theory		
	Direct observations illustrating stated theory		
	Coordinate results from multiple studies		
Studying Others' Research	Reading about topic in science trade books		
	Reading research of others		
	Building on work of others		
	Peer review of findings		

APPENDIX C

FOCUS GROUP CARD SORT

Focus Group Card Sort
Cognitive Processes Associated with Science

This focus group is made up of students that completed an independent inquiry project together during unit 4 of *Classroom BirdWatch*. The coding in each response cell was used in quantitative data analysis. A one (1) indicates a statement that reflects authentic science, a two (2) indicates a statement that reflects simple science and a three (3) was used for all maybe statements.

Tell me about the investigation that you conducted as part of *CBW*. What was your research question? What did you learn from your work? Have you developed any new theories? How did you come up with this? What was the best part about your project? If you had to do a science project next year in school, do you feel like you could complete the project?

Card Sort #1

I would like for you to sort the cards into three piles. The cards are about your inquiry project, they are not about any other part of *Classroom BirdWatch.* One pile is those statements that you would agree <u>definitely</u> describes what you did or thought about during your project. The second pile will be those cards that might (<u>maybe</u>) describe what you did or thought during your project. The third pile will be those cards that you would agree do not (<u>not at all</u>) describe what you did or thought during your project. I want you to only think about your bird project as you sort these cards. I have six different groups of cards represented by six different colors. Each group represents a different part of your project and I will tell you about that part of the project before you look at the cards. I want you to try to only think about that part of your project. As you go along, I may ask you some questions as you sort the cards. If, at any time, you want to change a card from one pile to another, that is perfectly alright. If, at any time, you don't understand a statement, please ask me. Do you have any questions?

I will give each person a stack of cards to read to the entire group. As a group, you will decide which pile the card will go into. You need to decide together.

Generate Research Questions

Researcher says: These statements are about how you came up with your research question. They are not about any other part of your project, just how you came up with your research question.

	YES	**NO**	**MAYBE**	**COMMENTS**
Our **research question** was suggested to us by our teacher or another adult.	2	1	3	
Our **research question** was based on something we saw.	1	2	3	
Our **research question** was based on something another student said or did.	1	2	3	
Our **research question** was based on something we read in the *Classroom BirdWatch* materials or some other type of research study.	1	2	3	
Our **research question** was based on our own curiosity.	1	2	3	
Being able to generate our own research question allowed us to be creative.	1	2	3	
We felt confident in generating our own research question.	1	2	3	
Our research question was based on ___________________________.	No code given here, only qualitative data.			

<u>Designing a Study</u>

Researcher says: These statements are about how you designed your research study. They are not about any other part of your project, just how you designed your research study.

	YES	**NO**	**MAYBE**	**COMMENTS**
We followed steps in the *Classroom BirdWatch* materials or from our teacher.	2	1	3	
We made up our own steps.	1	2	3	
*We decided on our own variables.	1	2	3	
*Our teacher told us what variables to use.	2	1	3	
We did not have any variables, we only observed birds.	2	1	3	
*Probe: variables, what was the independent (manipulated), dependent (responding), controlled variables? How did you decide on what to control? How many things did you control? [Any indication of external controls for equipment or procedure verification?]				
We thought about our procedures and wondered if they were any good.	1	2	3	
We changed our procedures to make our experiment better.	1	2	3	
We designed a good study because we worked together.	1	2	3	
*We figured out the kind of data we needed to collect on our own.	1	2	3	
Probe: What kind of data did you collect? How did you decide to collect this type of data?				
Our teacher told us what kind of data to collect.	2	1	3	
We were happy with the study we designed.	1	2	3	

Making Observations

Researcher says: These statements are about how you made observations or collected your data. They are not about any other part of your project, just how you made observations or collected data.

	YES	NO	MAYBE	COMMENTS
We looked at and counted birds.	1	2	3	
We only looked at birds.	2	1	3	
We checked each others observations or counts.	1	2	3	
We thought about whether our bird identifications were accurate.	1	2	3	
We thought about ways to improve our **observations** to make them more accurate.	1	2	3	
We used cameras or electronic sound recording devices to check our **observations**.	1	2	3	
The purpose of our experiment was to **describe something** through careful data collection.	2	1	3	
The purpose of our experiment was to **test our thinking** through careful data collection.	1	2	3	
We thought we did a good job of making accurate observations.	1	2	3	
We enjoyed identifying and counting birds.	1	2	3	

Explaining Results

Researcher says: These statements are about how you explained the results of your research study. They are not about any other part of your project, just how you explained the results of your study.

	YES	**NO**	**MAYBE**	**COMMENTS**
We made graphs of our data.	2	1	3	
We submitted our data to *eBird*.	1	2	3	
We found mean (average), median and mode with our data.	1	2	3	
We used statistics to help us understand our data.	1	2	3	
Our teacher or the *CBW* materials showed us how to organize our data.	2	1	3	
We sometimes got unexpected results from our data.	1	2	3	
We think our unexpected results are because we did something wrong.	2	1	3	
We think our unexpected results were because we did not understand the data very well.	2	1	3	
We think our unexpected results just shows that our hypothesis was wrong (not supported).	1	2	3	
We think uncertainty is just a natural part of the scientific process.	1	2	3	
Even though we got the results we expected, we wondered if our procedures were good.	1	2	3	

We thought about possible errors we may have made in our data analysis or interpretation.	1	2	3	
When we looked at our results we thought of other ideas for what the data might be telling us.	1	2	3	
We talked about ways we could check our findings.	1	2	3	
We were responsible for deciding how to analyze our data.	1	2	3	
We worked together to understand and explain our data.	1	2	3	

Developing Theories

Researcher says: These statements are about developed your ideas as a result of your project. They are not about any other part of your project, just how you developed ideas.

	YES	**NO**	**MAYBE**	**COMMENTS**
*We used evidence to support our explanations.	1	2	3	
*Probe: can you give me an example of this?				
*We used results from other studies to help us explain our data.	1	2	3	
*Probe: can you give me an example of this?				
***We read other studies that had similar results to our investigation.	1	2	3	
***Probe: how did you use this info to help you? [different level of analysis?]				
**We read other studies that said something different from what we found in our study.	1	2	3	
**Probe: how did you handle this? [resolving inconsistencies]				
We looked at other data on *eBird* to add to our learning.	1	2	3	
Our purpose in this investigation was to find out something that scientists already knew.	2	1	3	
Our purpose in this investigation was to find out something that scientists DID NOT already know.	1	2	3	
General Probe: What would you tell people that you have learned from this investigation? [explaining natural world or constructing a theory]				

Studying Others' Research

Researcher says: This last set of statements is on the subject of how you might have learned about other ideas during your project. They are not about any other part of your project, just how you might have learned about other ideas.

	YES	**NO**	**MAYBE**	**COMMENTS**
*We read other peoples research to help us develop or understand our research question.	1	2	3	
*We read other studies to learn about standard steps for collecting certain types of data.	1	2	3	
*We read other studies to learn about what variables we needed to control and measure.	1	2	3	
*We read other studies to think about how to fit our study in with the work of other researchers.	1	2	3	
*probe: can you give me an example of this research that you read?				
Other students read our work and gave us feedback (peer review).	1	2	3	
We used other student feedback to help us know what to do.	1	2	3	
We used other student feedback to help us understand our data.	1	2	3	
We reviewed the work of other students & gave them ideas (peer review).	1	2	3	
We looked at information in the *eBird* database to give us ideas about our research.	1	2	3	

[Feedback is suggestions or ideas that others give you to help you do better on something.]

APPENDIX D

TEACHER INTERVIEW PROTOCOL

Teacher Interview Protocol

Demographics

1. How many students are in your class? If you teach multiple classes of the same subject, what is the average number of children in your classes and how many classes do you teach?
2. About how much time per week do you spend teaching science to a single group of children?
3. What is your educational background?
4. How comfortable are you teaching science?
5. What types of science related workshops or conferences have you attended in the last five years?
6. What is your bird background?
7. How would you describe ___________ school? (Traditional, magnet, charter, public, private, etc.)
8. How would you describe the population of students? (SES, free/reduced lunch, title 1, etc.)

Questions

1. What attracted you to citizen science projects? [science process/birds, etc]
2. What attracted you to this citizen science project?
3. Have you participated in other citizen science projects? Which ones?

4. What were your goals/objectives in participation with *eBird/CBW*? [do these match the goals of the program? If different, how does this contribute to participation or values]
5. What were your inquiry goals through this project?
6. How would you describe your role during *CBW* [co-inquirer, authority]
7. How did you present the *CBW* lessons? 1 per week, consecutive days, sporadically-when time permitted, etc.
8. How did students communicate data, progress, findings, etc? – science conferences? Published findings in birdscope? Written other types of research reports? Other ways of sharing info?
9. How did students relate to each other during *CBW* participation?
10. How were students responsible for their own actions?
11. In what ways did students direct their own learning?
12. What types of choices (options) did you provide for students?
13. In what ways were students focused on grades, pleasing teacher or parent, learning for its own sake?
14. How has your participation in this project impacted student understanding of inquiry science? About how science knowledge is generated? Processes of science?
15. What changes have you seen in your students? [level of concern about welfare of organisms, habitat needs, About how science knowledge is generated? Processes of science? About your relationship with the environment, etc]

16. If present, how would you describe differences in student engagement between low and high achieving students?
17. Did you submit data? Why or why not?