THE IMPLEMENTATION OF A METHODOLOGY TO MEASURE AND ANALYZE THE EFFECTS OF INQUIRY TEACHING ON STUDENT DEVELOPMENT OF INQUIRY SKILLS

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ABSTRACT

Current science education standards mandate the inclusion of inquiry within curricula. However, existing research fails to address the correlation between the teaching of inquiry and the learning of inquiry skills. A unique opportunity presents itself at the Catamount Center where undergraduate students work with small groups of 5th grade students to facilitate a 4-week "Inquiry Unit." This paper adapts and applies an existing theory by Ruiz-Primo (2010) to introduce a methodology that assesses the presence and quality of conclusion components in 5th grade inquiry papers. As a result of this research, several hypotheses have been generated regarding the successful implementation of the Inquiry Unit at the Catamount Center.

INTRODUCTION

Science education provides students worldwide with the integrated skills and knowledge to become lifelong observers and stewards of the environment, to avoid impeding changes due to issues like climate change (Bell, 2003). Within science education falls the field of environmental education (EE). It falls upon EE to provide students with the skills and techniques to cope and address the issues, such as climate change, which infiltrate everyday life. While science education has long been regarded as a fundamental component of the education system, EE is relatively new (Carter & Simmons, 2010). The recent histories of conservation, nature study, and outdoor education shape the field of EE as it exists today. Since its early days of Tbilisi in 1977, EE has provided a relatively new platform upon which to instruct students about their surroundings (Carter & Simmons, 2010).

As a fairly young and evolving field, EE recognizes that the role of education in developing a relationship between individuals and their surroundings must be informed by the best available pedagogical practices (Carter & Simmons, 2010). Therefore, changes in this field attempt to integrate and adapt the application of the best models that are present today (Carter & Simmons, 2010). Specifically emphasized within the current educational framework is the importance that learners are able to construct their own meaning and knowledge within lessons (Bell, 2003). Of interest here are the following developments in the dynamic relationship of pedagogy and EE: Integral Theory as a framework through which to place the research at hand, the current status of science education, inquiry as a skill, and inquiry as a teaching technique.

Integral Theory

The word "integral" can be interpreted to be an approach that combines and utilizes the many perspectives of our cacophonous world (Esbjörn-Hargens, 2009). Wilber (1997) has taken this meaning and actualized it in the form of a theory: Integral Theory provides an all-encompassing framework to organize the various ways of knowing, providing an insightful method through which we can more holistically address the multitude of problems that people and the planet face.

This framework divides the world into four quadrants that represent the four dimensions of reality and/or the "four irreducible perspectives of the world" (Esbjörn-Hargens, 2009, 2). The two divisions that yield the four quadrants are those of interior versus exterior, and individual versus collective (Figure 1). The upper left (UL) quadrant corresponds to the area of intention and subjectivity, or the "I." The lower left (LL) encompasses intersubjectivity and culture, or the "We." The upper right (UR) denotes the quadrant of objectivity and behavior, or the “It,” and the lower right (LR) describes interobjectivity and the social realm, or the pronoun “Its.” The lens of each of the four quadrants is unique, and while an enhanced understanding can be accomplished by viewing the world through all four lenses, no quadrant can be understood through the lens of another. When using an integral approach for methodology, the quadrants are each divided into two zones: the odd zones (1, 3, 5, 7) look at a quadrant from the inside, whereas the even zones (2, 4, 6, 8) look at a quadrant from the outside perspective. The odd zones consider the insider’s perspective of a quadrant, while the even zones assess the quadrant in a removed fashion.

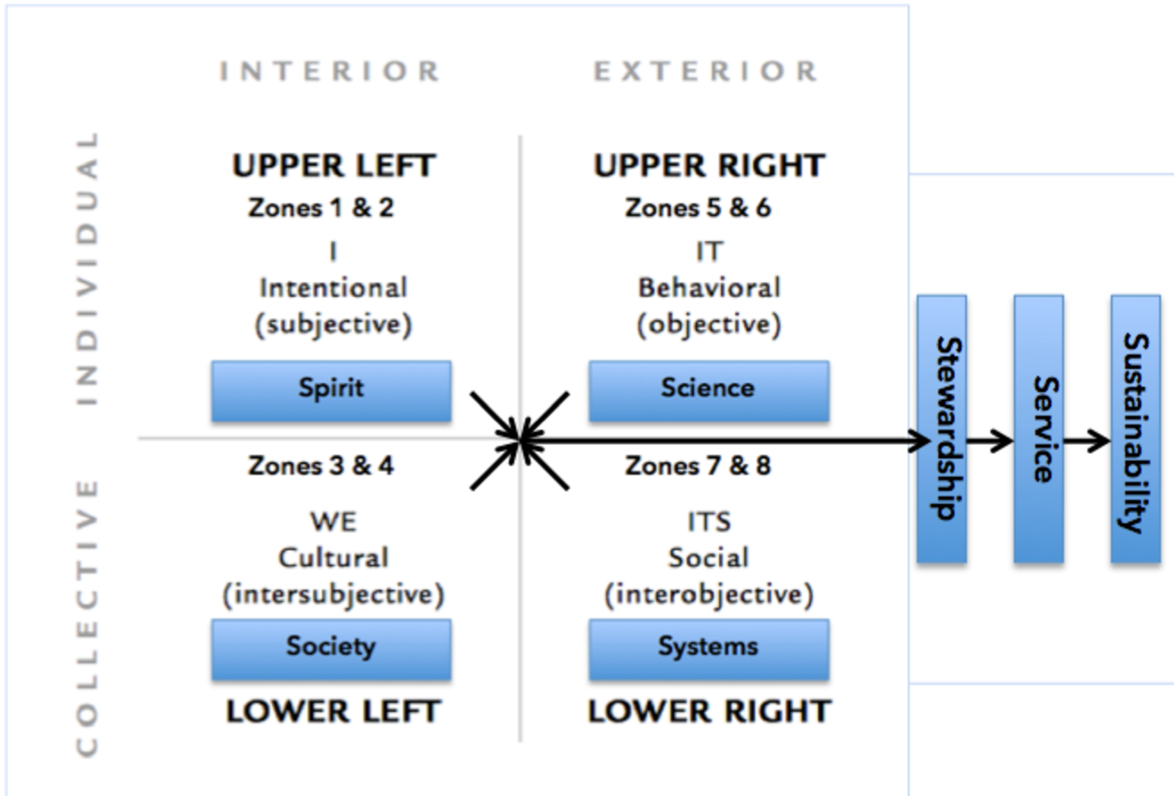

Figure 1*:* Esbjörn-Hargen and Zimmerman Integral Theory model meets the Catamount 7S model. The designation of zones, arrows, and blue text boxes are additions to the original figure (Esbjörn-Hargens, 2009, 3). I have added them for the purpose of applying the original figure to the 7S curriculum. 7S was developed at the Catamount Center, and is currently employed in the facilitation of Outdoor Learning School. Note the location of zones 2 and 6 in this diagram. Zone 2 falls in the upper left, the individual interior (subjective), or the spirit. Zone 6 falls in the individual exterior (objective), or science.

This research uses a zone 2 method for determining how 5th grade students perform on a zone 6 assignment. The research falls into the upper left quadrant because it looks at *individual* students and their *subjective* development. It is zone 2 because the research is from the perspective of the researcher – an outside perspective. This is also described as a structuralist method. Students were asked to look at the natural world (outside) from without by using empirical methods, therefore an upper right experience. These students engaged in Zone 6 education. It is zone 6 because it is study of *individual* components of the *objective* or *exterior* world from the *outside*.

Zone 2 provides us with a lens from which to assess the skills that must develop to achieve scientific competence. Scientific competence encompasses the ability to engage in the upper right quadrant. One such skill is that of scientific **inquiry,** which has substantial weight in both educational theory and practice. Since 1996, inquiry has been stated as a goal in the American National Curriculum Standards for Science (NRC, 1996). This national goal is backed by a considerable literature dedicated to inquiry. Currently, there is national emphasis for increased incorporation of scientific inquiry skills as an fundamental part of science education as the nation is looking to address the widespread problem of shallow levels of scientific understanding (Reiser et al., 2001).

Science education

When addressing these goals of science education, there exists a tension – whether we ought to teach the content of science versus teach the application of science (Bybee, 2015). However, arguably, there is no distinct delineation between these two areas of science education. Both need to be incorporated into a curriculum. There is increasing support in the literature that the mastery of scientific processes cannot occur alone – it must be accompanied by the development of content knowledge (Lehrer et al., 2008). To understand science requires an understanding of the nature of the scientific method (Reiser, 2001). The necessity of understanding science, and thus understanding the scientific method, leads to the justification of inquiry learning.

Science education emphasizes both the development of scientific skills to function as capable citizens, as well as the creation of scientific foundations for future scientists (Bybee, 2015). For science education to be successful, learners must be active participants in their education; they must engage in opportunities to construct meaning, and develop understanding (Bell, 2003). The development of scientific literacy requires that citizens understand, are receptive to, and appreciate the influence of science and technology as fundamentally intertwined in actively shaping culture and society (Bybee, 2015). All citizens must simultaneously possess an understanding of the application of the fundamentals of science (Bybee, 2015), which are seen by many as essential to effectively address complex problems such as climate change (Wilson, 2016).

The Catamount Center

The Catamount Center is nestled into the Rocky Mountain Front Range, just west of Colorado Springs. It is home to the Teaching and Research in Environmental Science (TREE) Semester, and Outdoor Learning School (OLS). The TREE Semester program enrolls undergraduate students from Colorado College, who are dubbed "stewards" for the duration of the semester. The TREE Semester program provides the stewards an incremental approach to teaching, primarily centered around instructing a small group of 5th grade students for 10 weeks at OLS. These 5th graders attend a local elementary school. Both the educators and the 5th grade students experience a scaffolded approach to inquiry: as the unit progresses, the depth and complexity of the experience increase at a pace that is intended to parallel the students' and stewards' zone of proximal development. The stewards are increasingly autonomous in the development and facilitation of lesson plans. The students engage in a full cycle of the "Catamount Cycle of Science," which is comparable to a 5th grade interpretation of the scientific method.

The Catamount Center has a unique "7S curriculum model." Four of the S's in the model relate to the quadrants, as described by Integral Theory (Figure 1, Esbjörn-Hargens, 2007). The UL corresponds to spirit, or the connection to things beyond oneself; the LL to society, or a set of beliefs, values, and norms that define a group; the UR to science, the process of understanding how natural systems work through inquiry; and the LR to systems, the recognition that nothing exists without a feedback whether that be ecological, political, or environmental (Figure 1*)*. Catamount operates under the belief that the simultaneous development of these four quadrants leads to stewardship (S #5), or management that allows for sustainability, observation, and connection. By acquiring and practicing stewardship, one's learning trajectory then leads to service (S #6), the act of contributing to both the greater and personal good. Ultimately, service leads to sustainability (S #7), which is defined as living in a manner that ensures a viable biosphere for the seventh generation.

The stewards are instructed to employ the 7S framework when constructing and guiding lessons. The 7S model is intended to fulfill the Catamount Center mission statement: "Inspire Ecological Stewardship."

LITERATURE REVIEW

"Apart from inquiry, apart from the praxis, individuals cannot be truly human" (Freire, 2005, 72).

Defining inquiry:

Inquiry is rooted in an understanding of the upper right quadrant, which corresponds to the "science" component of the 7S model. The synonyms for inquiry include: exploration, inquest, investigation, probing, research, study, quest, inspection, query, challenge, cross-examination, self-investigation, self-questioning, self-reflection, self-scrutiny, and soul searching (Merriam Webster Online, 2016). Broadly, inquiry is a way of discovering and learning about the world that surrounds us. When applied to educational pursuits, inquiry can be both an activity, and a way of knowing (Colburn, 2000; Kuhn & Dean, 2005). As an activity, inquiry describes the ways that students develop scientific skills, and learn scientific content (Anderson, 2002). As an epistemology, inquiry concerns the scientific process that scientific professionals use to study the natural world, and derive explanations from their findings. Thus, as an epistemology, the process of inquiry is scientific in nature, and is frequently applied to natural systems (Reiser et al., 2001). As a skill, inquiry is informed by an understanding of the scientific process (Reiser et al., 2001). There are three processes of inquiry: inquiry teaching, scientific inquiry, and inquiry learning (Anderson, 2002). However, one cannot understand any one process without some exposure and recognition of the others. Students efficiently develop inquiry skills when educators structure discourse and guide the process of scientific inquiry effectively (Reiser et al., 2001). However, what is meant by the term “effective” in the context of inquiry learning? Below, I highlight the distinctions between the two inquiries most prominent in answering this research question: student inquiry and teaching inquiry. The inquiry discussion starts with the topic of student inquiry, for one cannot comprehend the teacher’s role until they understand the goals of such an education.

Student inquiry

The National Research Council defines inquiry as an essential part of K-12 science curricula (NRC, 1996). These standards intend for students to be repeatedly exposed to inquiry activities to move students away from the cookie cutter approach to education (Reiser et al, 2001). The cookie cutter approach takes a very subject centric approach, in which students are seen as hollow vessels to be filled with information. In contrast, an inquiry approach enables students to develop the skills necessary to thrive amidst global cacophony, to navigate complexity, and to engage in a unique learning experience (Reiser et al., 2001). Kuhn and Pease (2008) define the goal of inquiry as: “help[ing] students learn how to think about and engage in scientific investigation […], in a context of scientific content, but without taking on the additional goal of their mastering any specific scientific knowledge” (p. 517).

Prior to engaging in inquiry, students first need to understand the objectives (Kuhn et al., 2008; Kuhn & Pease, 2008). They must recognize that inquiry provides a method for formulating their own questions and is the process through which human understanding of the world is constantly evolving; the process by which we discover, theorize, and construct our perception of the world (Kuhn & Pease, 2008). Only through recognizing this goal do students become capable of utilizing the powerful tool of inquiry – a means for figuring things out; often students recognize the power of inquiry when constructing their own questions. Inquiry is a method to deduce between the complex, intricate relation of correlation and causality; a framework that enables the mind to derive logical and rational discoveries about one's surroundings.

Kuhn and Pease (2008) accomplished their work through a three-year study that followed a group of students from 4th through 6th grade. During this time, the students enrolled in an inquiry-specific class. Their research question concerned how the realm of inquiry skills is best developed, and what challenges might arise during this development. From this work, Kuhn and Pease (2008) identify nine goals of inquiry pertaining specifically to the scientific method.

In order to demonstrate the acquisition of inquiry skills, students need to:

1. Recognize that there is new evidence to be found, and that the evidence may contribute to a new level of understanding.
2. Design experiments that will yield new evidence or the ability to design and coordinate a study that looks at the effects of multiple variables on an outcome (Kuhn et al., 2008).
3. Generate valid predictions that are grounded in evidence, and acknowledge the variables at play.
4. Understand the sources of information that they draw upon, be that evidence or prior understanding.
5. Successfully read and interpret data and analyze results.

6. Examine new evidence and be able to assimilate and/or coordinate it with their existing beliefs.
7. Make justified conclusions.
8. Use science as an argument in social settings, or enhance their ability to coordinate evidence and theory to skillfully present a scientific argument. The justification for using science as an argument is as follows: “A general goal of scientific argumentation is to articulate a causal mechanism that explains patterns of data. The need to generate causal mechanisms suggests the use of controlled comparisons, because they enable us to isolate and identify causal factors” (Reiser et al., 2001; Kuhn & Pease, 2008).
9. Revise theories and understanding as new evidence arises.

To develop these nine skills, students need to experience extended engagement in an inquiry environment, experiencing gradual increases in complexity over time (Kuhn & Pease, 2008; Reiser et al., 2001). The skills that fall under the umbrella of inquiry do not develop immediately, but rather require gradual retention over time through a variety of teaching methods.

Teaching inquiry

Inquiry is generally regarded as an effective teaching technique that leads to positive, but modest gains in learning. While existing research on inquiry indicates the feasibility of inquiry teaching for many teachers, the teaching of inquiry is ill defined as a practice (Anderson, 2002). Broadly defined, educators who use inquiry teaching, use student questions as the driving force for science teaching. These educators let the interests, curiosity, and misconceptions of the students guide the content, experiments, and structure of the class. On a national level, the NRC Standards (1996) demand that teachers implement techniques that promote inquiry-based learning. However, there is little specificity as to what these techniques are, and how they are promoted through professional development. In fact, within the National Science Education Standards (NRC, 1996), there is no formal definition of inquiry teaching. In other bodies of research, varying definitions and considerations of teaching inquiry exist. Specificity and direction for the teaching of inquiry is likely to improve teacher practices. The somewhat limited existing literature on this topic is discussed below.

First, there are social, emotional, and cognitive aspects to inquiry (Reiser et al., 2001). Prior to focusing on the scientific application of inquiry, it is essential that teachers set up a culture of inquiry. To effectively implement an inquiry-based curriculum, an educator must have the following in place: a classroom culture, appropriate attitudes, developed skills, sufficient support, beneficial behaviors, and a belief in the value of education (Colburn, 2000). This demands that teachers attend to the affective domain to allow for communication, debate, and negotiation (Reiser et al., 2001). Teachers also need to reinforce that the goal of inquiry is not empirical evidence, but rather the pursuit and evaluation of knowledge. This culture needs to be reconsidered frequently as development in the cognitive domain occurs. Due to the centrality of understanding of the scientific method and processes in inquiry learning, the literature primarily focuses on the cognitive aspects of inquiry.

Second, a frequent shortcoming of inquiry-based teaching is that educators assume their students have been previously exposed to the skills they need to engage in inquiry (Colburn, 2000; Kuhn & Pease, 2008). The assumption that fundamental inquiry skills are already in place is largely unwarranted for most students, as sustained engagement is essential for the development of an inquiry framework. For students, it is beneficial when educators reiterate and reintroduce frameworks for inquiry periodically; formative assessment, cognitive and affective awareness, enable the educator to determine when these reintroductions are necessary. As teachers develop inquiry-based instructional methods, collaboration and reflection are key processes in shaping and adopting this inquiry-based approach (Anderson, 2002).

It follows, then, that when we directly teach a student a concept, instead of letting them discover it, we prevent them from complete understanding (Piaget, 1964). There is substantial constructivist literature to support the premise that students learn best by engaging (e.g. Kuhn & Pease, 2008), whereas directly teaching the process of inquiry constrains the scope of meta-level understanding in students (Kuhn & Dean, 2005). Teachers need to minimize direct instruction and promote discovery learning to be the most effective in reaching the most students. An emphasis on direct instruction fails to give students the skills to explore broader issues through scientific inquiry, resulting in transfer failure. While direct teaching is indeed occasionally necessary, it is most effective in brief increments that are used to reinforce the essential framework of inquiry skills (Klahr & Nigam, 2004). For inquiry skills specifically, educators should tailor direct instruction towards guiding students to the understanding of why and how we use inquiry skills.

Inquiry as a teaching technique functions along a scale from "structured" to "open" (Colburn, 2000). Structured inquiry occurs when a teacher provides a hands-on problem to investigate, the procedures and materials necessary for an investigation, but not the outcomes. Guided inquiry refers to when a teacher provides a problem to investigate, and the materials necessary for the exploration. Open inquiry requires that students formulate their own problem to investigate, and carry out an independent exploration – this type of instruction is more available to students who can think abstractly, and who are familiar with the context of the problem (Colburn, 2000).

In addition to techniques, considerable amounts of research have delved into teacher attitudes and behaviors that contribute to student development of inquiry learning. Colburn (2000) identifies several teacher behaviors that increase the chances of improving student learning: experience with discipline and classroom management, the ability to ask open-ended questions, providing appropriate wait time, and responding reflexively or acknowledging what the student have said without criticism. Helping students to identify a question dramatically improves their development of subsequent inquiry skills (Kuhn & Dean, 2005). Educators must therefore facilitate a class founded upon a belief in the value of education, and teach from a framework built on knowledge, understanding, and formal operational thinking abilities, while simultaneously minimizing direct teaching time through brief, direct instruction (Kuhn & Dean, 2005).

Through the application of these skills, attitudes, behaviors, and experiences, an instructor can scaffold the inquiry process by reducing the structure of the inquiry process over time, while simultaneously increasing the complexity (Kuhn & Pease, 2008). This progression typically begins with structured inquiry, migrating towards open inquiry. Kuhn & Pease (2008) describe the complexity components of the scaffolding process as including the increase from single variables to multiple variables and the incorporation of probabilistic effects and interactive effects with time (Cadow, 2016a).

The NRC standards were just the first step in opening up a broad field for study and implementation. Today, an opportunity presents itself at the Catamount Center, where a program tailored to inquiry-based teaching is in place. This program offers a chance to examine what is being implemented in the undergraduate pre-service students' (stewards') training, what is demonstrated in the stewards' teaching, and what subsequently develops in their students from such practices. It provides the opportunity to determine if there is any correlation between techniques, attitudes, and behaviors, and the development of inquiry.

The intention of this research, is to look at the relationship between the development of inquiry skills in the 5th grade students the steward's teaching, facilitation, and implementation of inquiry curricula. Given the large scope of this research concern, I have chosen to focus on one of the nine inquiry objectives that Kuhn & Pease (2008) presented (included in *Student inquiry*): Using inquiry to make justified conclusions.

METHODS

Site

Outdoor Learning School (OLS) is held at the Catamount Center in Woodland Park, Colorado. The interaction of the undergraduate educators enrolled in the Teaching and Research in Environmental Education (TREE) Semester provides a natural laboratory to examine the effectiveness of various inquiry-teaching techniques. The subjects of the following analysis are the 5th grade students who participated in Outdoor Learning School (OLS), as well as their undergraduate educators, the “stewards” (Table 1)

Outdoor learning school

On ten Fridays throughout the 2016 fall semester, 75 5th grade students from a nearby elementary school take a bus to the Catamount Center. At this location, the students engage in five hours of inquiry-based learning at OLS. This learning experience delivers over 75% of the 5th grade fall semester science curriculum.

The four-week inquiry curriculum includes the “essential features” listed in the NRC guidelines: the creation of scientifically oriented questions, the development and implementation of methods to investigate these questions, the use of evidence to derive explanations that address the questions asked, the analysis of the success of such experimentation, and the communication and justification of findings (NRC, 2000).

The development of inquiry requires focus on a specific discipline through which inquiry learning can be scaffolded, i.e. students gradually build up expertise over time (Reiser et al., 2001). The content used to teach these inquiry skills varied between stewards and among groups: Aquatic (1), Wildlife (4), Trails (2), and Forests (3). The 5th grade students recorded the process of their inquiry instruction in science notebooks. Following the inquiry unit, the 5th grade students composed scientific papers that explained the research their inquiry group had accomplished.

The development of inquiry skills appears to be age-independent, and so it is appropriate to speculate that 5th graders should attain a grounded understanding and application of an inquiry approach (Kuhn & Pease, 2008). If so, how did educators effectively frame and address the objectives of inquiry in their lesson plans? Did transfer failure (the term for when students are unable to apply learned skills to new content) occur? If so, why? How did students differentiate between variables?

The TREE Semester

The TREE Semester is a program that prepares undergraduate students to instruct inquiry. Throughout the fall semester, the undergraduates are enrolled in the Environmental Practicum (ED 120) and Foundations of Environmental Education class (ED 225/EV 265) which focus on the fundamentals of pedagogy and development. The course material includes foundational papers, by authors such as Vygotsky and Piaget, to current and specialized research regarding issues such as multicultural education, inquiry, intelligence, the positive and negative roles of assessment in education, goals and policies of EE, and other topics. The stewards put these theories to practice in the Environmental and Sustainability Education curriculum class (ED 385/EV 365), which focuses on the development and teaching of engaging lesson plans that will be taught at OLS.

For four of the ten OLS weeks, the ten stewards enrolled at the TREE Semester practice the art of lead teaching inquiry to groups of 5th grade students the Catamount Mountain Campus. After the bus arrival at 9:15 a.m., the stewards work with their inquiry groups to facilitate a holistic learning experience based upon the previous days and months spent preparing for this opportunity; the Catamount stewards had become "experts" in scientific fields prior to designing and teaching the OLS inquiry curricula. They then use their expertise in fields such as wildlife, forests, trails, and aquatic systems as a framework to teach inquiry. Through these interactions, the Catamount stewards refine their lesson plans, develop instructional and management techniques, and reflect upon their positions as educators (Cadow, 2016c).

Coding

The papers written by the 5th graders fulfilled what Reiser (2011) describes as an important step in inquiry – the creation of products or artifacts to demonstrate understanding and execute skills. The written sections included introductions, background information, materials and methods, discussions, and conclusions. The discussion section is where the students drew their conclusions, from a scientific perspective. These discussion paragraphs provide the primary data set for the analysis of the development of inquiry skills.

The coding methodology that I employed to determine the success of students in producing justified conclusions is adapted from the work of Ruiz-Primo et al. (2010), who examined the development of student explanations from middle school science notebooks. Their analysis method was used to assess the students' learning process, teacher-student communication, and to determine the success of a 6th grade inquiry unit.

According to Ruiz-Primo et al. (2010, 586), an explanation is made up of three primary components: a claim, evidence, and reasoning:

> Evidence: Investigating data that helps to construct, support, and defend a claim.

Reasoning: Statements given to justify claims; that is, they are justifications to show why the data counts as evidence to support the claim through a conceptual and theoretical link.

Claim: A testable statement or conclusion that answers a scientific question. A scientific claim typically focuses on what happened, or how or why something happened.

I have employed the theory utilized by Ruiz-Primo et al. (2010) as it applies to the quality of the components of the students' explanations.

Within the three primary components of an explanation lie several nuances. The claim is only assessed upon the grounds of its "focus," or how the claim addressed the research question. However, reasoning can be further divided into the type of link (or the connection of the evidence to the claim), and the alignment of the claim and the evidence. The evidence is comprised of the nature of evidence provided, the type of evidence provided, and the sufficiency of provided evidence. These six categories, in addition to the assessment of conclusion elements, define the seven distinct categories under of sub-nodes coded. The sub-nodes are the specific descriptions of which each paper displays one specific characteristic.

I have taken the basic nodes (Figure 2 and Table 8) from Ruiz-Primo et al. (2010), and applied them to an analysis of the OLS 5^{th} graders' final papers. Rather than coding "explanations," I have applied the existing theory to the conclusion paragraphs of the 5^{th} grade papers. These nodes (Table 2) detail the results of the initial coding experiment. As I coded to this existing theory, I made slight adaptations as they applied to my study.

Given that this is the fifth-grade level, the conclusions did not always follow the instructed paragraph layout. Therefore, when elements of the conclusion appeared in the final paragraph, I coded these as if they were included in the conclusions. This decision is justified because the content is consistent with Ruiz-Primo (2010).

Within the analysis, I mostly coded entire sentences to a node. This procedure provides for a heightened level of clarity and context when referencing the quotes that arose from the coding. Additionally, I coded the student papers in a relative fashion to the other students in their inquiry group. This was based upon the fact that my knowledge of the available information was acquired by reading over the individual papers prior to beginning to code. For example, in steward C's group, if students made claims based on evidence that they failed to provide (but other students had cited), I marked the alignment to between evidence and claim as partial.

Under "Nature of Evidence Provided," the "data patterns" sub-node includes averages, final figures, and general statements about what was found. The "data examples" sub-node, on the other hand, refers to the raw numbers that students collected in the field. The sufficiency of evidence is based upon whether students listed sufficient data to address the prior sections of their paper, and to create and justify their claims.

In total, 37 papers were coded (Table 1). Following the initial coding in Nvivo, the results were compiled in a coding matrix on Microsoft Excel. The elements were then analyzed by simple comparisons, and tested for statistical significance through the use of t-tests. Given the small sample size, a p-value < 0.10 was deemed statistically significant.

Scoring

The evidence, reasoning, and claims underwent a different process than the analysis of the elements. Because each of the sub-nodes under these three components lacked independence, there was no feasible method in which to apply classic statistical analyses. To circumvent this problem, I assigned weights to each of the sub-nodes. A higher weight indicates a higher level of performance for the given node (Table 2). The frequency with which each steward's 5th grade students scored at a given sub-node was converted into a decimal. This decimal was multiplied by the score assigned to that sub-node. The total score was then summed. This total sum was divided by the maximum possible score to normalize the scores for each node for the purpose of comparison.

RESULTS

Elements

Figure 2a displays the occurrence of the sub-nodes included under the element component. When considering the occurrence of elements in the 5th grade inquiry papers, first note that no students included Yes/No responses, nor did they compose conclusion paragraphs without substance. 64% of the 5th grade students, refer to their original hypothesis. Next, we see that data is regularly present in student papers. This is consistent with the further breakdown and scoring of the evidence component. When contemplating the conclusions that students draw, we see that the majority of students are at least beginning to make claims about the outcome of their research – why or how they got their results. However, the justification, which can be likened to the reasoning component, is less present, with 55% of the students including some aspect of justification. Finally, we see that only 5% of the students ask questions in their conclusion statements. These students were all in steward C's group, and asked questions that would provide further information and clarification related to their original hypotheses and questions.

Evidence

From Figure 2b, it is clear that the Catamount stewards are effective agents in providing their students with opportunities to collect evidence in relation to their inquiry projects. The average evidence score, when considering all three nodes of the evidence component, is 0.78 (Table 3). This component scores the highest of the three considered in this research. Note that steward B has the highest evidence score at 0.93.

Reasoning

The Catamount stewards' students score lower when analyzing the reasoning component of inquiry (Figure 2c). The average score is a 0.52 (Table 3). Note that, in comparison with the evidence scores, steward B scores the lowest in this category with a 0.25. When looking at steward E's score, we find a stark contrast with a substantially higher score of 0.79. Also, note that steward C's students had the second highest reasoning score. Interestingly, for reasoning to be present, justification must be occurring. However, given the element graph (Figure 2a), we can see that justification is less present than claims in the element assessment. This means that while reasoning is less present, when it is included within the student papers, it is of better quality than the average claim.

Claim

Finally, when we assess the claim component of inquiry (Figure 2d), scores are dramatically lower than for the evidence component. The average steward score is a 0.35 (Table 3). The majority of 5^{th} grade students fail to meet the requirements laid out by Ruiz-Primo that translate into a high score. Note that steward C, whose students asked questions in their conclusion statements, exercised substantial creativity and thought when developing claims. Not only were the claims present, but they were often elaborate as well.

Statistical Analysis

While the evidence, reasoning, and claim components tested the quality of conclusions, the element component analyzed the present of different of elements. In order to determine if this presence differed significantly between steward groups, we ran a series of t-tests on the elements sub-nodes. If one steward group displayed substantially more claims in their papers, was that a significant difference? A p-value of <0.10 was adopted as significant. These tests yielded few significant results (Table 4). The stewards who differed the most significantly were stewards B and C, with five of the seven tests resulting in significant p-values. Stewards B and E, as well as stewards B and F displayed two instances of significant differences. This is important because these findings are consistent with the individual steward results discussed below – steward groups B, C, and E not only differed in terms of element presence, but also in the scores attributed to evidence, reasoning, and claims.

Individual Steward Results

A: About average for reasoning, well above average for evidence, but below average for claims, steward A's students scored above average overall. Steward A has a considerable amount of education experience for an undergraduate steward, cares greatly for her students, and studied scat with her students. She employed a variety of techniques including songs, games, experiments, and activities.

B: Steward B's students perform the most poorly of any group in the reasoning and claim categories, yet score the highest in evidence.

C: Steward C's students score the second highest in reasoning, about average for evidence, and the highest for claims, leading to the second highest score overall.

D: Second lowest for reasoning, the lowest for evidence, and tied for the lowest in claim score, steward D's students score the lowest on average. Steward D was concerned about the success of their project, based upon the fact that there was too little information for their students to derive any interesting claims.

E: Steward E's students attain the highest reasoning score, well above that achieved by any other group. However, their students include an average amount of evidence within their conclusions, and score second highest in claim generation. Steward E displays a truly moderated approach to inquiry instruction. Upon discussion with steward A, they discussed the importance of guiding their students towards an experiment with straightforward, tangible outcomes. Additionally, they mentioned that they repeatedly discussed the key takeaways of the experiment with their students by allowing their students to acquire a thorough understanding of the outcomes of the inquiry project.

F: Steward F's students score about average for reasoning, 2nd to last in average for evidence, and above average for claims. Overall, steward F's inquiry group ranks 5th in average score. Again, we see a potential shortcoming for this inquiry group in the limits of evidence generated in the experiments during the inquiry unit.

DISCUSSION

The "Balance Hypothesis"

We begin this discussion by turning to the results that described the differences between stewards. While the data set (n=6) is relatively small, there is sufficient evidence to draw some preliminary hypotheses. Table 3 indicates the score attributed to each steward's group of 5th grade students. From the analysis of all stewards, we begin to see an emerging trend. The trend describes the relationship of the inclusion of evidence, which appears to be directly correlated to the amount of experiential data provided in that specific steward group; and reasoning and claim, which appear to be influenced by the amount of free time provided for reflection, and clarity of relationships within the evidence. Therefore, it seems likely that an overabundance of evidence, as displayed in the steward B group, can lead to a state of cognitive overload that inhibits 5th grade students from higher levels of analysis and complexity of thought. A moderated, average approach to collecting evidence, as demonstrated by students C and E, appears to be the most effective for enabling students to derive more complete conclusions from their data. On the opposite end of the spectrum, we see stewards D and F failing to provide sufficiently intriguing and robust experiments for their students to fully engage in any of the components.

Thus, it is important to balance time spent experimenting with time reflecting upon, and absorbing such information. Perhaps, additionally, it is essential for the educator to guide the inquiry group to a specific, tangible experiment. It is not that the students are incapable of understanding such an intriguing, complex system, but that the time constraints and the expectations of the final paper require the implementation of more intentional, focused, and specific curricula. These students showed substantial interest, investment, and piqued curiosity to continue studying such systems. In relation to this finding, the best predictor of steward group score can be found in the reasoning average – it can be used to predict all but two of the steward group scores relative to one another. This connection likely carries weight for how stewards allot time to their students during the inquiry unit. If reasoning demands increased attention, stewards should consider how to include this within their lesson plans.

This directly relates to Kirschner's (2006) primary argument against inquiry-based teaching – that if you open up an investigation beyond the students' zone of proximal development, or beyond the realm of the students' capabilities, then the students will fail to learn anything due to the effects of cognitive overload. Thus, it falls upon the teacher to guide the students when presenting new information (Kuhn et al., 2008).

The "guided versus open" hypothesis

When reconsidering Colburn's work on guided to open inquiry, it is essential to consider how the findings of this research affect the facilitation of inquiry at OLS. While open inquiry is alluring, as it enables the student to direct the learning process, the stewards must guide the students sufficiently for the 5th graders to develop their desired skills. This may mean limiting the experiments of the inquiry unit to those that will result in tangible outcomes, although the specific outcomes will still not be known. It means ensuring that students remain focused, on track, and have sufficient time to reflect and make sense of the copious quantities of data that they encounter. For the stewards, choosing which stage of inquiry a student requires depends on what the student needs to effectively engage in their zone of proximal development (Vygotsky, 1978; Colburn, 2000); what will provide the appropriate amount of cognitive dissonance, without pushing the 5th graders into cognitive overload. Open inquiry is available to those who can engage in abstract thinking, and this needs to be accounted for when working with 5th graders.

Statistical Analysis

There are two different sections of the statistical analysis that require our consideration. First, the elements component displays significant difference between the elements included within the papers of steward groups (Table 4). This indicates that stewards groups differ in what content is included within their conclusion papers. It is not simply a difference of quality, but also in quantity.

Second, the statistical analysis resulted in very few significant differences between the evidence, reasoning, and claim components of the steward groups (Table 4). However, this can be interpreted in two ways: first, the sample size was fairly small, with the total of six steward groups. This first hypothesis holds that there are indeed differences between steward groups based upon the techniques, attitudes, and methods that were emphasized by the different stewards. Or, second, there simply is not much difference between the steward groups. This second hypothesis is supported by the fact that the stewards were exposed to the same instruction, curriculum, and expectations for student development of inquiry skills and content matter. Despite the lack of significance revealed by the t-tests, we can complete a preliminary analysis between the steward groups to determine if the first or second hypothesis holds more validity. Regardless of whether the first or second hypothesis is true, we can use the data set to assess whether specific aspects are lacking across the steward groups.

As mentioned in the results, the stewards who differed the most frequently across the tests were steward B, C, and E. This is important because these findings indicate that steward groups B, C, and E not only differed in terms of element presence, but also in the scores attributed to evidence, reasoning, and claims. These findings add weight to the hypothesis that too much evidence inhibits the inclusion of claims or reasoning within the 5th grade papers.

Methodology and implications for the Catamount Center programs

Finally, and perhaps most important, this paper introduces a methodology for assessing the success of OLS based upon the 5th grade paper conclusion paragraphs. It takes an existing theory, implements the use of the components, nodes, and subnodes, and devises a scoring system to adapt the theory to the data set produced at OLS. It appears that this methodology produces scores that allow for interpretation of the relationship between inquiry teaching and inquiry learning.

This work has direct implications for the TREE Semester. There is a substantial amount of time dedicated to learning how to be a constructivist teacher, and the stewards are encouraged to be both students and teachers within these learning experiences. They are encouraged to discover their inner fifth grader, as well as to learn how to channel such vibrant energy into the construction of meaning. If this work indicates that specific aspects of the professional development at TREE increase the success of inquiry teaching, then I would recommend that these experiences should be emphasized in future semesters. Alternatively, if gaps in the curriculum are exposed, then the curriculum shall be tailored to address such voids.

It goes without saying that much of what an inquiry experience at OLS can accomplish depends upon the steward's mastery of the content being explored. Perhaps the interconnection of content mastery with teaching techniques should be assessed in further research endeavors related to the TREE Semester. Potentially, this comes as a call to revamp the EV221 class taught at the TREE Semester. According to Bell (2003), the teacher preparation programs need to mirror the hands-on, inquiry-based, NRC five-step framework that teachers are expected to implement with their students. This is based upon the findings that teachers needed to go through the full inquiry cycle prior to understanding how to incorporate all features in an inquiry lesson. Therefore, not only does EV221 have the potential to increase steward subject mastery, but also the class could additionally be better aligned with the inquiry objectives by chronologically preceding them within the semester.

Next year at TREE, we will have an inquiry evaluation plan in mind prior to beginning the semester. This plan will incorporate both the findings of the final version of this thesis, as well as be based in the broader literature. It will be easy to use, and enable a more fluid analysis of the strengths and weaknesses of the program.

Future Research

Unfortunately, time constraints restricted a more thorough analysis of the students' papers. For an improved approach, there are several considerations to examine. First, Ruiz-Primo's existing theory should be combined with a grounded theory approach of what one should expect from 5th grade paper conclusions. This approach would allow for a more precise investigation of what skills are developing. Additionally, there are multiple sub-nodes that are irrelevant in the case of the six papers that have already been coded. It is likely that in the next revision, these sub-nodes would be removed, and potentially replaced by more important sub-nodes. For example, the "artificial data" and "anecdotal data" subnodes were not present in the data set. Investigation data could be further subdivided into "qualitative investigation data and "quantitative investigation data."

Second, a coding of the lesson plans created and facilitated by the stewards must be executed at some point soon. This analysis will provide much needed information as to what attitudes, techniques, behaviors, components of the 7S model, and level of guided to open inquiry, lead to the development of the conclusion component of inquiry. This research will address a gaping hole in the field – the correlation of teaching inquiry and subsequent student response.

Third, the scoring scale is still in a primitive phase. The weights assigned to each sub-node are a basic approach to scoring. Uncertainty remains as to whether the weights are appropriately scaled, if all weights should be normalized, and what value system is informing the weighting system. However, there is room for reproducibility in future years at OLS, and therefore, this refinement should be considered before implementing the methodology again.

Fourth, inter-rater reliability is a key measure of any coding work. However, the coding that has occurred thus far has been limited to one individual. This needs to be corroborated prior to increasing the sample size.

Given that there is no formal operational definition of inquiry teaching (Anderson, 2002), it is of imminent concern that we begin to identify inquiry-teaching techniques that lead to the development of recognized inquiry skills in students. Thus, the potential for this work is pertinent. The opportunity to pursue further research, through the coding of both instructor and student work, to look at the relationship between what is taught in the lesson plan, and what develops in the final paper, is essential for the progression of inquiry skills and teaching techniques, and for environmental and science education. At places like the Catamount Center, EE has the potential to create a paradigm shift from traditional education, to an education system that promotes inquiry, critical thinking, and creates passionate leaders of tomorrow (Cadow, 2016b). However, we cannot blindly implement curricula without taking the time to reflect, assess, and evaluate the success of the program. Thus, it is essential to critically analyze the intent and the impact of the curricula we create and instruct, to determine the outcome of the pedagogy we implement, and to ensure that our students are growing the intended skills.

CONCLUSION

Marcinkowski (2010) identifies three major challenges that the field of EE faces today: professional development, sustainable development, and the integration of the issue of climate change. This study concerns all of these challenges, for it is through the process of inquiry that one discovers, to investigate meaning, and realizes the implications of multiple perspectives of truth. If our intention is to inspire ecological stewardship, we must equip the stewards of the future with the tools for understanding ecological systems, to teach from a systems perspective, to empower their students to develop inquiry skills. As Wohlleben (2016) states, “Many human attempts to conserve particular landscapes fail. What we see is always a brief snapshot of a landscape that only seems to be standing still. The illusion is almost perfect in the forest, because trees are among the slowest-moving beings with which we share our world and changes in the natural forest are observable only over the course of many human generations” (211). Thus, inquiry becomes essential for the ensured endurance of ecological stability, of a relationship between humans and the biosphere, and for the enduring success of the TREE Semester.

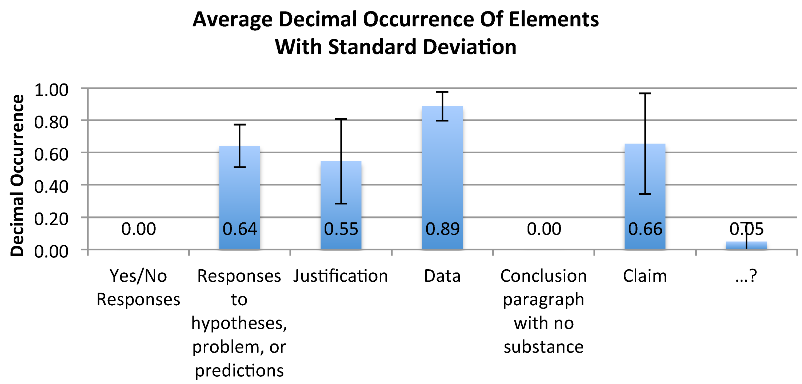

Figure 2a: The average occurrence of the element subnodes across the OLS steward groups. Error bars signify the standard deviation of the 37 5th grade student papers that were coded for these results.

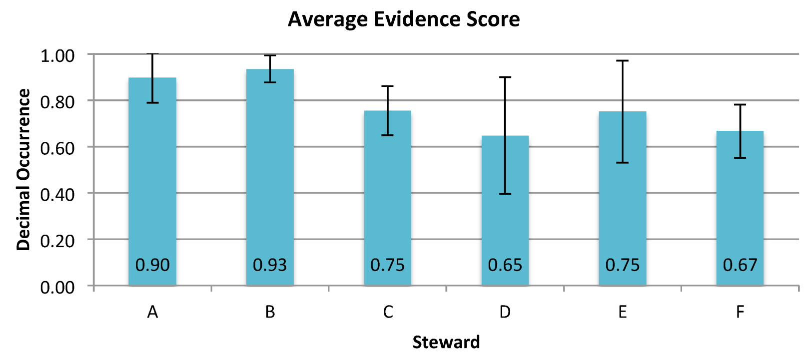

Figure 2b: The average score of each steward group for the combination of all three evidence nodes. Error bars indicate standard deviation values.

Figure 2c: The average reasoning score for each steward group. The average score accounts for the two nodes of the reasoning component. Again, error bars indicate standard deviation values.

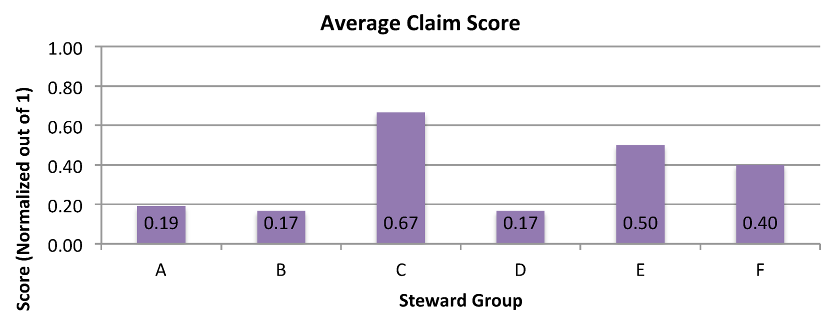

Figure 2d: The average claim score for each steward group. There are no standard deviations included because the claim only consists of one node.

							Total
Steward Group	A	B	C	D	E	F	6
5th Grade Students	7	6	7	6	6	5	37

Table 1: The data set consisted of 6 steward groups, each of which had between 5-7 5th grade students. In total, there were 37 5th grade students who generated the inquiry papers that were coded for the purpose of this research.

EVIDENCE	Score
Type of Evidence Provided	
Word data ony mentioned	1
No evidence	0
Data Pattern only	2
Data pattern and examples	3
Data examples only	2
Maximum Possible Score	**3**
Nature of Evidence	
Word data only mentioned	1
No evidence	0
Investigation Data	2
Investigation and artificial data	2
Artificial data	0
Anecdotal data	0
Maximum Possible Score	**2**
Sufficiency of Evidence	
Sufficient	2
No Evidence	0
Insufficient	1
Maximum Possible Score	**2**
REASONING	
Type of Link - Connection of Evidence to Claim	
Simple Connection	1
Not applicable	0
No connection	0
Elaborated Connection	2
Maximum Possible Score	**2**
Alignment of claim and evidence	
Partial	1
Not applicable	0
No	0
Hard to know	0
Maximum Possible Score	2
Maximum Possible	**2**
CLAIM	
Claim Focus	
Some incorrectly addressed	1
Some correctly addressed	1
No explanation	0
No claims, only evidence	0
Did not address any element	0
All incorrectly addressed	0
All correctly addressed	3
All but partially correct	2
Maximum Possible Score	**3**

Table 2: A list of the components (i.e. CLAIM), the nodes (i.e. Claim Focus), as well as each of the subnodes (i.e. some incorrectly addressed). The components, nodes, and subnodes are adapted from (Ruiz-Primo, 2010). They were the existing theory used to code the 5th grade papers. The numbers to the right of the subnodes delineate the scores, or weights, assigned to each of the subnodes. The greater the weight, the more complete the student's inclusion of the node in their paper.

Steward	A	B	C	D	E	F	Average for Node
EVIDENCE							
Type of Evidence Provided	0.90	0.89	0.76	0.61	0.67	0.60	0.74
Nature of Evidence	1.00	1.00	0.86	0.92	1.00	0.80	0.93
Sufficiency of Evidence	0.79	0.92	0.65	0.42	0.59	0.60	0.66
Average	*0.90*	*0.93*	*0.75*	*0.65*	*0.75*	*0.67*	*0.78*
REASONING							
Type of Link - Connection of Evidence to Claim	0.57	0.25	0.64	0.42	0.83	0.60	0.55
Alignment of claim and evidence	0.57	0.25	0.64	0.33	0.75	0.40	0.49
Average	*0.57*	*0.25*	*0.64*	*0.38*	*0.79*	*0.50*	*0.52*
CLAIM							
Claim Focus	0.19	0.17	0.67	0.17	0.50	0.40	0.35
Overall Average Score	**0.67**	**0.58**	**0.70**	**0.48**	**0.72**	**0.57**	**0.62**

Table 3: The above table displays the average steward score for each subnode, the average for each node, and the average steward scores.

Component	**Elements**	**Evidence**			**Reasoning**		**Claim**
Node	Elements	Type	Nature	Sufficiency	Type of Link	Alignment	Claim Focus
A-B	0.919	0.964	1.000	0.742	0.186	0.181	0.351
A-C	0.310	0.736	0.363	0.742	0.919	0.866	0.448
A-D	0.882	0.757	0.695	0.646	0.348	0.189	0.351
A-E	0.171	0.840	1.000	0.742	0.718	0.704	0.390
A-F	0.851	0.627	0.363	0.374	0.971	0.529	0.476
B-C	**0.032**	**0.034**	0.264	0.270	**0.058**	**0.098**	**0.099**
B-D	0.916	0.194	0.283	0.230	0.165	0.106	0.148
B-E	0.104	0.142	0.259	0.250	**0.060**	**0.097**	0.245
B-F	0.666	**0.079**	0.266	0.296	**0.049**	0.101	0.158
C-D	**0.091**	0.847	0.542	0.552	0.785	0.548	0.422
C-E	0.488	0.902	0.363	0.742	0.182	0.208	0.821
C-F	**0.025**	0.640	0.363	0.863	0.650	0.342	0.537
D-E	**0.034**	0.957	0.695	0.423	0.633	0.473	0.351
D-F	0.964	0.980	0.220	0.765	0.841	0.815	0.406
E-F	**0.088**	0.929	0.363	0.972	0.235	0.296	0.763

Table 4: The above table lists the p-values calculated for the difference between each pairing of steward groups. "Elements" considers the difference between the basic decimal occurrences between steward groups. Evidence, reasoning, and claim, analyze the difference between steward group scores. Significant findings are bolded ($p < 0.10$).

A 5th grade student in steward B's group:

Our research crew found that the upper lake and lower lakes succession rates have many differences. Our results told us that the upper lake outnumbers the lower lake's vegetation. (at least when we canoed the perimeter.) The upper lake also outnumbers the lower lake in wetted area. The majority of the upper lake vegetated was 60-70%. Vs. the lower lake was 40-50%. The majority of the upper lake wetted perimeter was 90-100%. Vs. the lower lake's 70-80%. We used bar graphs to express this data. My hypothesis was not supported by the data we had collected, because I hypothesized that the lower lake would be bigger, because water runs to the lower lake when it floods, snows, or precipitates, but the upper was bigger in its place. Our results are confusing because the percentage of each lakes vegetation shows that the lower lake has 38% and the upper lake has 33%. Odd. Our results matter because now we know how and why our Catamount lakes differ. By knowing this, we can determine how biotic each lake is, and biodiversity affects how healthy each lake is, and that will conclude to many differences in the lakes. Results from each of our experiments: Pebble count: more/smaller pebbles in the lower lake. The upper lake appears to have more energy, because a lake needs more energy to be able to move heavier/larger rocks. The upper lake has more D.O, (Dissolved Oxygen) but the lower lake appears to be colder than the upper lake. Odd. The lower lake collects more light than the upper, but that was only taken at one time of day. Results might differ depending on the time of day. Our results had many good things, but all experiments have flaws, as well.

5th grade student from steward C's group:

We found our information from the data we got. The data supports my hypothesis because it has all the biodiversity we got. Our results of our data told us that plot 1 had to thin more biodiversity which is thinned but plot 4 was also thinned and had the least biodiversity on the Simpsons index. My hypothesis correct because the data showed that the untinned forest has more biodiversity but you would half to thin a whole forest to get more biodiversity.

	Student 1	Student 2	Student 3
What elements does the conclusion have?			
Yes/No Responses	0	0	0
Responses to Hypotheses, etc.	1	1	1
Justification	1	0	1
Data	1	0	1
Conclusion paragraph with no substance	0	0	0
Claim	1	1	1
...?	0	0	0
EVIDENCE			
Type of Evidence Provided			
Word data only mentioned	0	1	0
No evidence	0	0	0
Investigation Data	1	0	1
Investigation and artificial data	0	0	0
Artificial data	0	0	0
Anecdotal data	0	0	0
Sufficiency of Evidence			
Sufficient	1	0	0
No Evidence	0	1	0
Insufficient	0	0	1
Nature of Evidence Provided			
Word data ony mentioned	0	1	0
No evidence	0	0	0
Data Pattern only	0	0	1
Data pattern and examples	1	0	0
Data examples only	0	0	0
REASONING			
Type of Link - Connection of Evidence to Claim			
Simple Connection	1	1	0
Not applicable	0	0	0
No connection	0	0	0
Elaborated Connection	0	0	1
Alignment of claim and evidence			
Partial	1	1	0
Not applicable	0	0	0
No	0	0	0
Hard to know	0	0	0
Complete	0	0	1
CLAIM			
Claim Focus			
Some incorrectly addressed	0	0	0
Some correctly addressed	1	1	0
No explanation	0	0	0
No claims, only evidence	0	0	0
Did not address any element	0	0	0
All incorrectly addressed	0	0	0
All correctly addressed	0	0	0
All but partially correct	0	0	1

Table 5: A sampling of student's conclusion paragraphs. Excerpts from Steward groups B, D, and E. The associated coding is included to the right of the paragraphs, with student 1 corresponding to the first paragraph, and so forth.

5th grade student from steward E's group:

Now that we have done our experiment we can start having a discussion about our data. My hypothesis was correct because I said that elk decrease aspen population because elk eat the aspen seedlings then they rot then die. In site 1 more aspen seedlings were declining outside the aspen enclosure then inside the enclosure. In site 2 more aspen seedlings were declining inside the enclosure than outside the enclosure. In site 3 more aspen seedlings were declining outside the enclosure than inside the enclosure. So that means that more aspen seedlings are declining outside the enclosure that inside the enclosure two out of three. The aspen seedlings are declining more outside the enclosure than inside the enclosure because the elk are browsing the aspen seedlings. My results matter because we might need to reduce the number of elk by maybe having a longer hunting season or maybe putting more predators in the forest to make the elk population decline and aspen population increase to save the aspens in our forest. We used a bar graph because we wanted to show the average percent of aspen seedlings declining inside the enclosure and outside the enclosure in site 1,2 and 3. We also wanted to show the average number of aspen seedlings recovering inside and outside the enclosure in site 1,2 and 3.

References

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, *13*(1), 1-12.

Bell, C., Shepardson, D., Harbor, J., Klagges, H., Burgess, W., Meyer, J., & Leuenberger, T. (2003). Enhancing teachers' knowledge and use of inquiry through environmental science education. *Journal of Science Teacher Education*, 14(1), 49-71.

Bybee, R. (2015). Scientific literacy. *Encyclopedia of Science Education*, 944-947.

Cadow, Charlotte (2016a), Rivers and Roads to Achieve Balance. CAEE master level portfolio submission.

Cadow, Charlotte (2016b), Em-Powell Your Students?: The Paradox of Policy. CAEE master level portfolio submission.

Cadow, Charlotte (2016c), TREE Rings: Growth, Reflection, and Success of a Semester. CAEE master level portfolio submission.

Carter, R. L., & Simmons, B. (2010). The history and philosophy of environmental education. In *The inclusion of environmental education in science teacher education* (pp. 3-16). Springer Netherlands.

Colburn, A. (2000). An inquiry primer. *Science Scope*, *23*(6), 42-44.

Esbjörn-Hargens, S. (2009). *Integral Ecology*. Shambhala Publications.

Flowers, A. B. (2010). Blazing an evaluation pathway: Lessons learned from applying utilization-focused evaluation to a conservation education program. *Evaluation and Program Planning*, *33*(2), 165-171.

Freire, P. (2005). Chapter 2: The Banking Model, In *Pedagogy of the Oppressed*: Continuum Publishing. (Original work published 1970)

Inquiry (n.d.). In *Merriam Webster Online,* Retrieved November 27, 2016, from http://www.merriam-webster.com/dictionary/inquiry.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41(2), 75-86.

Klahr, D. (2000). Exploring science. *The cognition and development of discovery processes*.

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction effects of direct instruction and discovery learning. *Psychological Science*, *15*(10), 661-667.

Kuhn, D., & Dean, D. (2005). Is developing scientific thinking all about learning to control variables?. *Psychological Science*, *16*(11), 866-870.

Kuhn, D., & Pease, M. (2008). What needs to develop in the development of inquiry skills?. *Cognition and Instruction*, *26*(4), 512-559.

Kuhn, D., Iordanou, K., Pease, M., & Wirkala, C. (2008). Beyond control of variables: What needs to develop to achieve skilled scientific thinking?. *Cognitive Development*, *23*(4), 435-451.

Lehrer, R., Schauble, L., & Lucas, D. (2008). Supporting development of the epistemology of inquiry. *Cognitive Development, 23*(4), 512-529.

Leopold, A., & Udall, S. L. (1966). *A Sand County Almanac* (pp. 237-63). New York: Oxford University Press.

[NRC] National Research Council. (1996). National Science Education Standards.

National Research Council. (2000). Inquiry and the national science education standards: A guide for teaching and learning. National Academies Press.

Piaget, J. (1964). Part I: Cognitive development in children: Piaget development and learning. *Journal of Research in Science Teaching*, *2*(3), 176-186.

Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., & Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. *Cognition and instruction: Twenty-five years of progress*, 263-305.

Ruiz-Primo, M. A., Li, M., Tsai, S. P., & Schneider, J. (2010). Testing one premise of scientific inquiry in science classrooms: Examining students' scientific explanations and student learning. *Journal of Research in Science Teaching*, 47(5), 583-608.

Toulmin, S. (1958). The Uses of Argument. Cambridge University Press. Cambridge, UK.

Wilson, E. O. (2016). *Half-Earth: Our Planet's Fight for Life*. WW Norton & Company.

Wilber, K. (1997). An integral theory of consciousness. *Journal of Consciousness Studies*, 4(1), 71-92.

Wohlleben, P. (2016). *The Hidden Life of Trees: What They Feel, How They Communicate Discoveries from a Secret World*. Greystone Books.