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The mediating role of scientific tools for elementary school students learning about the Everglades in the field and classroom

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There has been an increased use of authentic practices in both science and environmental education in recent years. Such practices can utilize social constructivist frameworks to consider the learning that may be taking place as students become engaged in tool use. The current study focuses on a group of elementary school students studying the Everglades in the field and in a classroom setting during one academic year. In particular, we observed students' use of tools (identified as tool-conventions to include both artifacts and conventions) and compared their use in both settings. We found that in the field, students spent considerable amount of time engaged in data collection activity such as taking observations and measurements that resembled what scientists might be doing and included the invention of new tools to facilitate data gathering. In this context, students generally worked more independently from the teacher, collaborated in small work groups, and engaged in more self-directed inquiry. In the classroom, while some of the scientific field tools were practiced in anticipation of their use in the field, activity included more teacher direction, often resembling what might be found in other types of classroom work and the tools used there often supported this work. Models of tool use based on Yrjö Engeström's activity approach were constructed for both settings. Implications of the results include the importance of viewing tool use in authentic learning with a sociocultural and activity perspective to reflect the socially constructed nature of such learning.

Keywords: authentic science, tool use, sociocultural approaches

Introduction

In recent years, authentic approaches to education have involved students in finding answers to questions that have real world implications. These efforts to make children's learning more "authentic", i.e. solving real problems such as making contributions to the recovery of ecosystems, have important advocates among contemporary science and environmental educators (Boyer & Roth, 2006; Braund & Reiss, 2006; Buxton, 2006; Krasny & Roth, 2010; Lieberman & Hoody, 1998; National Research Council, 2001; Sobel, 2004) and include "citizen science" programs that have been organized to permit data gathering by nonprofessionals for use in scientific studies (e.g.; BioBlitz, 2012; Project FeederWatch, 2012; The GLOBE Program, 2012). Such programs provide opportunities for the use of tools that scientists use. These include both

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artifacts (e.g. thermometers, notebooks) and conventions (e.g., how to use leaf characteristics to identify a species, how to take measurements of a plant) – identified here as "tool-conventions" to remind the reader of their links to tools. Students' use of tools in these types of contexts may come to mediate different kinds of learning than tools might in more traditional teaching contexts. In order to explore such potential learning differences, this study investigates the use of tools by elementary school students studying the Everglades using both authentic and traditional learning approaches.

The use of authentic approaches in science education to impact student thinking has been the source of some discussion. For example, recognizing the potential of authentic inquiry tasks for stimulating scientific reasoning, Chinn & Malhotra (2002) developed a framework comparing cognitive aspects of authentic science inquiry tasks to inquiry tasks typically found in textbook-based science curricula. While the description of such features provides important goals for educators to consider while developing inquiry curriculum, it does not capture the socially constructed nature of learning that happens during authentic practice. Other researchers have underscored the importance of social exchange and how students may develop their thinking and reasoning and have developed approaches that situate authenticity in problems of concern to the students themselves (Rahm, Miller, Hartley, & Moore, 2003) or even how students may be limited in accessing practices and learning in authentic situations (Hogan, 2002). Although somewhat different, research approaches to authentic science education have not sufficiently considered the role of tools in mediating the learning that is taking place.

In encouraging student participation in programs that involve authentic science learning, we may be shifting the learning context in important ways that highlight different kinds of tools and tool use than are found in traditional classroom settings that follow more didactic teaching practices. In both settings we expect that ways that students practice tool use with others to reach goals is an important factor in the way they learn to use them. To study such shifts, it is important to examine theoretical approaches that underline the role of social contexts in learning. Kirch (2009), for example, has written recently about the importance of cultural tools of discourse for students to learn about the role of uncertainty in science. Thus, in investigating student learning where more authentic practice is a goal, it is crucial to consider viewing learning with a sociocultural and activity based perspective, especially as it focuses on the use of tools to mediate such learning.

Theoretical Framework

Social constructivist approaches built on ideas from Vygotsky are generally widespread in science education and undergird popular approaches like Project Based Learning (Krajick & Czerniak, 2007). Vygotsky analyzed ways that individuals build cognitive structures during participation in practices that were linked to historically shaped goals. In Vygotsky's developmental constructivism, a sign form (such as a word) is initially shared between persons (adult and child) and then eventually becomes internalized by the child. This process is not straightforward, but undergoes a complex change as it moves from something external to the child to something that becomes part of the child's development (p. 11, Saxe, 1991). While Vygotsky described this primarily in terms of the speech sign form (see Vygotsky, 1986) the same process of internalization can be seen with other socially and historically created tools.

Wertsch (1994) and Wertsch and Rupert (1993) extend Vygotsky's insights with an approach that is concerned with the way that mental action (including remembering and reasoning) is linked to the context in which it occurs, which has been shaped by culture, institutions, and history. In doing so, Wertsch and his colleagues focus on the importance of mediated action as a centerpiece for such study. Its essence entails what he characterizes as a tension between "the meditational means as provided in the sociocultural setting, and the unique contextualized use of these means in carrying out particular, concrete actions." (1994, p. 205). For Wertsch, there is a two-way street between individual action and the cultural tools, which can be seen in an individual's ability to creatively apply cultural tools.

For purposes of this paper, we will focus on the use of tools as mediators in different educational contexts and how we might consider their role in transforming children's cognition. The use of tools to mediate the individual's work in science has been the subject of recent research work. Kirch (2009) highlights how science has developed a variety of tools including "specialized equipment, physical spaces, investigative methods, concepts, criteria, measures, models, and schema" to answer questions and solve problems. (p. 310). Kirch implies that the start of scientists' efforts to generate new knowledge involves interactions between scientists using mediation tools such as specialized equipment and investigation methods and that it would be important to heed Wertsch's call for studying the mediated action to understand what role these tools have provided. Kirch goes on to analyze how conversational tools allowed both scientists and children to identify and resolve uncertainty when solving scientific problems.

The use of tools assists in structuring activities, saving mental work, avoiding errors, and serve to distribute intelligence across people, environments, and situations (Pea, 1993). Resnick describes tool use in work settings as extensive and playing a direct role in reasoning (1987). Rogoff (2003) views artifacts as social and historical objects, which are formed by their use in practice but are also shaped by that practice. In recent years, sociocultural approaches to studying learning and development have expanded these notions by investigating problem solving across a variety of practices (e.g., tailoring, navigating ships, calculating deliveries) (Greeno, 1998; Rogoff & Lave, 1984). A number of researchers have shown that such sign forms have critical roles in shaping thinking.

The impact of tools on thinking has been studied extensively in domains such as literacy and mathematics that are important both inside and outside school. For example, studies in a variety of settings (candy sellers, dairy workers, abacus users) show that people readily utilize culturally constructed forms in their mathematical problem solving that can differ markedly from school mathematics. Mediating tools derived from school tool-conventions may lead to mental actions that have surprising consequences. For example, Rogoff (2003) describes how schooled children have better recall of lists of unrelated items than unschooled children. Rogoff attributes such differences to schooled children's practice on tasks where they are required to learn unrelated pieces of information- a traditional school learning tool-convention.

Accordingly, this approach to studying cognitive development highlights how learners come to participate in practices including use of particular mediating tools as a central focus of learning (see Greeno, 1998). We highlight the research by two investigators, Saxe and Engeström, whose work places a premium on the role of two types of tools - artifacts and tool-conventions - within their models. We find that their representations offer an important way to think about the roles of mediating tools in authentic science education in transforming student thinking.

In the course of developing a sociocultural approach for studying ways that mathematics becomes used by children and adults in their attempts to solve problems within particular culturally shaped activities, Geoffrey Saxe (1994, 2002) provides a framework that has important implications for how we might view the learning of science as an interplay between cognitive development and culture and thus has critical implications for learning authentically where the learning environment contains important elements of the actual practice.

Saxe studied a variety of contexts in which individuals show developmental changes in the use of mathematics that are linked to cultural practices. He developed a framework linking activity structures, tool-conventions and artifacts, prior knowledge, and social interactions to the creation of emergent goals that help guide the activity.

To illustrate the use of this framework for studying mediating tools, Saxe investigated the developing mathematics that Brazilian child street vendors used to solve buying and pricing problems. Saxe found that the sellers used various pricing tool-conventions linked to the wholesale prices to help determine the prices they would charge customers. Their acquisition of tool-conventions to set appropriate pricing levels was most impressive in the face of serious economic inflation issues. By studying the practice of candy selling, Saxe was able to link specific mathematical forms that the children used to solve problems within their practice. He found additional evidence for the internalization of these forms by comparing how candy sellers and school children with no candy selling experience solved a set of problems. Saxe showed that school children resorted to school like algorithms (one type of mediating tool) when solving such problems, while the candy sellers resorted to other types of mediating tools they had learned in the course of their candy selling experiences.

For Saxe, the use of mediating tools is a critical factor in how individuals develop and address emerging goals in an activity. In this model, tool-conventions become internalized over time by the learner as a result of participation in cultural practices, and thus come to mediate goal-directed activity in ways that are tied to that practice. When learners confront new problems, they draw upon these now internalized tools to solve them.

The focus on the use of tools as serving socially mediated devices received additional attention in recent years through the study of Activity theory. This approach views thinking as emerging in the context of an activity that brings together artifacts and human actions in a way that also helps us think about how social participation can also be tied to individual action. Yrjö Engeström has contributed to this perspective by developing several models of important components that contribute to the activity. Engeström points out that the simplest model links a subject (individual, dyad, or group) using a tool (such as machines, writing, speaking, etc.) to effect an object/motive (1999). While focusing on the activity as the central unit of analysis, Engeström developed a model that included links between the nodes of *mediating artifacts*, *subjects*, *rules*, *community*, *division of labor*, and *object* (Shown in figure 1 below).

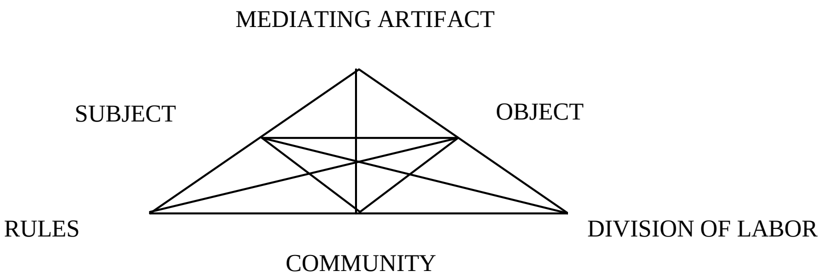

Figure 1. Engeström's model

In Engeström's figure, *mediating artifacts* represents tools and signs, *rules* include norms and sanctions that regulate behavior, *subject* is the individual, *community* is a space comprised of individuals working together, *division of labor* includes the negotiation and distribution of tasks, powers, and responsibilities among the participants, and *object* is the goal of the activity.

The following example of the analysis of a reciprocal reading program using this model may be helpful. Cole and Engeström (1993) created a small-group reading activity with elementary school children who were having reading difficulties. The *mediating tools* for the students included the texts and a set of role cards. During the early sessions of the activity, a leader gave students reasons for the importance of reading and then introduced the different roles they would play (e.g. questioner, identifier of the main idea) and the rules of how to participate. Over time, children increased their ability to carry out Question-Asking-Reading and showed improved performance in their classrooms.

Together, Saxe and Engeström place socially situated tools in a crucial role in the development of thinking. They help us understand that as tools are used in practices, they come to mediate our thinking and problem solving. This perspective leads us to predict that as students work over time in different contexts and internalize tools associated with each practice, we would expect them to draw upon these tools as they solve novel problems. Thus, learners who have internalized tool use as a result of engaging in different practices might solve similar problems in different ways.

We now move from a discussion of the research on the place of tools in a social constructivist framework to research done on their impacts in science and science education. At the paper's conclusion, we will return to a discussion of the use of a sociocultural framework using Engeström's model for analyzing tool use in the study of science and environmental education.

Studies of Tools and Artifacts in Science and Science Education

In the field of science, there are a tremendous number and variety of mediating tools that contribute to data gathering, constructing hypotheses, and writing journal articles. Research in the sociology of science (Latour & Woolgar, 1979) has shown that use of inscriptions such as graphing and drawings play an important role in communication and idea formulation in the work of scientists. Rogoff describes the affordances and constraints of the science journal article form for allowing scientists to reconstruct the scientific process while writing the article itself (Rogoff, 2003).

Artifacts such as microscopes and electronic spreadsheets and tool-conventions such as use of placebos and random placement of quadrats in the field while studying plant populations can be viewed as sign forms that exist in a sociohistorical context that an individual can appropriate. For example, if a scientist learns to gather data about an endangered bird population using scientific tools such as charts for bird identification, recording numbers of birds using a data entry sheets, and making data comparisons at different locations over different seasons, we might expect her to suggest using similar tools when studying a different animal population. Thus, in future work, the tools associated with the practice of studying the bird populations have become internalized in the problem-solving repertoire of that scientist. A similar transformation of thinking may be taking place while students utilize tools in authentic practices to engage in scientific study.

This approach gives us a greater appreciation for the interdependencies between development and social processes and represents a different way of thinking about learning science. If we accept the notion that science in general embodies a culture that, among other things, provides a set of important goals and contains mediating tools (most often associated with a particular scientific field) to assist in reaching those goals, then theories of how students develop scientific understandings as a result of being enculturated into the practice of science become paramount.

The Use of Mediating Tools in School Science Learning

The use of mediating tools is an important means by which children are initiated into cultural practices. In order to master the cultural knowledge they embody, students must use them in the activity in which the knowledge is used and must be assisted by more knowledgeable others in doing so (Lave & Wenger, 1991; Rogoff, 1990; Wells, 2001). The science classroom may also be seen as a cultural setting that comes with mediating tools that children use in accomplishing particular learning goals such as constructing experimental studies with the assistance of knowledgeable others. Specific science tool-conventions might include how to read a thermometer, how to focus a microscope, and how to create a bar graph to record the height of growing plants. Science classroom artifacts might include worksheets, use of calculators, and science texts.

In recent years, a number of studies have emerged that examine the use of such mediating tools in the science classroom. For example, Windschitl (2001) traces the way that tool use and ideas can diffuse across a middle school classroom as students observed each other solving design problems.

In a study of a high school science teacher using a project-based approach, Polman and Pea (2001) discussed the importance of teacher introduced tool-conventions critical in student project development. These included making claims only when backed up by references to data, using data representations such as graphs with two variables represented, and assembling a scientific paper in the process of doing the study.

Educational researchers have focused on practices in the science classroom to investigate how both students and teachers utilize tools such as inscriptions when they are using more authentic based approaches. (Lunsford, Melear, Roth, Perkins, & Hickok, 2007; Roth & McGinn, 1998; Wu & Krajcik, 2006). Such a process is complex, however, and as shown by Roth and colleagues (1994, 1995, 1995, 1997) is very much imbedded within a social process.

Roth and colleagues have written extensively on the use of a particular type of inscription – graphing – in science classrooms. For example, Roth and McGinn (1997) found that middle school students who were accustomed to using mathematical representations to convince peers and teachers of their arguments in studying real environmental problems, outperformed college students who typically did not use graphs to solve a representation problem. For Roth and McGinn, graphing data collected in more authentic based projects leads to the type of science talk which resembled what scientists actually do when they are engaged in scientific activity; graphs serve as representations which can be used to convince others of their knowledge claims. They become "tools for constructing facts and for mediating, in a reflexive relationship, the interactions during which facts are constructed." (p. 100)

Some Caveats

It is also important to keep in mind some limitations with this approach. For example, tool-linked mediation may not come automatically with use by students. In a study investigating the use of tools by middle school students studying electric circuits during a three week instruction unit, (Carter, Westbrook, & Thompkins, 1999), the authors found that providing tools for use in the classroom did not necessarily lead to their being useful as mediators of learning. However, the problems that students were asked to solve were typically school-like (e.g. making a bulb light, exploring the effect of adding additional batteries and bulbs to parallel and series circuits) and students were unfamiliar with the tools and concepts being explored. Thus, it is critical to consider the conditions under which such mediation does come about. It may be that situating learning in more authentic contexts is more likely to lead to different kinds of use of scientific tools than in more traditional science teaching contexts but this can be constrained by the nature of students' participation in such settings.

Significance of the Study

As interest grows in engaging students in citizen science projects and project based activities, a variety of contexts will be available for students to engage in authentic science work. It will be important to have appropriate theoretical models for studying such settings that can guide our inquiries and the methods we use to make sense of the learning taking place. The function of tools in mediating learning is a critical feature of the activity in settings and its study can yield important insights about learning in authentic approaches. In order to explore such potential learning differences, this study investigates the use of tools by elementary school students studying the Everglades using both authentic and traditional learning approaches.

Hands-on-the-Land Program

This study examined learning as elementary school students investigated habitats in the Everglades as part of the National Park Service Hand-on-the Land program. The national Hands-on-the-Land (HOL) network features "field classrooms connecting students, teachers, and parents to their public lands and waterways" (http://www.handsontheland.org/index.cfm).

This particular HOL program represented a partnership between nonformal (Everglades National Park) and formal education settings (the local school district). The unique aspect of the Everglades Park HOL program was to involve students directly in projects that emulated scientists' data collection as they visited particular habitats during the year and noted changes in these habitats tied to seasonal variations in precipitation and temperature.

Students from four elementary school classrooms in South Florida were involved in the Everglades HOL project under the direction of the educational division of Everglades National Park. Teachers were chosen for the program based on their commitment and previous work with the Park ranger in charge of education. The Park service selected habitat sites for each school group, provided teachers with benchmark lessons, activities, field guides, and scientific tools, involved scientists in developing data-gathering protocols, and assigned Park rangers to schools to assist in activity implementation and data gathering during the field trips. Teachers participating in the program were given several days of in-service training with scientists in using the protocols, field guides, and scientific tools. School groups were assigned to particular sites as a result of their proximity to various regions of Everglades National Park. Each school group visited a particular habitat site (pine rockland, cypress slough, sawgrass prairie, or hardwood hammock) four times over the year collecting data using a variety of scientific instruments.[1] The goal of the observations was for students to look at changes in their site across the year with respect to flora and fauna and to connect their data about such changes to changes in the wet and dry seasons.

While public school students in the state of Florida regularly study the Everglades as a part of their 4th grade curriculum and large numbers of students in south Florida visit the park annually as part of the Park's education program, the HOL project gave students opportunities to learn about the Everglades through authentic activity in ways that learning through the established visitor program and school-based Everglades programs do not. For example, the materials that are provided to students by the Park typically try to teach them concepts about the Everglades using more traditional lessons such as "Animal Olympics" where students make comparisons between different animals and humans and "Algae: It feeds, it kills, it's dying" where students study Everglades food chains and how contaminants such as fertilizers and chemicals can disrupt these chains (Everglades Activity Guide). These activities are generally focused upon answers that are known or provided. Many of the students also visit the Park and participate in day programs that consist of hikes along trails where they identify flora and fauna and discuss different environmental issues.

As part of the HOL program, in contrast, students used scientific inquiry tools in order to gather and interpret their own information about changes in habitats across seasons. For example, the students used artifacts such as rulers to measure the height of plants, and used tool-conventions to help them to decide which plant to measure and where to begin and end the measurement. If such tools are important for this purpose, then we might ask if there are differences in the types of tools that are used in solving authentic scientific inquiry problems vs. traditional classroom science problems. Such settings may provide opportunities to use different practice-linked tools in different ways. Thus, we might predict that different kinds of tool-conventions might be found in these settings than in contexts where students participate in traditional environmental educational programs through Everglades National Park or school-based studies of the Everglades.

Therefore, during this program, students had opportunities to engage in both what might be characterized as a more authentic type of practice in the field as students conducted inquiries about the presence of flora as well as more traditional classroom practices in the classroom. Thus one goal is to describe any similarities and differences in use of tools that students might utilize while engaged in these practices. We were also interested whether students' use of such tools during this period might come to mediate their thinking about new problems. It is important to note that we identify tools in this study to include artifacts and tool-conventions used to solve scientific problems. Thus, tool-conventions such as use of the metric system for measuring are considered mediating tools for solving scientific problems, while conventions such as turn taking or sitting on the rug are not viewed as such. In order to help the reader link conventions to tools, we use the term tool-convention here instead of convention.

In this paper, we use a sociocultural framework to explore tool use in the context of a program where students monitored habitat sites and studied about the Everglades over the course of an academic year. We were guided by these study questions:

1. What tools are being used in the HOL field and classroom settings?
2. Are these different or similar across these settings?
3. Can we characterize the tool use in both settings using an activity model that sheds light on how such use might mediate learning?

Method

In order to study students' uses of tools, we collected observation data on tool use during visits with the participating students as they worked in both the classroom and in the field. A naturalistic paradigm (McClintock, O'Brien, & Jiang, 2005; Moschkovitch & Brenner, 2000; Erlandson, Harris, Skipper, & Allen, 1993) was used for this study. The paradigm combines the linear structure of the traditional research design (i.e., define the research question, design the study, collect the data, and analyze the data) with a more circular qualitative research process. Extensive field notes were taken during the classroom visits and field trips and most were audiotaped for later transcription. We used an iterative process of identifying examples of tool use (artifacts and tool-conventions), checking and rechecking these with the field notes and transcripts, and reviewing these with each other to confirm the interpretation.

Participants/Setting

For the study, we followed students at one of the four schools, which was responsible for monitoring a pine rockland habitat (Lodge, 2011) site. The location of the site is shown in the map in Figure 2.

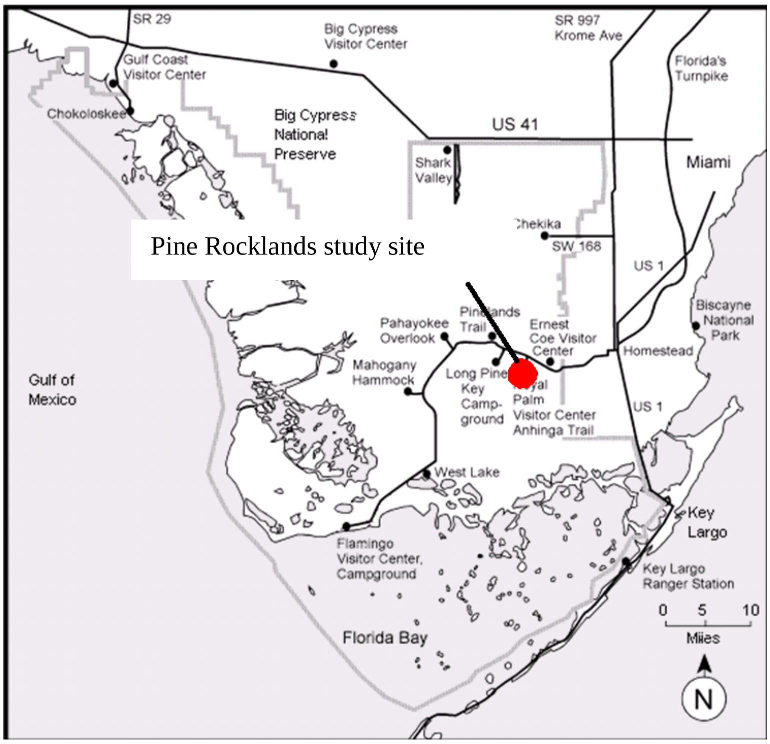

Figure 2. Map of Everglades National Park showing Pine Rocklands study site

The researchers selected for convenience only one of four HOL program schools to be included in the study because only one school provided opportunities for the researchers to observe HOL sessions at a consistent time and on a regular basis during the academic year. The other three schools utilized class times which often varied during the day and thus were not as accessible to the researchers. At Grand Park[2], where the study was conducted, the HOL program was held after school during the entire school year. Students were observed during most after-school class meetings (29 in total). Researchers attended all four class trips where the students worked in the pine rockland habitat during the field component of the HOL program.

Grand Park School had a predominantly Hispanic student population. Demographics indicated that the school population was 67% Hispanic, 19% White Non-Hispanic, 7% Black Non-Hispanic, and 7% Asian/Indian/Multiracial at the time of the study. There were about equal numbers of boys and girls in the group over the course of the year.

Participants at the Grand Park School had been selected by the teacher, Mr. Graham, mostly from students he had the previous year as their 4th grade teacher. While he taught his regular combination 4th/5th grade class during school hours, additionally he organized the HOL program into an after-school club - the “Herons”- with about 25 participants during the study period.

(There was some variation through the year in group size). The "Herons" met after school from 0-3 times a week during the year from September until May, with two meetings a week being the most frequent occurrence. There were few meetings held in December (due to the approach and holding of school holidays) and in April (due to statewide testing which restricted after school events).

Findings

We examined observation notes from class and field for instances of use of tools and their possible impacts on student thinking. These are described below. First, in order to provide the reader with a general picture of typical activities in both settings, we give a general description of events in school and in the field.

A typical at-school meeting for the Herons. Students met from 3-4 pm directly after school in Mr. Graham's classroom, which occupied a single portable classroom at the back of the school. Most of the students who were in the Herons group arrived at the classroom within a few minutes of the closing school bell and the others arrived soon after as they finished with various duties such as student patrol. Generally, students would come in and sit at an area rug located at one end of the classroom while Mr. Graham completed teaching duties for his regular class such as discussing homework assignments and talking with parents.

After the majority of the Herons had arrived, Mr. Graham would start the HOL activity for the day. These activities varied and included planting a garden of native plants, discussions of problems that beset the Everglades, slide shows from the Park Ranger, use of the Internet to find data, and practice of data collection procedures. Meetings during the early part of the year provided opportunities to orient students and practice data gathering procedures. For example, on two occasions, students practiced the data recording tool-convention involving drawing a square meter and recording the plants in the plot (Sutherland, 1997). Mr. Graham often created competitive games or contests to facilitate the learning of facts or concepts and sometimes even data gathering procedures. For example, on one occasion, Mr. Graham had a contest between teams to see which could set up a quadrat the fastest, and on another, teams competed to see who could recall the most facts about the Everglades.

Mr. Graham had an engaging interaction style with students, often joking with them and using nicknames with students. Activities such as those described above filled the hour and were sometimes continued in the next meeting. At a little before the four o'clock end of meeting time, Mr. Graham would get everyone's attention and give some final reminders about things to complete in the near future before dismissing the group.

Typical field trip day. The Herons took four field trips during the year to their field site in Everglades National Park. A typical field day consisted of leaving the school early in the morning by school bus and arriving at the field site about 10 am. Pre-selected teams of four or five students assembled near the site and followed the Park ranger into the site single file. The teams carefully walked single file behind a Park ranger over rocky terrain a few hundred meters into the site avoiding poisonwood *(Metopium toxiferum)* along the way. Each team would then gather at its designated spot which had been flagged by a Park ranger along the transect line. The team would then deploy a flexible meter square (named here as a "quadrat marking tool") marking the boundaries of a study quadrat and then proceeded to record data in their journals (Sutherland, 1997). Students in a team who are measuring a plant specimen is shown in Figure 3.

Student data gathering consisted of identifying plant species within the quadrat with a designation of T1, T2, T3, etc., drawing a map of the quadrat in a notebook, and recording measurements such as height and width in centimeters. A student notebook example is given in Figure 4.

Figure 3. Group measuring plant specimen in quadrat in Pine Rocklands

Because not every species was initially identified, students were asked to mark different species within the quadrat as T1, T2, T3, etc. with the notion that these would be identified later. Usually, one student (the team captain) would be responsible for designating which plant was T1, T2, etc. and either measuring the plant him or herself or asking others in the group to do so. The measurements were read off and the other team members would then record these measurements in their own notebooks. The groups spent about an hour at their first quadrat and then moved to a different transect line where each group was responsible for recording data at a second quadrat. Thus, all students participated in recording data from their quadrats.

Data gathered at the site also included any records of fauna such as insects and birds observed. At the end of the second hour of gathering data at the two quadrat sites, students returned to the buses. During the few minutes that students boarded the bus, one or more students helped gather weather data using a thermometer, wind gauge, and hygrometer to record temperature, wind velocity and direction, and humidity. Sometimes soil samples or plant specimens were also collected. Students were then bussed to another locale for lunch and engaged in additional activities such as visiting with the Park rangers to learn about fire control or viewing a large-scale restoration project to remove Brazilian pepper *(Shinus terebenthefolia)* - an invasive exotic - from the park. Such post-data gathering activities varied in focus across the four field trips.

Instances of tool use in field and classroom. We began our analysis by identifying what tools were used in the program and how they were being used by examining our field note observations for instances of their use. This was done by reviewing notes identifying possible instances of tool use and then examined these instances together to reach agreement on whether these qualified as tools (i.e. artifacts and tool-conventions).

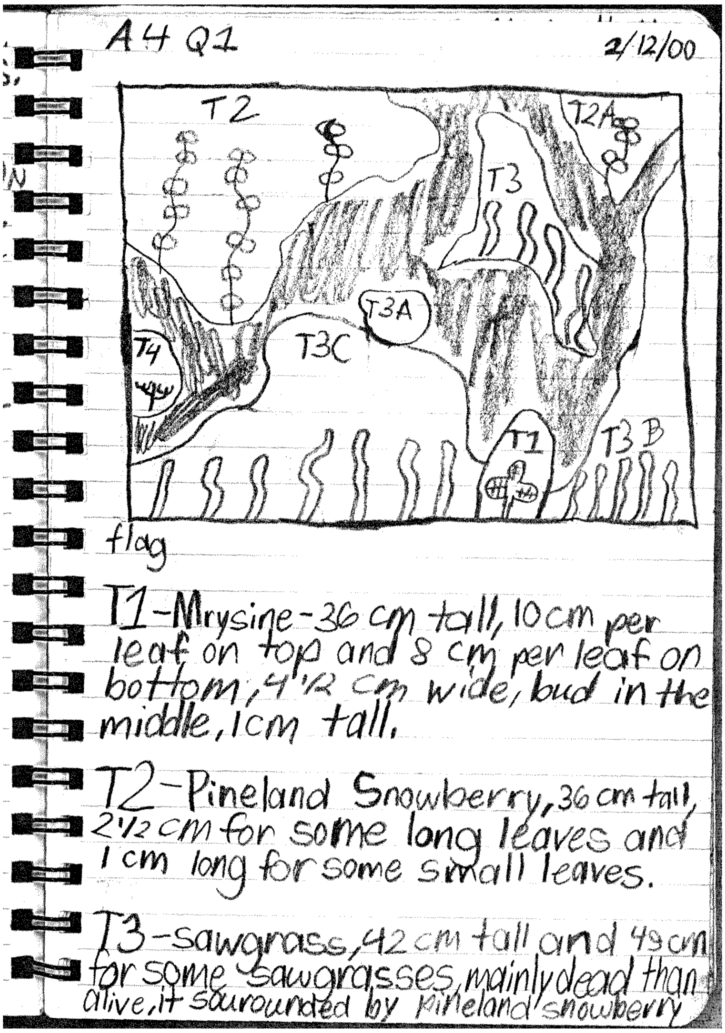

Figure 4. Student notebook entry

We also noted that there were a number of rules used in the two settings. In the classroom for example, these included: sitting on rug, sitting in designated spots, use of stories by teacher to illustrate points (e.g. sea turtles and Australian pine), students take turns reading out loud, and the use of a signal so that students stopped talking. In the field, these consisted of: walking to field site in single file and avoiding stepping in the quadrat. While not the focus of our study, such rules are a critical node in Engeström's model.

In order to illustrate some of the typical conversation that was carried on in both settings and the tools such talk was associated with, we give examples of talk in the classroom and field. We provide an example from the classroom where the teacher (T) is leading a discussion on things that might stress the Everglades.

22. T: Animals were encountering stress, why?
23. David: only large pond had water
24. T: When else has it been stressed? That is opposite as before-
25. Rachel: how much land has been [inaudible]
26. [Students are discussing across each other]
27. T: interrupts (T warns that there should be one person talking at a time or sharing ideas)
28. David discusses issue of noise [he is saying that noise pollution might stress the animals]
29. Brazilian pepper taking over
30. David (T) - fertilizer
31. Rachel: pollution
32. (LOTS of Students): FIRE
33. (Yoshi talks about new seeds)
34. T: let me ask you... did a good job of stress impact animals or does stress impact
35. everything?
36. Chorus of students: everything
37. BB- (talks about stress working through food chain)
38. Rachel: everything in Everglades needs water to grow...
39. T: How about too much water?
40. BB- (talks about hurricane problem)
41. T: What is main polluter in Everglades?
42. (T talks about food chain poisoning)
43. T: does it help plants?
44. (T goes to talk to parent-comes back)
45. T: concentrate on fertilizer,
46. Cassie says it helps plants (T complements students on discussion), plants need fertilizer
47. T: Does fertilizer help plants in Everglades?
48. Miguel (B) Does it help?
49. Yeah...
50. T: Joseph?
51. Joseph: Don’t need fertilizer for native plants...
52. Rachel: cats can get poisoned easily it at something... the birds was fertilized
53. Marco: It can be overfertilized
54. T: forgetting about the animals...
55. T: Jennifer, there are 2 types of fertilizer
56. Jennifer: [inaudible]
57. T: can the fertilizer stress the plants....? When you put native plants... are you going to
58. put in fertilizer in marshes?
59. Yessenia: cattails
60. T: is there one stress worse than others?
61. Rachel: Us taking Everglades land away...
62. David: (talks about problems of noise with animals) [there is an issue now about the
63. Homestead airport with noise being an issue there]

In this sequence, the teacher is encouraging the students to think about what sorts of factors might be stressing the Everglades Ecosystem. He is very much guiding the conversation using a typical classroom talk tool-convention to help students identify stresses in the Everglades system. Students are generally giving short answers as individuals or in group shout-outs to answer the question. At one point, the teacher clarifies the response about fertilizer being a stressor as some students think it may help plants. [Because the Everglades is naturally a low nutrient ecosystem, even low concentrations of nutrients can lead to significant changes]. In this context, the IRE science framework tool-convention (teacher question – student answer - teacher explanation) serves to focus student attention on what the teacher is saying and to promote answering out loud (Mehan, 1978). A comparison of observed artifact and tool-convention use is shown in Table 1.

Table 1. Observed artifact and tool-convention use

Classroom only	Field only	Both Classroom and Field
Use of stories by teacher to illustrate points (e.g. sea turtles and Australian pine)	Drawing quadrat map in field journal with drawings of plants	Use of the letter "T" for unknown plants found in quadrat (T1, T2, etc.)
Games to reinforce knowledge acquisition	Use of Field journals to record data	Deciding which plant is designated for which "T"
Competitions to see which group could set up a quadrat the fastest or complete a task	Using pencils to record data in journals (prevents ink running in rain)	Writing key for quadrat drawings
Creating summary tables of data	Measuring plants in the same place on the plant for consistency	Taking and recording weather measures for day (temperature, wind speed and wind direction, humidity) with thermometer, hygrometer, weather vane and wind speed indicator
Testing pH of soil with pH paper	Recording plant color	Use of quadrat tool to mark area
Taking notes on teacher lectures	Taking plants samples in plastic bag for later identification	Use of plant guides to identify plant
	Wearing latex gloves when handling unknown plants	Use of toothed/entire leaf edge shape to help identify plants
	Using finger as place holder on plant to slide ruler up to measure heights greater than 1 foot	Writing "no data" rather than not writing anything
		Measuring height and width of plant
		Use of metric system in measuring
		Use of hand lenses
		Use of ruler

In the classroom setting, students typically had such interactions during discussions with the teacher. The majority of classroom events involved such whole group discussions. Less frequently, students worked individually or in groups on short term projects after receiving directions from the teacher.

Students did have a number of opportunities to learn how to use data gathering tool-conventions in the classroom, several of which were used in the field. For example, students learned to differentiate opposite/alternate leaf pattern arrangements, measure height and width of specimens. In this example, the teachers spent some time demonstrating the distinguishing feature on the board to the whole group, then giving students the opportunity to practice using the tool-convention. In some cases (e.g. creating a quadrat, using the sling hygrometer or thermometer), while students were given an opportunity in the classroom setting to see or to use a tool-convention, these were never used or were only used by a small number of students during the field trips.

In contrast, the field sessions usually had a different type of focus and interaction pattern and numerous artifacts and tool-conventions were utilized in the service of field science activities. After the initial field session where students were introduced to the site and the application of the data gathering techniques, students broke up in their teams and spent the majority of the time at two quadrats gathering data about what plants were there. During the time that they gathered data, students had little extraneous talk. The following dialogue example is provided from the 3rd field trip.[3]

122. Male 3: t-6 is, um, limestone.
123. Um-hmm.
124. Isn't t-5 white topped sedge?
125. t-5 is saw palmetto,
126. Right
127. t-6 is white topped sedge.
128. What's t-5?
129. Nothing
130. t-5 is the saw palmetto
131. white-topped sedge
132. Saw palmetto!
133. That's not saw palmetto!
134. Yes it is.
135. Michael, that's a baby saw palmetto.
136. It is?
137. Yes it is.
138. Male 3: man, why didn't you tell me this people? I put t-5 down for white sedge.
139. No, t-5 is for saw palmetto.
140. Oh, now you people tell me.
141. Ok, and then this area right here?
142. Ok and this area right here where the baby pine trees are…?
143. No, 'cause you have to put it down.
144. It's myrsine.
145. You're the smart one.
146. Thank you.

In this sequence, students are discussing how to apply the identification tool-convention (T-5) to various features they see in the quadrat. There is some initial confusion (lines 124-131) about which plant is T-5 and which is T-6 and then additional discussion (lines 133-137) about the identification of a plant. There are several noteworthy features here. First, students are working within a space that has been defined with the use of the quadrat tool. Second, students are very much engaged with the data gathering process. During this sequence, there is very little off task behavior even though the teacher is not in the vicinity. Third, they are using the tool-conventions and goals to guide their behavior. They are intent on using the procedures of labeling the objects within the quadrat (T-5, T-6) and identifying the plants there. While they are talking, they are using another artifact - their field journals - to record the data.

Both sequences illustrate the way that tools are being used to accomplish goals. Speech conventions help structure the activity and learning that is taking place. However, in the first sequence, the IRE convention is typical of traditional science classroom conventions. Discourse was often teacher directed. In the second sequence, the students have appropriated the labeling scientific tool-convention to structure their data collection work in the quadrat. This scientific tool helps them to coordinate their observations and to tap the expertise of team members who can identify the species there. They are also using the field journals artifact to record their data. In the field, students frequently engaged in direct talk with to each other.

Overall, students were engaged in the field in using a number of the tools that are characteristic of biological field research work such as using centimeter measuring units and identification practices using field guides. Because the number of species of plants in this habitat is significantly richer than other South Florida habitats, the teacher's focus was on developing tool-conventions for plant identification and data collection. For example, students used field guides to help identify some plants and attempted to look at leaf arrangements (opposite, alternate) to help in this identification. They also collected plant samples for later identification. Students became proficient at using their notebooks to designate species type, length, and other measures of plants growing in their quadrats. These tools helped focus students working at their two quadrats during the field trip data gathering.

The use of a designated T1 and T2 was a tool-convention that Mr. Graham had practiced in the classroom and then used in the field that permitted students to record a variety of plants on site without having to identify them immediately. Though students did have picture guides, we rarely saw them using these to help identify plants in the field. It became clear that the picture guides were of limited value as they only contained some 30 plant species that were found in the pine rockland habitat, an area which has hundreds of species in it. The difficulty of identifying plants in this habitat was highlighted when a research assistant who had expertise on such plants accompanied the students on one of the field trips and brought a self-made identification list of hundreds of species of pine rocklands plants and their distinguishing characters and used this list to help identify plants in the field for students. Nevertheless, students were able to consistently identify several plants such as poisonwood *(Metopium toxiferum)*, white-topped sedge *(Dichrometa colorata)*, and dwarf rattlebox *(Crotalaria pumila)*. Students were also allowed to take plant samples as part of a Park permitted process, so that they were able to identify some of these later.

There was also evidence that students invented tools. For example, because the rulers used by the students were shorter than some of the plants they were measuring, students we observed from one team developed methods of measuring plants longer than the ruler by holding a finger at the point of the plant where the ruler top edge reached and then sliding the ruler up to that spot to begin to measure again from that new point. They then calculated the total length by adding the length of the ruler to the second measure.

Discussion

Similarities and Differences in Use of Tools in the Two Settings

The use of tools was an important part of the work done by students who participated in the HOL program. It was an integral part of the way that the goals of the project were met in both the field and classroom settings. There is overlap in some tool use in the two settings, but there are some important differences as well. Students received an introduction to a range of artifacts used to study the Everglades in the classroom setting and had some opportunities to practice their use in the classroom setting before using these same tools in the field. In addition, each of the settings provided particular tool-conventions to assist in student participation in the activities. In the field, these were critical in helping students gather data, while in the classroom, they were important for a variety of tasks, including reviewing concepts and giving answers to factual questions about the Everglades.

In reviewing the tools that were used by HOL students in their field work, we find two types. The first - we might call "general tool use"- encompass general approaches that might be found in a number of different research areas. For example, it is customary for researchers to record data in some manner and to transform the data for analysis purposes as students did by keeping journals with the measurements and then making tables summarizing the data measured in the field.

Another type of tool use we might describe would be "domain specific tools". For example, to assist in plant identification, plant ecologists use features such as leaf arrangements and leaf shape. Such tools are particular to the area of research being studied.

We also found evidence of the development of new types of tool use to assist in data collection or analysis. Consistent with the analysis of tool use by Wertsch, Saxe, and Engeström, the way that the science was applied through the use of tools in the field setting gave rise to new problems which in turn lead to the development of new tools. This was observed when the teacher developed the quadrat marking tool and students developed tool-conventions for extending a ruler to measure plant length.

In order to characterize the tools as linked to the activity structures in both settings, we have organized our findings using Engeström's model to create figures showing the activity in the field and the classroom.

In the diagram outlining activity in the field, nodes include: *mediating artifacts* consisting of the artifacts and tool-conventions such as the quadrat tool and notebooks to record the data, *rules* consist of norms such as walking to the site in single file, *subject* is the individual, *community* is most frequently the individual team that is responsible for a data collection in a quadrat, *division of labor* involves mostly the students themselves doing things like negotiating the designation of T1, T2 and collecting quadrat measurement data in their notebooks, and *object* is the collection of data within the two quadrats during each of the field trips.

Using this model, we see a number of ways that artifacts and tool-conventions may be linked to the other nodes. Thus an artifact such as the quadrat tool was used by the community (team) to mark an area for the group to collect their data. Each of the team members uses their notebooks to collect the data. The artifacts and tool-conventions can be seen to play a central role in facilitating the data collecting activity. In this data collection work, the activity structure stayed very similar during the four site visits.

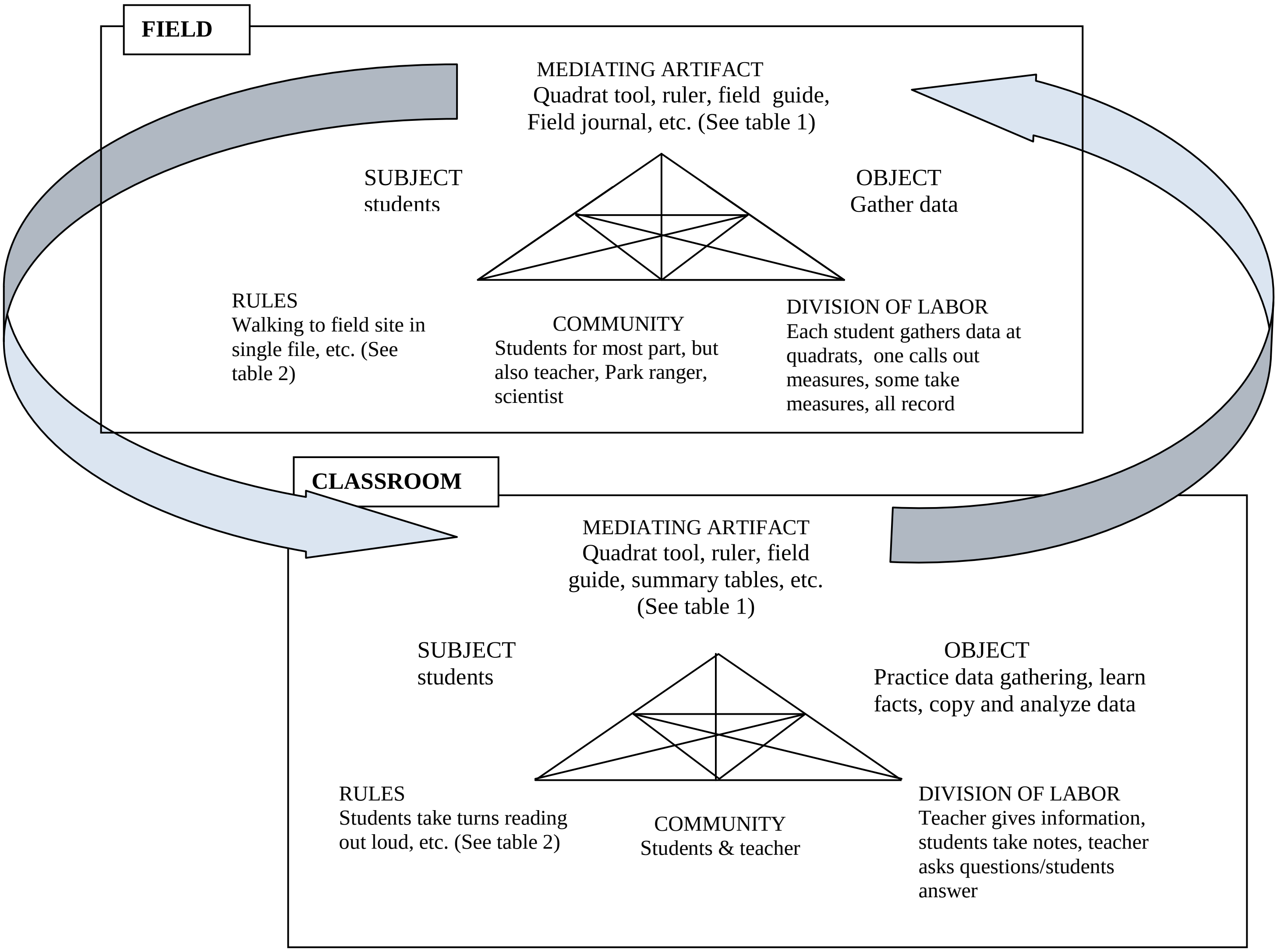

Figure 5. Using Engeström's model to linking field and class activity models through tools

In the classroom setting, however, the activities were much more varied and included typical school tasks such as report writing as well as opportunities to practice field skills like use of the quadrat marking tool. This is outlined in the diagram of the classroom in Figure 5. Here, nodes include: *mediating artifacts* representing a variety of physical tools such as student note-books as well as tool-conventions such as turn taking in the IRE speech pattern, *rules* consist of norms of classroom behavior like floor seating arrangements (e.g. sitting on the floor to listen to stories), *subject* is the individual, *community* was mostly at the classroom level though there were some instances when students worked in teams, *division of labor* consists of students mostly following what the teacher laid out in terms of particular tasks for the day and all students were usually assigned the same responsibilities such as trying to answer questions, and *objects* varied from answering game show type knowledge questions to demonstrating research writing skills in synthesizing information about animals in the Everglades.

Using this model of the classroom activity we also can see nodal connections. For example, in the context where students are participating in a game to give verbal answers to questions about the Everglades, the IRE speech pattern sets up the give and take verbal interactions, students follow classroom norms regarding seating arrangements that facilitate such answering, and students participate as a whole group. Due to the shifting nature of the activities in the classroom, however, students spent time in a variety of activities that could differ with respect to several of the nodes (e.g. mediating artifacts, rules, objects).

Tools served as a structuring device for the students in what they are doing in the field and were a critical feature of the activity that went on there. Most students were engaged in the data gathering activity the majority of time they were in the field. We found that the tools employed in the field allowed students to spend considerable amount of time engaged in activity that resembled what researchers might be doing.

In the after-school classroom setting, activity often resembled what might be found in other types of classroom work and the tool-conventions used there often supported this effort. For example, we found that tool-conventions of dialogue (such as IRE discussed by Mehan) were common in the classroom setting but rare when students were actually engaged in their studies in the field.

We did find there was some overlap between tools used in the classroom and in the field, particularly as students practiced procedures in the classroom that they would be using in the field. However the classroom tool use was often the first exposure that students had for such tools and necessitated a great deal of support by the teacher in the usage, including verbal directions and demonstrations. In contrast, as students worked in the field with the tools, they were mostly self-directed.

Finally, as Figure 5 indicates, the two activity settings are linked by their use of tools and in some instances, the changes in tools in one setting are linked to changes in the other. For example, the creation of the quadrat marking tool by Mr. Graham during his work in the classroom led to its use in the field. Another way to view this is to consider that the outcome of creating the new tool in the classroom led to that tool becoming part of the activity system in the field (Krasny & Roth, 2010). In another example, the recording of data in the field journals led to its incorporation in the classroom in developing summary tables with the data. While this linkage was apparent with some tools, changes in the use of one tool in the field (the development of the tool-convention of measuring plants in the field by moving up the hand when the plant being measured exceeded a ruler in length) never made their way back to the classroom setting.

There are several issues related to the differences in tool use across contexts that should be noted. For example, there was less talk in the field setting, though when it did occur it was rich with tool-conventions such as requests for naming plants with temporary placeholder names, and calls for measuring and sharing the data so that it could be copied to field journals. From our observations, it seemed that students quickly "got down to business" in the field in order to gather data at their sites, which included time drawing and recording observations. Given different goals in class and field, it may not be surprising that there would be differences in amount and type of talk. The different discourse patterns that were noted might also be linked to these goal differences as well as differences in division of labor.

Differences such as goals and labor divisions might also have contributed to different types of problem solving with tools in the two contexts. For example, the measuring convention invented by students in the field when the size exceeded their one foot ruler was a problem solving response to the goal of measuring a plant when the ruler was not long enough by itself to provide an accurate measure. It took place in a labor context where students were performing most of the work themselves.

Of course, given the interrelationships that are outlined in the model, it might be expected that differences in nodes like goals, tools, and division of labor would be factors in differences in problem solving behavior and perhaps learning as well. The model underscores the complexity of these relationships and calls for methods of analysis that can be further explored by researchers. For practitioners, keeping these models in mind might lead to thinking about ways that students might perform differently in authentic settings than in the classroom. For example, teachers may find that students who do not perform well with classroom tools-conventions are quite adept at learning and problem solving in the field with a different set of tools-conventions.

Obstacles and roads not taken. There were several program goals involving the development of data representation and analysis that were not completed by the students.
Because of a postponement of the start of the field activities due to tropical storm flooding in the Park, students did not begin the field work until January. Soon after this initial outing, the Herons group met infrequently at the end of March until the middle of April as students had their spring break and then the school prepared for statewide testing. Even after the testing was done, the group met less frequently as end of the year responsibilities required Mr. Graham to use after-school meeting time for other duties.

Towards the end of the year, Herons after-school meetings centered on groups of students copying their data in groups to cards. These were intended to be loaded on a web site to facilitate analysis. Mr. Graham collected this information from each of the groups, but the task of constructing a web site with the data was not completed.

Because the beginning of the program and field trips were delayed after hurricanes flooded the Park, final data was not gathered until very late in the year. Consequently, planned activities for using tools such as bar graphs to analyze the findings and to identify change in numbers of plants were not completed for the Herons group. Thus some critical tools used by scientists in typical analyses of such data were never used by the students.

Implications of the Study/Future Considerations

The use of a sociocultural framework for studying mediating tools allows us to make distinctions in the two settings in terms of how artifacts and tools-conventions play important roles in the activities in each that are linked to other critical components of the activity. While there was overlap in some tool use in both settings, especially as students learned to use some of the tools that would be used later in the field during actual data gathering, there were some differences as well. Differences between tool-conventions students used regularly in the classroom included IRE patterned discussions and participation in game show formats for displaying knowledge of concepts; while in the field they regularly used a field journal for recording data and a T1, T2 to designate different species in the quadrat. If this example is typical of the types of opportunities that students may have when using authentic approaches, prospects for students to engage in regular tool use in authentic practice may lead to very different kinds of learning than students who only participate in classroom practice.

Following Saxe's methodology, a stronger test for the theoretical framework linking learning and cognitive changes to the use of tools situated in cultural practice could have been made if a non-HOL group that used one of the tool-conventions in a classroom setting had been included. This might have been possible, for example, if HOL students would have been able to practice using graphing tools in service of their data representation. In this case, problem solving comparisons might have been made contrasting HOL students' use of graphing to graphing done by students not in the HOL program. Such comparisons are suggested in future studies of students using authentic data. The use of an activity based framework that highlights tool use allows us to appreciate a new set of relationships that the use of authentic tools may introduce when it is accompanied by other features of that setting. Thus, efforts such as Chinn and Maholtra (2002) to characterize more authentic science approaches can be supplemented by research that shows that authentic approaches introduce a suite of sociocultural factors that should be taken into account by educators desiring to introduce authentic practices. The study of the role of such factors in mediating learning has been applied to studying tools that help students understand the of role of uncertainty (Kirch, 2009) and could be expanded to include research on an extensive variety of artifacts and tool-conventions being used in settings where students are using more authentic approaches. As this study shows, such settings not only introduce new tools for use by students, but also a number of features that influence how that tool is used and how closely it resembles what scientists do.

In conclusion, the use of more authentic approaches in education may result in more opportunities for students to utilize research tools in their work that are part of real practices. Because such tool use may critically impact student learning while engaged in authentic learning, consideration of methods to study such mediation is vital. Thus, future research should include further exploration of tool use and problem solving used by students who have learned to use these tools in different contexts. Such an approach can also benefit teachers by underscoring the need to identify the tools and conventions that scientists themselves use to study the domain and the best ways to assist students' tool use while using authentic inquiry. This might include consideration of how to provide support for students to create their own tool-conventions to assist in such inquiry. This could involve monitoring student activity for emergence of such tool-conventions, giving positive feedback for attempts at such development, and classroom discussion about the use of such tool-conventions to help students comprehend their effectiveness as well as the role of creative use of such tools in the scientific enterprise.

Endnotes

1. A brief description of the Everglades' biogeographic features and the featured Pine Rockland study habitat can be found in Appendix A

2. The school, teacher, and students, are identified throughout with pseudonyms

3. In this segment, it was difficult to identify speakers from the audiotape, thus names have been omitted.

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Appendix A.

Everglades National Park has been designated a World Heritage Site, International Biosphere Reserve, and Wetland of International Importance, signifying its global importance. This vast subtropical area has essentially two seasons - wet and dry - that governs the tempo of life in the environment. Because of its southern location and the proximity of the Atlantic Ocean and Gulf of Mexico, this ecosystem has warm weather most of the year (with monthly daytime temperatures ranging between 78° – 91° F and nighttime temperatures ranging between 56° -73° F). It receives most of its rain from clouds associated with cumulus buildup in the months between April and October with monthly rainy season averages of about 6-9 inches though an occasional front will bring brief periods of rain during the period from November through March. The Everglades is subjected to periodic droughts and fires that race across the landscape on a seasonal basis, most often started by lightning. The slight differences in elevation provide enough of a difference for the water to begin its southward flow from the middle of the state. Historically, the Everglades system starts as water that overflowed the south end of Lake Okeechobee and continued through the end of Florida as a slow moving sheet some 60 miles wide in spaces and eventually spilling into the straits of Florida. A variety of measures to control this flow after a devastating hurricane in the 1940's and pressures for development have lead to a complex series of canals, locks, and pumping stations that now interlaces South Florida. A number of other problems have beset this region from the last century, including the wholesale slaughter of birds in the quest for plumes, the near extermination of alligators. More recent problems include the loss of significant numbers of particular species including the Florida panther (*Puma concolor coryi*), Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), and woodstork (*Mycteria americana*); the invasion of significant numbers of exotic plants and animals, including Brazilian pepper (*Schinus terebenthefola*); the discovery of toxic amounts of mercury in higher levels of the food chain; and the raising of the levels of phosphates in levels south of the farm areas south of Lake Okeechobee which have lead to the replacement of sawgrass with cattails in large areas.

The Everglades Ecosystem encompasses a number of habitats, including sawgrass praries, cypress domes, and hardwood hammocks. At the most elevated portions of the system, the pine rocklands habitat may be found. This is the habitat that the students in this study were investigating. Pine Rocklands are a globally endangered ecosystem, occurring only in South Florida, the Bahamas, and Cuba. They are known by their tall South Florida slash pines (*Pinus elliotii* var. *densa*) and saw palmettos (*Serenoa repens*), and they support 374 kinds of native plants, of which 31 are endemic, five are listed as federally endangered, and five are candidates for listing. Many of the plants and animals have remarkable adaptations to this habitat.

İlköğretim öğrencilerinin doğal alanda ve sınıf içinde bataklıklar ile ilgili öğrenmelerinde bilimsel araçların arabuluculuk rolü

Son yıllarda fen ve çevre eğitimi alanında gerçek ortam uygulamaları artış göstermektedir. Bu tür uygulamalar sosyal yapılandırmacı yaklaşımları kullanırlar, bu yaklaşımlarda öğrenmenin, öğrencilerin araçları kullanırken gerçekleştiği kabul edilir. Bu çalışmada doğal alanda ve sınıf içinde bir yıl boyunca bataklıklar üzerine çalışan bir grup ilköğretim öğrencileri üzerine odaklanılmıştır. Özellikle, ilköğretim öğrencilerinin bilimsel araçları kullanımı gözlenmiş ve farklı durumlardaki kullanımları karşılaştırılmıştır. Çalışma sonucunda öğrencilerin doğal alanda veri toplama ile ilgili gözlem yapma ve ölçme gibi etkinliklere önemli miktarda zaman harcadıkları bulunmuştur. Bu bağlamda, öğrenciler genellikle öğretmenden daha bağımsız küçük grup çalışmalarıyla ve kendi öz-yönelimleriyle araştırmalarını yapmışlardır. Sınıf içerisinde bilimsel çalışmalarda bazı araçların daha fazla kullanılması beklenirken, özellikle fazlaca öğretmen yönlendirmesi içeren etkinliklerde, benzer sınıf etkinliklerinde kullanılan araçlar bu etkinlikleri desteklemiştir. Bilimsel araçların kullanım modelleri Yrjö Engeström'nin etkinlik yaklaşımı temel alınarak her iki durum için düzenlenmiştir. Elde edilen bulgular bu tür öğrenme durumlarında bilimsel araçların kullanılmasının önemini, gerçek öğrenme ortamlarında sosyo-kültürel ve etkinlik perspektiflerinin yansıtıldığı öğrenmenin sosyal olarak oluşturulduğunu yansıtmaktadır.

Keywords: fen , bilimsel araçlar, sosyo-kültürel yaklaşımlar