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Student Mental Models of the Longleaf Pine Ecosystem

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ABSTRACT

There is a nationwide focus in science education in the United States on the ability of students to develop and use models. Using the Contextual Model of Learning that considers learning is inseparably bound to the context in which it occurs, this study looks at drawings of the longleaf pine ecosystem created by 293 4th Grade students prior to and again after their multiple day visits to an environmental education center in the southeastern United States. Using flora and fauna processes considered as indicative of the ecosystem by ecologists, seven distinct mental model categories were developed from student artifacts. Comparison of the pre to post-frequencies in each model demonstrate a statistically significant increasing level of sophistication in the mental models to more closely approximate the conceptual models of ecologists after participation in instruction at the Center. Progression to more sophisticated mental models was documented even when addressing these models and their development was not a direct intent of the instruction. These data also support the importance that context can play in the learning of ecological concepts and the significance of including informal experiences to the formal K-12 curriculum.

Keywords: environmental education, informal education, drawings, mental models, conceptual models, longleaf pine ecosystem

INTRODUCTION

The National Research Council (2012), in a document entitled *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*, identified the ability to develop and use models as an essential scientific practice for elementary and secondary students in the United States. The construction, revision and improvement of mental models leads to deeper understanding of scientific concepts and to improved reasoning skills. The Next Generation Science Standards also recognized models and modeling as one of the seven essential crosscutting concepts found across all the domains of science and engineering (NGSS Lead States, 2013).

Any discussion of models in science and education requires an understanding of the distinction between mental and conceptual models. Mental models are an individual's internal representations of events, objects or settings that correspond to something external (Johnson-Laird et al., 1998). Vosniadou (2019, p.1) considered these to be "*intuitive understandings of the physical world*" formed by individuals as a result of common, everyday experiences and exposures. They are particular to the individual, often underdeveloped, and are subject to change over time; yet they are useful to the individual in meaning making (Norman, 1983; Greca & Moreira, 2000).

Conceptual models are those created by experts – scientists, engineers, and educators – as a means of understanding or describing a process or a system (Greca & Moreira, 2000). Scientists use conceptual models to accurately represent complex and abstract concepts in a manner that facilitates communication within their peer groups and to others (Nersessian, 2008). As a student learns domain-specific science content this growth is incorporated into their changing mental models (Nersessian, 2002). The growth of knowledge is an active and iterative process, and models are the foundation of this knowledge in science (Glynn & Duit, 1995).

Vosniadou (2002) argued "*the ability to form mental models is a basic characteristic of the human cognitive system and that the use of models by children is the foundation of the more elaborate and intentional models of scientists*." (p. 353). Therefore, understanding students' mental models of science concepts, and the progression of initial mental models closer to those accepted conceptual models of experts should be a goal of science education.

Purpose

This study is focused on understanding the mental models of a local ecosystem as represented by the drawings of 4th Grade students (approximately 10 years of age) before and after a prolonged engagement at an environmental education center. The questions framing this study include:

- What are the mental models of young students concerning a local ecosystem prior to visitation at an environmental education center?
- In what ways, if any, do student models change after an extended engagement with the environmental education center?

THEORETICAL FRAMEWORK

The construction of new knowledge takes place in a context and that context is situated within a socio-cultural framework (Cobern, 1993; Tobin & Tippins, 1993). Cobb (1994) suggested that the disequilibrium needed for learning to occur is most often associated with social interactions, and while knowledge is processed on an individual level, it is created and negotiated at the group level. Central in this framework is a place-centered lens that offers the physical features and specific activities associated with those features are central in learning and learning outcomes.

Within this constructivist framework, Falk and Dierking (2000) developed the Contextual Model of Learning, which considers that "*what someone learns, let alone why someone learns, is inextricably bound to the cultural and historical context in which learning occurs.*" (p. 41). Learning is viewed, therefore, as a process of continuous meaning making between the individual, the environment and the context learning is occurring within (Falk & Storksdieck, 2005). This framework arose from a need to understand the complexities of learning in informal settings, and it considers the interaction of the personal, sociocultural and physical contexts and how that varies over time in the individual. In essence, learning is viewed as a process of meaning making, where the "never-ending dialogue between the individual and his or her physical and sociocultural environment" is in play (Falk and Storksdieck, 2005, p. 745).

These fundamental concepts are particularly pertinent in the current study which was situated outside of the formal school environment, strongly tied to a unique context, and involved group engagements over extended periods of time. As such, the Contextual Model of Learning serves as a lens with which to evaluate student mental models of an ecosystem and how these may change over time.

DESIGN

Conventional assessment is typically absent from most informal learning experiences (Ellenbogen & Stevens, 2005), and while that practice is valuable for learning, some form of assessment is often needed to justify programs and initiatives. Therefore, a conscious effort was made to select an instrument that would not be labor intensive for the students or the educational center, yet still be grounded in the literature. One protocol that arose from the literature that would not detract from the experience for the participants was the use of student drawings.

The link between art and learning is well supported (e.g. Vygotsky, 1971). As a means of assessing children's understanding, they are considered reliable and accurate (Lewis & Greene, 1983), and multiple researchers have found value in the use of drawings to assess understanding. White and Gunstone (1992) believed drawings are a useful method for assessing children's learning and, because of their open nature, serve to compliment other more common closed assessments. Thomas and Silk (1990) contended that the cognitive demand needed and the fact that children consider drawing enjoyable combine to make a valuable assessment tool. Guillenim (2004) argued that drawings provide an alternative window into an individual's interests and understandings than those revealed by other metrics.

Various researchers have used drawings as a mechanism to visualize and characterize children's perceptions of science concepts. Bowker (2007) analyzed pre and post-drawings of 9 to 11-year-old children after a visit to a tropical rainforest exhibit as a reflection of the understanding and learning that occurred. Shepardson et al. (2007) used drawings as representations of student understanding of the environment and found that students often represent the environment as a combination of animals, plants and natural elements, with a distinct human disconnect. Kalvaitis and Monhardt (2012) used drawings and narratives to understand young children's self-perception of their relationship with nature. These demonstrated that nature is represented in many ways by the children, suggesting a varied personal relationship with the term. Judson (2011) used drawings by 4th and 7th grade students as representations of mental models of the desert environment. Drawings have also used with older individuals including the “draw-a-science-teacher-test” (Thomas et al., 2001), for pre-service teachers, and the “draw yourself doing science” instrument (Roseler, 2013), which looked at the informal science experiences of undergraduate students.

This study is situated within a constructivist perspective where cognition is considered to be individualized and formed in association with social interactions (Creswell, 2013; Patton, 2002). This acknowledges there is no “*other kind of learning other than constructing meaning*” (Mogashoa, 2014, p. 51). A mixed methods exploratory design was employed where the results from the initial qualitative methods informed the subsequent quantitative analysis (Creswell, 2013; Green et al., 1989). Student drawings pre and post-attendance at an environmental education center were qualitatively analyzed and placed into distinct mental model categories, and the changes in frequency of the models were subsequently assessed quantitatively.

Setting

The informal instruction was offered by an environmental education center (Center) situated in the Southeastern United States on the edge of a 54,000-acre private conservation project. Much of the land had been homogenized through conversion from historic longleaf pine forests to intensive agriculture and silviculture, resulting in the loss of native communities and adverse impacts to species that evolved in association with those communities. Restoration of this dwindling resource and the re-connection of the region’s youth to the ecosystem are the primary goals of the founder, Mr. M.C. Davis (M.C. Davis personal comm.).

The regional significance of the longleaf pine community in the Southeastern United States makes it an important ecosystem to understand. Longleaf pine, *Pinus palustris*, has been eliminated as a dominant tree species from 97% of the lands it once covered prior to European settlement (Frost, 1995). The precipitous decline of this species as a major community component can be attributed to the land use changes that have occurred since early pre-settlement years, including conversion for agriculture, grazing by livestock and fire suppression (Frost, 1995). The single most devastating impact, however, was logging for timber production for ship masts and dwellings throughout the continent and Europe (Whitney et al., 2004). Once logged from its historic range early foresters documented the inability of this pine species to naturally restock and determined that the destruction of seedlings by free ranging hogs and fire were the primary causes (Frost, 1995). While hogs may indeed impact longleaf seedling survival, the suppression of fire may be the real limiting factor in the regeneration of this species. In fact, fire is a required disturbance for the health of longleaf pine ecosystems.

The Center offered a multi-day environmental education program for the public-school district in which it is located at no charge for either the students or the District. Students had an opportunity over four separate visits to learn about the greater longleaf pine ecosystem flora and fauna through interpretive exhibits at an Exhibit Hall, hikes and instructor led activities. Activities were led by ecologists, naturalists and educators and were supported by school-based curricular unit; however the use of this curriculum in the formal classroom is unknown and presumed to vary by teacher. During their visits to the Center students were engaged in specific activities designed to provide a multi-modal experience with the flora, fauna and processes occurring within the longleaf pine ecosystem. While these activities were not individually evaluated by the author, the basic intent of each is outlined below.

Introductory Video on Dr. Wilson and Center

This video was presented in the Center’s theater and introduced students to the namesake of the facility, Dr. E. O. Wilson, and the mission and importance behind the development of the Center.

Exhibit Hall Exploration

The hall includes a combination of free exploration and staff guided discovery of various exhibits. Displays include large sculptures of animals (gopher tortoise, harvester ant and indigo bunting), a cast/mold of a harvester ant mound showing the intricacies of the tunnel, displays of historic and archeological artifacts, a frog biome that is humidity controlled with several species and corresponding calls, a bird window with placards identifying bird species that may be visible, a molded gopher tortoise burrow suitable for students to crawl into, a true to scale longleaf pine diorama that shows the various stages of the longleaf pine life cycle, a large interactive display depicting a leaf and photosynthesis, an aquatic exhibit with turtles, a snake exhibit (pine, corn, king and indigo snakes), a diorama of a transition from upland ridge to a wetland community, and numerous taxidermies and replicas of birds and mammals. This exhibit provided opportunities to explore important processes and species of the ecosystem, many of which are more difficult to observe physically in nature.

Turtle Trail Hike

This hike took students along a wetland finger adjacent to a bluff upland where they could see the change in elevation and corresponding changes in vegetation. Students observed the characteristic markings made by the yellow-bellied sapsucker foraging on pines, the evidence of beaver activity and its role in ecosystem differentiation, and various aquatic wildlife that were collected in traps pre-set along the trail. This exposed students to the community diversity found embedded within that larger longleaf pine ecosystem.

Tortoise Carrying Capacity SIM

This simulated activity demonstrated how populations might fluctuate over time through the introduction of the concept of carrying capacity using the gopher tortoise as a model. The gopher tortoise is a key element in the educational component of the Center and an iconic species in the longleaf pine ecosystem.

Prescribed Fire PowerPoint, Remnants of a Forest Video, and Analysis of Burn Plots

These activities combine to assist with the understanding of the role of fire in shaping ecosystems in the Southeast. The PowerPoint provided information about the value of prescribed fire for the longleaf pine ecosystem and the natural fire regime of the system. Remnants of a forest is a multimedia presentation that discussed the longleaf pine ecosystem and its decline in the southeastern United States.

Students were provided with a brief history of the longleaf pine ecosystem, the role of fire in maintaining the community and its diverse groundcover, and some of the prototypical species of the ecosystem, including red-cockaded woodpecker, pitcher plants, gopher tortoise, quail, indigo snake, flatwoods salamander, gopher frog, pine snake and rattlesnake. The value of the gopher tortoise as a keystone species of longleaf pine was introduced in this video**.**

Understory Exploration

During this activity the students returned to the forest burn plots to look specifically at the understory of the longleaf pine ecosystem. The students documented the plants (using general descriptive terms or drawings) they saw at ground level, one foot above ground level, and then those even taller but still within the understory. This was designed to emphasize the vertical structure of the longleaf pine forest and how it is managed/shaped by fire.

Jeopirdy

Fashioned after the popular game show, this version used a similar format of providing the answer with the students needing to provide the response in a form of a question. Topics focused on the experiences the students have both in the Exhibit Hall and on the trails at the Center.

Harvester Ant Activity

In this activity the students investigated the foraging behavior of the Florida harvester ant which is common to the upland longleaf pine forest communities. As the name implies, these insects gather seeds, store them in underground chambers, and deposit the chaff from husked seeds around the main entrance to the chamber. Students worked in teams to examine harvester ant mounds in the field and conducted guided inquiry on preferred food types through several simple experiments. The harvester ant is a subtle, yet iconic, species in the flatwoods surrounding the Center.

Wetland Animal Collecting and Identification

This activity took place in an artificially created pond next to the Center. Students used dip nets to collect aquatic invertebrates and small fish, which were later identified using simple photographic and drawing keys assembled by the Center staff.

METHODS

This study utilized a purposeful sample of 293 students that attended a 4-day program at the Center, completed both a pre and a post-drawing, and submitted the necessary consent and assent forms (Patton, 2002). Each student was provided with a standardized drawing sheet with the following specific prompt:

> On the back of this page please draw what you understand the longleaf pine forest (ecosystem) to look like in northern Florida. Please include the plants, animals and processes that you feel are part of this natural community. Please feel free to label any part of your drawing or to add comments to make your drawing clearer.

The students' individual teachers at their respective schools administered this assessment prior to their first day at the Center and again after their last visit. Six schools and 20 individual classes were included in the study. The four days of engagement were spread over a period as little as 16 days to as long as 162 days between the first and last visit, depending upon the requirements of individual schools (Table 1).

Table 1. Duration between the first and last visit and the number of students for each school included in this study

School	Days Between First and Last Visit	Number of Students
1	16	73
2	34	11
3	35	26
4	41	101
5	42	52
6	162	30

Interviews of a subset of students were completed in an effort to internally validate the researcher's interpretation of images on the drawings through a form of member checking. A total of 41 students were asked to review their drawings and to explain and describe what they included. Substantial agreement between student intent and researcher interpretation was found.

Analysis

A list of the essential features, processes and components characteristic of the longleaf pine system was developed by the researcher and validated by two ecologists knowledgeable about the longleaf pine ecosystem (Table 2). These criteria served as a priori codes for the initial categorization of drawings into progressive levels of complexity. Drawing analysis continued using a constant comparative process until the transitions and distinctions between the levels of mental models reached a stable structure (Glaser & Strauss, 1967; Lincoln & Guba, 1985). Once substantially static, each pre and post drawing was place within one of the seven discrete mental models. An independent researcher used the final classification scheme to code 60 individual drawings. These drawings were selected using proportional stratified random sampling that ensured that drawings from each mental model category were represented. When the results of this scoring were compared to those on the same drawings from the researcher there was substantial agreement ($r = 0.800$, $p < .001$) and the classification system was deemed to be reliable.

Table 2. Features used to initially classify student drawings

Category	Description
Fauna	Three or more appropriate animal species are present. Appropriate animal species include humans, and in the event of images difficult to classify, they are assumed appropriate.
	Important species, including red-cockaded woodpecker, gopher tortoise, eagle and black bear.
	All animals present are appropriate and no animal misconceptions are depicted, such as tiger, lion, monkey, etc. At least one appropriate animal needed to be present, including humans, to be considered for this category.
Flora	The diversity of the flora is recognized by the representation of three or more appropriate plant species. In the event of images difficult to classify, they are assumed appropriate.
	The groundcover is dense, covering $> 50\%$ of the substrate and/or shrubs represent $\leq 25\%$ cover. A dense groundcover of grasses and herbs and a sparser cover by shrubs is associated with a high functioning longleaf forest maintained by fire.
	All plants represented are appropriate and have no misconceptions. At least one appropriate plant needed to be present.
Ecosystem Diversity	All ecosystem components are appropriate without any alternative conceptions such as waterfalls and snow-covered mountains.
	Pine trees have clear characteristics on the longleaf pine, including deep tap root, big cones, flaky bark or very long needles.
	More than one stage of the life cycle of the longleaf pine is represented – grass stage, bottlebrush stage, sapling, adult.
	Trees are widely spaced representing mature conditions and contrasting with pine plantations.
	Includes some pine trees (not only deciduous), and characteristics are consistent with southern pines and not northern coniferous pines.
Forest Processes	Abiotic factors depicted or referenced.
	Decomposition/nutrient cycling is present, including skulls, logs, stumps, and fallen leaves/pine cones.
	Fire, lightning or charred bark is referenced.
	Appropriate predator-prey relationships/interactions are depicted.

RESULTS

Qualitative Analysis

Mental Model 1

Student drawings that demonstrate Mental Model 1 represent an ecosystem that is either Inadequate or Inappropriate. This is expressed by the absence of any community structure (i.e. animals disassociated from a community and "floating" on the page), animals not found in southeastern natural ecosystems and indicative of alternative conceptions (e.g. lion, monkey, cobra), and/or a misrepresented community type (e.g. snow-covered mountains). Figure 1 represents an example of this model completed prior to attendance, where the student includes alternative and atypical community features (waterfall and cliff), inappropriate animals and plants (koala bear, apple tree), and pine trees that resemble northern coniferous forests and not those typical of southeastern U.S. forests.

Mental Model 2

Mental Model 2 is titled Anthropogenic; student drawings focus largely on man-made environments, including residences, farms, parks, and the Center. Figure 2 shows one student's post-attendance representation of the layout of the Center including the pond used for aquatic sampling in the upper left corner, the gopher tortoise pen in the upper center, a Center building in the lower right portion and references to experiences and activities (e.g. dip-netting). While indeed representing ecosystems, including ecosystems that can be found in their region, these have little connection to the target longleaf pine ecosystem.

Figure 1. Drawing expressing Mental Model 1

Figure 2. Drawing classified as Mental Model 2 referencing physical features of the center

Mental Model 3

The third level of mental models is termed Naïve Level 1. In this model drawings are dominated by either plants or animals that are generic/undifferentiated, but not both. Therefore, not only do they represent an incomplete ecosystem, but they contain no specifics associated with the longleaf pine forest (Figure 3). Representation of either only animals or only plants suggests that the student's prior knowledge of the concept of what comprises a complete ecosystem was incomplete.

Mental Model 4

The next level of increasing complexity of mental models is represented by Naïve Level 2. This level demonstrates a more complex understanding of an ecosystem than Mental Model 3 with the inclusion of both plants and animals, although both remain unspecified and not specific to the target longleaf pine community. Figure 4 shows a forest scene with deciduous trees, birds, and snakes, and could be virtually any natural community (or man-altered community) in the Southeastern United States. While these represent increasing sophistication over models 1-3 with a more complete picture of an ecosystem, they continue to lack any connection to the longleaf pine ecosystem.

Mental Model 5

In Mental Model 5, termed Incomplete, the student drawings demonstrate an increase in the ecosystem specificity with either appropriate plants or appropriate animals of the longleaf pine forest, but not both. Plant specification generally includes evidence of a key feature of a longleaf pine tree, or the inclusion of some other plant characteristic of the ecosystem, such as wiregrass. Figure 5 shows a single longleaf pine tree with the characteristic branching and needle clump at the terminal ends of the branches. Other characteristic longleaf pine features considered include the distinct life stages of the tree, extremely long needles, large pine cones, specific labels identifying the image as a longleaf pine, or "pom-poms" at the end of branches, often used as a way to describe the needle clump characteristic of the tree to students.

Mental Model 5 drawings could also include animals that are most closely associated with the longleaf pine ecosystem than with other regional ecosystems, but not necessarily unique to the longleaf community (e.g. gopher tortoise), and species that are highlighted at the Center, either in taxidermies or lessons (e.g. fox squirrel, harvester ant, and beaver). The beaver is included because of

Figure 3. Drawing representing Mental Model 3

Figure 4. Drawing reflecting Mental Model 4

the role this species plays in shaping micro-communities adjacent to the Center. The inclusion of animals in drawings that were only represented through replicas conveys the power of the context in promoting what someone retains for later retrieval. Bamberger and Tal (2007) found that both live animals and taxidermy specimens in an informal setting were important triggers in connecting students to their prior knowledge. Such a connection

Figure 5. Drawings providing an example of Mental Model 5

to prior knowledge is important in determining what a student learns from such an experience.

Mental Model 6

In Mental Model 6 (i.e. Informed), the student generally brings together appropriate plants and animals in a longleaf pine setting; however, it may also include drawings virtually devoid of animals if the longleaf pine community structure is well developed (i.e. multiple appropriate plants, canopy/subcanopy/ground cover differentiation, and well-established burrow system). Figure 6 is an example of an Informed mental model which represents multiple animal species, trees with the characteristic “pom-pom” needle configuration, and additional plants associated with the longleaf ecosystem. Although the Venus fly trap (*Dionaea muscipula*) is not native to this area, it has been introduced in some locations and the instructors at the Center often discuss this more commonly known plant when introducing the native carnivorous pitcher plants (*Sarracencia* spp.).

Mental Model 7

Mental Model 7 is considered Sophisticated because it includes appropriate plants, appropriate/keystone animals, and either a well-developed community structure, references to an ecological processes (fire), or embedded micro-communities (e.g. wetlands, upturned tree, well defined burrow system). Figure 7 is a drawing from a student that includes longleaf pine, gopher tortoise and burrow, and the “apron” or entrance to the gopher tortoise burrow that consists of excavated sand from the burrow, all being acted upon by fire. Mental Model 7 may also represent an understanding of the underlying ecological principals that drive the system. A second example of Mental Model 7 is provided in Figure 8; and while the trees are not well formed, they are labeled, and the animal diversity and

Figure 6. Example of informed Mental Model 6

Figure 7. Student drawings showing Mental Model 7

other components of the community structure are advanced.

Quantitative Analysis

Mental Model 1

The frequency of Mental Model 1was greater in the pre-drawings than the post-drawings, 26 to 14, respectively. This pre-drawing frequency can be interpreted to reflect prior alternative conceptions of the ecosystem held by the participants before instruction at the Center. Brooks (2009, p. 322) offered that young children's drawings of scientific ideas can "*…illustrate surprising misunderstandings or gaps in children's knowledge*" since they are

Figure 8. Drawing classified as Mental Model 7

tapping into their everyday lives. Even though these students lived in the immediate vicinity of the target ecosystem, their representations were informed by their personal experiences with various media.

Mental Model 2

The increase in the frequency in the Anthropogenic category in the post versus pre-drawings, 31 and 18 respectively, highlights the importance of the setting to learning for these students. Of the 31 post-drawings in this category, 29 focused on physical features of the Center or on the Center instructors that engaged with the students. Prior work has concluded that representations such as these that focus on the physical space would indeed be expected to be dominant in the lasting memories of visitors to an informal experience (Falk & Dierking, 2000). This post-attendance frequency highlights the important role of context to cognition situated within a socio-cultural framework.

Mental Model 3

As might be expected, Mental Model 3 was more common in the student drawings developed prior to attending the Center, with a pre-drawing and post-drawing frequency of 34 and 11, respectively. Similar to Mental Model 1, it is considered to represent a reflection of student's prior, incomplete knowledge.

Mental Model 4

Mental Model 4 was the most dominant model in the pre-drawings, represented by 177 of the 293 students. This is consistent with the findings of Linda Cronin-Jones (2005), who contended that the drawings of elementary age *"…students include more details and realistic representations for subjects they know more about*" (p. 228), and by extension, when children are less knowledgeable or comfortable with the level of their understanding, details are often absent. Prior to exposure to the content at the Center, many students represented a generic understanding of an ecosystem, and little about the specifics of the target system. The systemic decrease in this model to 34 post-drawings, however, conveys the increasing conceptual understanding developed after attending the Center.

Mental Model 5

Mental Model 5 showed an increase in frequency after attendance with numbers moving from 35 in the pre-drawings to 89 in the post-drawings.

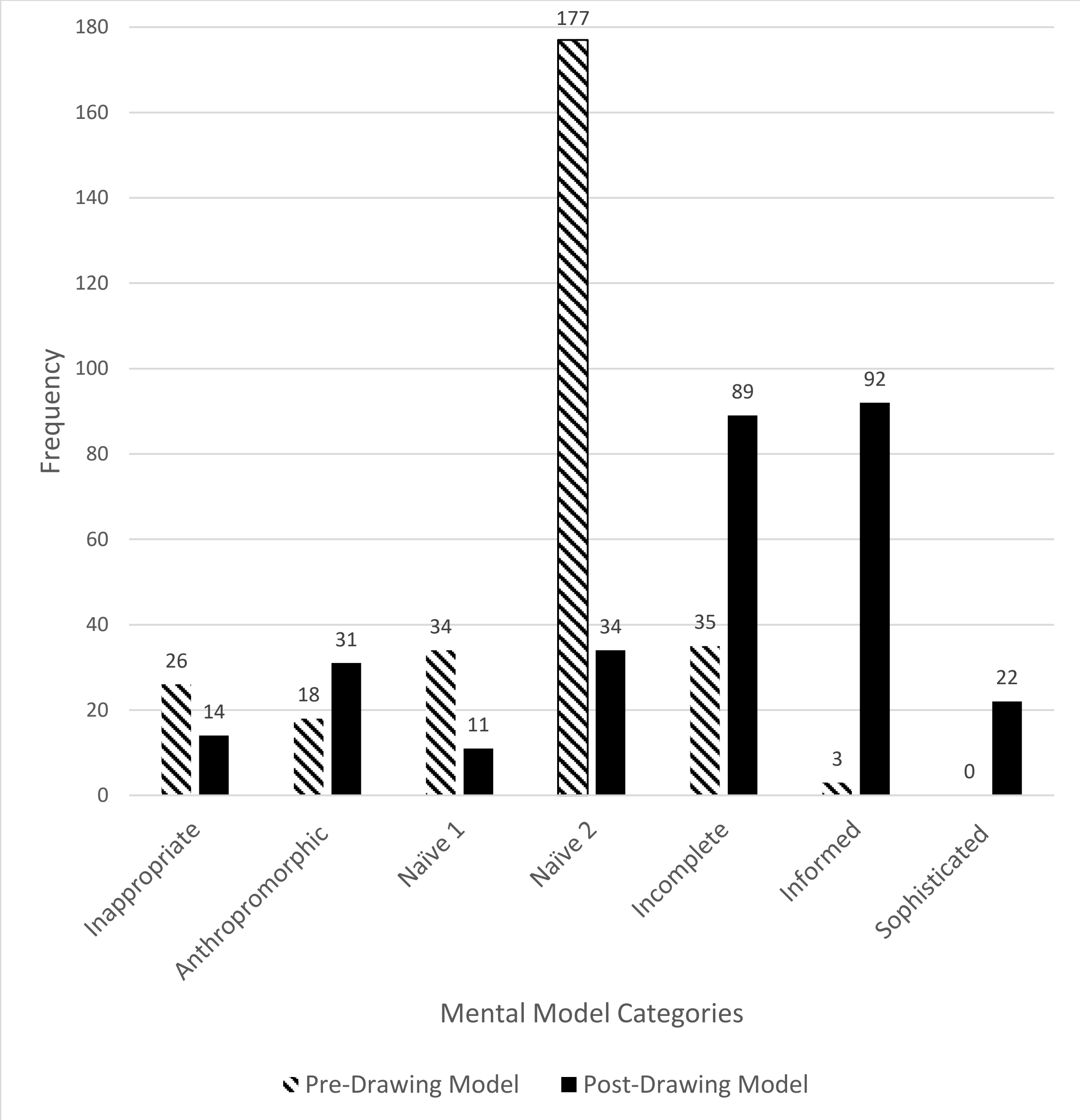

Figure 9. Distribution of Mental Models pre and post attendance at center

Mental Model 6

Mental Model 6 was considered to represent an informed view of the target ecosystem. Only 3 students provided Informed mental models in the pre-drawings, but this frequency increased to 92 in the post-drawings, suggesting a movement closer to the conceptual models of ecologists.

Mental Model 7

The Sophisticated model was not represented in any pre-drawings, and only minorly represented in the post drawings at a frequency of 22 out of 293. This model is considered to represent the most complete mental model available through the drawing exercise, and one that most closely approximates the conceptual models of scientists.

Cumulative

When all student data were aggregated there was a clear shift towards the increasing complexity of mental models as represented from before attendance to after attendance at the Center (Figure 9). While other mediating factors may have played a role outside of the experience, the general trend was for the accommodation of new, more specific information about the ecosystem, into the cognitive structure of the majority of students. This is a clear goal of science learning.

The frequency shifts visually evidenced in the figure are also supported statistically using Chi Square. In order meet the assumptions underlying that statistic, the categories for Informed and Sophisticated were collapsed into one, and with this aggregation, there was a significant shift in frequency distribution of mental models from the pre to the post, $X^2(5, N = 293) = 2{,}226.8$, $p < .001$. This effect was considered large and meaningful as determined by Cramer's phi of 0.889. When each mental model category was evaluated individually the pre/post frequency changes identified in Figure 9 represented statistically significant differences in the appropriate directions for all categories except Mental Model 2, Anthropomorphic (MM1, $p = .043$; MM3, $p < .001$; MM4, $p < .001$; MM5, $p < .001$; MM6, $p < .001$; MM7, $p < .001$).

While the changes in the entire sample are informative, the growth made by individual students is also important. When examined at this level, increasing sophistication of longleaf pine ecosystem mental models was demonstrated for 205 students, or approximately 69.9% of the sample population. Of the total 293 students, 54 demonstrated no change in their mental models and 34 demonstrated a decrease in their mental model complexity. Many of those "decreases" were associated with students focusing on the physical aspects of the Biophilia Center in their post drawing, again speaking to the significance of context.

DISCUSSION

Substantial previous work has demonstrated that drawings can be used to reflect the meaning-making of children concerning scientific concepts (e.g. Flowers et al., 2014). The data herein support that drawings can also be an effective tool to elicit young students' mental models of an ecosystem, and that multiple drawings over time can document growth in those mental models. The growth, as demonstrated by the sample, documented statistically significant increasing sophistication of the post attendance mental models of the longleaf pine ecosystem when compared to those generated prior to any visitation or instruction.

As we value this shift in mental models, consider the quote from Glynn and Duit (1995):

> *the learning of science facts and procedures is important; however, the construction of valid conceptual models is the hallmark of students' science achievement. When students construct conceptual models they are making sense of their experiences – they are constructing meaning. Scientifically literate students are those who can construct and apply valid conceptual models of the world around them (p. 4).*

These data furthermore support the conclusion of Reith (1997) and Cronin-Jones (2005), that drawings can be used to indicate an individual's understanding of a topic, issue or concept, and that these become more precise and complete as they incorporate a more accurate understanding of the concept over time.

The NRC (2012) considers this ability to develop, broaden and enhance models as an essential component of a student's science proficiency; one that is both a practice of science and a concept that cuts across all disciplines of science. Students able to align their personal, internal models more closely with the conceptual models held by ecologists are better prepared to comprehend the cross-disciplinary aspects of science. This will hopefully provide them with the foundation to become critical consumers of information and productive participants in addressing the societal problems they will face. Shepardson et al. (2007) argued that improved understanding of environmental issues comes from the development of internal mental models that are closely aligned with the conceptual models of experts. Hopefully, the experiences of these students and the growth in their mental models of this ecosystem will better equip them to understand and potentially advocate for this imperiled ecosystem, and to position themselves as ecologically literate citizens with the capacity for individual conservation ethic.

In this study, student advancement in mental models occurred without an explicit focus by the Center to achieve this end goal. This contrasts with previous findings that suggest that active and explicit addressing of mental models is required for naïve models to move towards increasing complexity (Judson, 2011). Judson used a pre/post format with a draw-and-write protocol to look at student mental models of the desert environment and found little change in their mental models after a field trip to a desert preserve and educational facility. Judson argued that mental model development must be an explicit goal of instruction if we want an individual to progress towards scientific conceptual models, and that exposure to an ecosystem or an organism was not adequate in and of itself.

The current data, however, would indicate that something deeper is involved in the conceptual change in student mental models. In this study there was no explicit attempt by the staff of the Center to develop appropriate mental models of the longleaf pine ecosystem, and any progression towards that end was a byproduct of attendance. The alternative and incomplete conceptions of the students in this experience are significantly changed, and it would appear that explicit engagement that highlights what is inadequate with their entering mental models was not a requirement for this change. This suggests that the outdoor context and/or duration of the exposure at the Center may better influence the development of appropriate mental models than the need to specifically address model transformation. This has implications for the development of scientific literacy and supports the value and importance of attending to the context in which learning occurs.

Cachelin et al. (2009, p.13) asserted that the "*rich peripheral signals generated in outdoor contexts actually allow the brain to store the information differently in spatial memory*." This is in line with Knapp (1992) who maintained that memory is enhanced when concepts imparted are stored in spatial memory. In our climate of increasing accountability, opportunities like those provided by the Center are becoming increasing rare and educators struggle with the emphasis on testing and the pressure to cover all of the standards. Yet, these outdoor learning opportunities situated outside of the formal classroom appear to have substantial benefit in cognition. We should strive to enrich our students with multiple experiences including those outside of the formal school setting. These may prove important for developing the broader literacy competencies we hope that our future citizens will demonstrate.

There are some limitations associated with this study. First, the interpretation of drawings, especially those of adolescents is open to some subjectivity. An attempt was made to account for such uncertainty through interviews with a limited number of participants, and while a strong alignment between reported student intent and researcher interpretation was noted, this sample represented students that self-selected for an interview, and likely enjoyed the experience. Care must be taken to assume that simply because of the inclusion of certain key aspects of the target community in a drawing that the student understood both the importance of that component or the relationship of that component to the larger whole. Yet the same can be said for most of the assessments we utilize to understanding learning. Also, the exclusion of items from the drawings does not necessarily relate to a lack of understanding of the importance of that component, and could simply be an artifact of available time, space or inclination to make a drawing "look good." Finally, the positive results are only an indication of correlation and not causation. There are substantial time spans between the first and last visit, providing ample opportunity for the students to engage in further learning about the ecosystem on their own, or to allow for the teacher to incorporate additional infusions of ecology and the longleaf ecosystem in their regular curriculum. In any case, however, the result is the same – increasing development of mental models of an imperiled ecosystem that more closely match those held by scientists. Such is what we strive for in environmental and science education.

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