Environmental Education Research, 2014
http://dx.doi.org/10.1080/13504622.2014.930728

The development and validation of an alternative assessment to measure changes in understanding of the longleaf pine ecosystem

Michael W. Dentzau[a]* and Alejandro José Gallard Martínez[b]

[a]*Oxbow Meadows Environmental Learning Center, Columbus State University, Columbus, GA, USA;* [b]*College of Education, Georgia Southern University, Statesboro, GA, USA*

(*Received 30 August 2013; accepted 22 May 2014*)

A drawing assessment to gauge changes in fourth grade students' understanding of the essential components of the longleaf pine ecosystem was developed to support an out-of-school environmental education program. Pre- and post-attendance drawings were scored with a rubric that was determined to have content validity and reliability among users. In the specific context of this intervention, the assessment documented significant growth in the understanding of the essential components, processes, flora and fauna of the ecosystem. This assessment found no significant differential advantage with respect to gender or dominance status of the students and is offered as an alternative to traditional assessments that favor select groups. Extensions of this framework to other ecosystems, and implications for in-service/pre-service educators and science proficiency, are discussed.

Keywords: drawings; instrument; assessment; learning; environment

Introduction

In the fall of 2009, an ambitious environmental education facility was launched in the Florida Panhandle – The E. O. Wilson Biophilia Center at Nokuse Plantation ('Center'). The Center's mission 'is to educate visitors on the importance of biodiversity, to promote sustainable balanced ecosystems, and to encourage conservation, preservation and restoration' (E.O. Wilson Biophilia Center at Nokuse Plantation, n.d.), and is situated within a 50,000 acre environmental restoration project advanced by a nationally recognized conservationist, M.C. Davis. The primary focus of this restoration project is the reestablishment of longleaf pine, which was largely removed from this site and replaced with other pine species.

Longleaf pine, *Pinus palustris*, was the dominant tree in the landscape of the Southeastern United States prior to European settlement and has been eliminated as such from 97% of its historic range (Frost 1995). Although fire was initially believed to be an impediment to the regeneration of stands of longleaf pine, it has been documented that fire is a required disturbance for the maintenance of longleaf ecosystems and the species that depend upon them (Whitney, Means, and Rudloe 2004).

The Center developed a fourth grade curriculum that utilizes its unique context as a vehicle for addressing Florida's Next Generation Sunshine Standards (Florida

*Corresponding author. Email: dentzau_michael@columbusstate.edu

Department of Education, n.d.). Lessons were designed to work in concert with the public schools and extend learning beyond the classroom by utilizing interpretive exhibits, trails, natural communities, and the educators and scientists of the Center. The necessary conditions for survival and perpetuation of the longleaf pine ecosystem and its integrated micro-communities were the focus of the fourth grade curriculum, exhibits and trails at the Center. As the foundation for the experience, the Center utilized *Life in the Longleaf Forest Ecosystem: A Fourth Grade Thematic Unit for the Biophilia Center at Nokuse Plantation*. The lessons and brief descriptions are provided in Table 1. The curriculum was structured to have students return over multiple days with supplemental learning opportunities occurring in the students' residence school. At the Center, students came in direct contact with animals,

Table 1. Lessons included in the Life in the Longleaf Pine Forest curriculum.

Lesson	Topic	Summary
1	What do they know about the longleaf pine forest ecosystem?	Provide an assessment of the student's prior knowledge of the longleaf pine forest ecosystem.
2	Overview of the longleaf pine forest ecosystem.	Introduces the concept of an ecosystem with specific reference to the longleaf pine forest and utilizes the Longleaf Pine Trail at the Center.
3	Wetlands in the longleaf pine forest ecosystem.	Text explores the wetland components of the longleaf pine forest and activities include dipnetting in a pond and a review of aquatic turtles.
4	Fire in the longleaf pine forest ecosystem.	Investigation of the role of fire in the structure and function of the longleaf pine ecosystem complex, wetlands and uplands. Utilizes established burn plots next to the Center to look at changes with different treatments.
5	Lookin' at longleaf.	Explores the specific adaptations and life cycle of the longleaf pine to understand how it is uniquely adapted to thrive in fire. This is completed on the Longleaf Pine Trail hike.
6	The story of the understory.	Reviews the understory components of the ecosystem and understanding how the abiotic components shape its structure and is designed to be completed at the individual schools.
7	Ants and ant eaters.	Explore several common ant species found in the longleaf pine forests and uses a specifically designed ant lesson.
8	Go for gopher tortoises.	Introduces keystone species using the gopher tortoise as an example, and uses a gopher tortoise SIM and a home range exercise.
9	The bears of Nokuse.	Explores the life history of the Florida black bear in the longleaf ecosystem and uses a specifically designed bear lesson.
10	Birds of the longleaf pine forest ecosystem.	Looks at the variety of birds that populate the longleaf pine forest and explains how birds are adapted to life in this ecosystem through the use of a 'bird bingo' lesson.
11	How does oil affect the ecosystem?	Lesson developed to look at how an oil spill can impact the environment.
12	'Talking Trash'.	A lesson developed in association with Waste Management to look at recycling issues.

plants and ecosystem components in ways that were designed to pique their interest in an effort to provide a transformative experience with their local environment. This informal learning environment, although tied to formal educational efforts, was meant to provide not only a rich context for learning, but also one that was removed from the stressors of high-stakes accountability (e.g. Emer and Banks 2012).

Assessments

Assessment protocols are absent in many informal settings (Ellenbogen and Stevens 2005), however the need for evaluations of environmental education programs is clear (Bennett 1989). School science is most typically assessed using conventional instruments that use items such as multiple choice, true/false and short answer. When assessing younger students, in particular, true/false tests are commonly adopted because of their simpler structure and perceived ease of construction. These, however, are plagued by shortcomings, including vague wording, the tendency for measuring obscure items and the increased opportunity for blind guessing with a reasonable probability of success (Oosterhof 2009).

The Center's curriculum team developed a 25-question true/false test tied to the specific lessons as a means to assess program impact. The test was designed to be provided to students prior to attending the Center and again after the student's final visit. However, since 'good learning styles follow from frequent experience with diverse test forms' (White and Gunstone 1992, 2), the Center and the participating school districts searched for a supplemental assessment format. Essential to this search was a format that would be minimally intrusive on the students as well as easy to implement and score. Drawings, as a means of assessment, were selected given the context of the learning, as well as it being a task generally considered fun and engaging (Thomas and Silk 1990).

Drawings as an Assessment

Vygotsky (1971) considered art and learning to be closely linked; as such, drawings could be expected to reflect some aspect of learning. White and Gunstone (1992, 105) found drawings to be an 'efficient and effective method' in assessing children's learning, often providing understanding that was hidden in other procedures. Drawings are very open assessments with few limitations placed on responses, and as such may be complementary to more common closed assessments and may 'tap different aspects of understanding' (White and Gunstone 1992, 105). Lewis and Greene (1983, 23) suggested that drawing analysis as a means of assessing children's understanding is reliable and 'among the most accurate obtained through any means of assessment'. Thomas and Silk (1990, 159) considered the act of drawing to be 'a cognitively complex activity', and Guillemin (2004) argued 'that drawings offer a means of gaining further insight into the ways in which participants interpret and understand their world' (287). Nossiter and Biberman (1990) concluded that drawings 'focus a person's response' and lead to 'honesty and parsimony' (15).

The linkage between drawings and learning has also been explored in literacy strategies. McConnell (1992) developed an approach termed 'talking drawings' whereby 'translating mental images into simple drawings helps students at all levels bridge the gap to better comprehension and learning' (260). Fello, Raquette, and Jalongo (2006) extended this to science education where the methodology enabled 'children to combine their prior knowledge about a topic with new information derived from expository text' (80). Chang (2012, 1) suggested that since drawings are mechanisms of expression for children that it 'would be logical and reasonable to incorporate children's drawings into building science concepts'.

Drawings have been used to visualize and characterize children's perceptions of the environment and scientific concepts (Alerby 2000; Barraza 1999; Shepardson et al. 2011; Tunnicliffe and Reiss 1999; Zoldosova and Prokop 2006). Cainey et al. (2012) assessed informal learning in an aquarium setting using pre- and post-drawings of children between 4 and 11 years of age. The authors concluded that since the same child was used for each pre-/post-comparison that the changes observed equated to the learning that occurred as a result of the visit. Kalvaitis and Monhardt (2012, 220) used drawings and written narratives to characterize elementary students' understanding of their relationship to nature, finding that 'children had a positive deep-seated appreciation' for nature. Bowker (2007) established that the pre- and post-drawings of 9 to 11 year olds after a visit to a tropical rainforest exhibit provided insight to the understanding and learning of the experience. Shepardson et al. (2007) used drawings as representations of student understanding of the environment. Judson (2011) used drawings by fourth and seventh grade students as representations of mental models of the desert environment.

Not all researchers, however, are in agreement over the utility of drawings and their linkage to student understanding. Rennie and Jarvis (1995) found that the use of drawings by children to demonstrate understanding of technology did not always reveal the depth of understanding, but that using words with the drawings increased the opportunity for students who believed they were poor drawers to feel more comfortable with their responses. Ehrlén (2009) found an 'unclear relationship between children's choice of convention for depicting an object and their conception of the object"; however, that study involved negotiating meaning of an abstract issue – the earth.

Focus

This study is a portion of a larger study looking at the impact of the Center's out-of-school environmental education program on students' understanding of a local ecosystem. The specific research questions addressed are:

(1) Can pre- and post-drawings be used to assess changing understanding of the essential components of the longleaf pine ecosystem for fourth grade students who attended an informal environmental education program?
(2) Can a rubric be developed to reliably score and document these changes in understanding?

Methods

Two years of data were collected and analyzed for this research. Only fourth grade students (9–10 years old) who attended for multiple days of curriculum experiences were eligible for participation in this study. While several thousand children visited the facility, only those students that supplied both pre- and post-drawings as well as the necessary consent and assent forms were retained for analysis. Students attended multiple days which varied based upon the year and the school district (Table 2).

Table 2. Participants from the center involved in the study.

	Students attending 2 days	Students attending 5 days	Students attending 4 days
First Year	205	201	
Second Year			293

The Draw a Longleaf Pine Forest Ecosystem (D-LLPFE) assessment was designed as a pre- and post-measure to evaluate the desired educational impact of the experience related to the ecologically important criteria of the longleaf ecosystem. For the First Year of students, all instructions concerning the test were conveyed via e-mail to the individual teachers. Students were asked to produce a drawing that represented their impression or understanding of the longleaf pine ecosystem that is typical of north Florida. Teachers were asked to instruct students to include the plants, animals and processes associated with the ecosystem. No prescribed format or size of the drawings was stipulated, nor was a specific script developed to ensure that all teachers approached the assessment consistently.

The protocol for the Second Year of students was altered to include the following prompt provided to each student:

> 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.

In both years, no interaction between the researcher and students occurred. The drawings were completed prior to attending the first day at the Center and again after the last class visit.

Data analysis

The evaluation of the D-LLPFE was facilitated through the development of a scoring rubric focusing on key ecological features of the longleaf pine ecosystem and the expression of those features at the Center. Initial items of the rubric emerged from trends observed in a pilot study of drawings and were combined with guiding ecological principles. Subsequent to this initial development, a draft of the rubric was submitted to two independent science educators, along with sample drawings for their scoring. Next, the lead researcher met with the reviewers, discussed discrepancies, incorporated suggestions and revised the rubric for another draft. This process continued through several iterations until the researcher and the reviewers felt confident that a final version had been developed that could be further tested for reliability.

In this final form, the drawing rubric consisted of 20 items that were grouped under the broader headings of Fauna, Flora, Ecosystem Diversity, (Characteristics specific to) Longleaf Pine and Forest Processes. Drawings were to be scored based upon the presence or absence of a particular item in each drawing and therefore a top score of 20 was possible. Table 3 provides these items along with descriptions and clarifiers that were negotiated by the researchers and the review team. Some justifications concerning the appropriateness of items are provided in italics. This final

Table 3. Item analysis for drawing rubric developed for D-LLPFE.

Fauna

1. 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. *The longleaf pine forest is a diverse ecosystem that supports many animals.*
2. Important species as referenced at the Center are present, including red-cockaded woodpecker, gopher tortoise and black bear. *The instructional programs of the Center highlight the gopher tortoise, and to a lesser extent the red-cockaded woodpecker and black bear. The gopher tortoise is considered an ecological keystone species upon which many others depend upon. The red-cockaded woodpecker is a federally threatened species that requires high quality longleaf pine forests for its survival in the Panhandle. The black bear is a symbol of Nokuse Plantation, the parent project of the Center, and represents the need for large areas of preservation for the survival of some species.*
3. 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. *Do the students harbor misconceptions in the animals associated with the forest.*

Flora

4. Three or more appropriate plant species are present. In the event of images difficult to classify, they are assumed appropriate. *This aims to address an understanding of the high diversity of plants found in this ecosystem.*
5. The groundcover is dense, covering > 50% of the substrate. *A dense groundcover of grasses and herbs is associated with a high functioning longleaf forest. It is this material that helps carry fire through the system.*
6. Shrubs represent ≤ 25% cover. *With a healthy fire regime or return interval, the shrub layer would be kept low. So while the shrubs do not carry the fire as with the groundcover, a low percentage is indicative of a healthy system.*
7. All plants represented are appropriate and have no misconceptions. At least one appropriate plant needed to be present. *The inclusion of 'garden plant species' or 'exotic plant species' is target of this item.*

Ecosystem diversity

8. Two or more natural communities – including pines, wetlands, ponds, swamps, creeks, rivers, etc. – are portrayed. *Since longleaf pine systems are complex associations of micro-communities, the activities at the Center focus on multiple community types.*
9. Burrows or mounds are present (includes ant mounds and beaver dams). *Much of the instruction at the center exposes students to the gopher tortoise burrow and its value to many other species. Also prominent at the Center is an introduction to ants and beavers. Ants are primary research interest of the Center's namesake, Dr. E.O. Wilson and they figure into activities and exhibits. Beaver dams are another community type that individuals are exposed to both in the exhibit hall and on the trails.*
10. Nests or cavities (including bee hives) are present. *The presence of nests, tree cavities and beehives demonstrates ecosystem complexity and references some of the unique animals highlighted by the Center.*
11. All ecosystem components are appropriate without any misconceptions such as mountains, waterfalls and pine plantations. *This criterion is targeting community misconceptions, including tall mountain ranges and even aged pine plantations.*

Longleaf pine

12. Pine trees have clear characteristics of the longleaf pine, including deep tap root, big cones, flaky bark or very long needles. *These unique characteristics are highlighted in the exhibit hall and the trails.*

(*Continued*)

Table 3. *(Continued).*

13.	More than one stage of the life cycle of the longleaf pine is represented – grass stage, bottlebrush stage, sapling, adult. *The longleaf pine is uniquely adapted to life in a fire maintained ecosystem and the various stages of the life history of this tree are central to that success.*
14.	Trees are widely spaced. *This is the hallmark of the historic longleaf pine communities and represents the influence of fire.*
15.	All characteristics are consistent with Florida pine trees. To be considered appropriate for this criterion there needs to be at least some pine trees (not all broadleaf, deciduous trees) and the trees should resemble southern pines and not northern coniferous pines. *This addressed misconceptions about longleaf pine.*
Forest processes	
16.	The water cycle is represented. This can include depictions of rain, clouds, storms, waterbodies and even groundwater. *This is an important abiotic factor prominent at the Center.*
17.	Decomposition/nutrient recycling is present such as skulls, logs, stumps, leaves, fallen pine cones.
18.	Fire or lightning (including charred bark) is referenced. *This is a central concept in the understanding of the unique structure and characteristics of the longleaf ecosystem. The effects of fire are captured in other items, however, this represents a direct understanding of the importance of fire.*
19.	The sun is present or sunlight is otherwise depicted.
20.	Predator–Prey relationships are depicted and these are appropriate interactions for the ecosystem.

prototype was then validated for inter-rater reliability, content validity and the scoring of the pre- and post-drawings in the study. The data collected from the First Year were used to determine the efficacy of the instrument on a large scale and were subsequently used to adjust the rubric for Second-Year data.

Findings

Content validity

Content validity was established by review of the rubric by two PhD biologists with extensive experience with the longleaf pine ecosystem. Reviewer 1 indicated that the rubric included 'all of the necessary basic content' concerning the longleaf pine ecosystem and that the constructs were valid (Aresco 2011, personal communication, email). This reviewer recommended that item 20 be expanded to include not just predator–prey relationships but also plant and animal interactions (herbivory). Reviewer 2 also stipulated that the rubric was adequate and added the recommendation to consider burrows made by other species, including pocket gophers (*Geomys pinetis*) (Gunzberger, 2011, personal communication, email). Both of these recommendations were already subsumed within the rubric and clarifying language was added, and from a content perspective the rubric was deemed to be suitable.

Rubric inter-rater reliability

Once content validity was documented, inter-rater reliability was determined by a comparison of the individual scores of 35 randomly selected students generating 70 pre- or post-drawings from the First Year. The raters included the lead researcher, a prior high school biology teacher with a Master of Science in Curriculum and Development and a doctoral candidate in Science Education with over 10 years of experience teaching middle school science. IBM SPSS 21® was used to calculate the Pearson's product-moment correlational analysis and generated correlations for the three pairs of $r = 0.867$, 0.871 and 0.886, $\rho < 0.001$. This represented sufficient correlation between raters and suggested the rubric was reliable.

Group comparison of pre- vs. post-drawing scores in First Year

When the drawings in First-Year data were assessed using the rubric, significant improvement was identified when all 406 students were considered together (Table 4). Significant differences were also identified when data were separated into those students who attended the center for two days and those that attended five days (Table 4). These data suggested a significant and meaningful improvement (large Cohen's *d* effect size), in the portrayal of key aspects of the longleaf pine ecosystems as captured by the rubric and facilitated by the experience at the Center, even for the shorter duration experience.

Individual examples of drawings and rubric utility

The utility and the application of the rubric were best demonstrated through a review of the pre-/post-drawings from individual students. Figure 1 is a pre-drawing from a student that attended the Center for 2 days which showed a pond ringed by pine trees and minimal wildlife. This drawing received a score of 10 based upon the rubric. It contained appropriate animals (3), dense groundcover (5), minimal shrub cover (6), appropriate plants (7), multiple community components (8), appropriate ecosystem components (11), longleaf pine characteristics (12), appropriate pines (15), hydrologic cycle (16) and the sun (19) (see Table 2 for references). This drawing provided a good example of some of the assumptions that are required when making interpretations. The marks or coloring on the ground were assumed to suggest grass, but the student could have been trying to represent pine needles.

The post-drawing from the same student (Figure 2) received a score of 15 for items 1–7, 9–12, 14, 15, 17 and 20 (Table 2). Missing from the drawing was the representation of two or more natural communities (8), more than one life cycle stage of the longleaf pine (13), the water cycle (16), fire (18) and the sun (19). The drawing included substantially more animal life, threatened and endangered species found in the ecosystem and good community structure. It is also clear that the addition of labels to the drawing substantially added to our ability to identify images that might otherwise be difficult to classify.

Figures 3 and 4 represent another pre-/post-comparison from an individual student. The pre-drawing (Figure 3) was assigned a score of two for shrubs ≤ 25% cover (6) and the sun (19). No animals were included, and the trees were densely grouped and suggestive of northern coniferous pines. In contrast, Figure 4 demonstrated substantial growth in understanding and received a score of 12 for items 2, 3, 6, 7, 9, 11–16 and 20. The community structure was good, included trees representative of longleaf pines, and iconic inhabitants, such as the gopher tortoise, were represented.

Figure 5 provides the pre (left) and post (right) of a single student that demonstrated a seven-point increase. In the pre-drawing, the student only included a single tree that bore little resemblance to a pine tree of north Florida. However, it received

Table 4. Statistics for pre- and post-drawing assessments.

Days of attendance	Pre/post	Mean (*M*)	Change in *M*	*N*	SD	*t*	*df*	*p*	Cohen's *d*	Effect size
Treatments Combined	Pre	8.00	3.05	406	2.47	−20.50	405	<0.001	−1.155	Large
	Post	11.05			2.80					
2	Pre	7.60	3.35	205	2.59	−15.03	204	<0.001	−1.220	Large
	Post	10.95			2.89					
5	Pre	8.41	2.74	201	2.28	−14.08	200	<0.001	−1.095	Large
	Post	11.15			2.70					

Figure 1. Pre-drawing of student attending for 2 days.

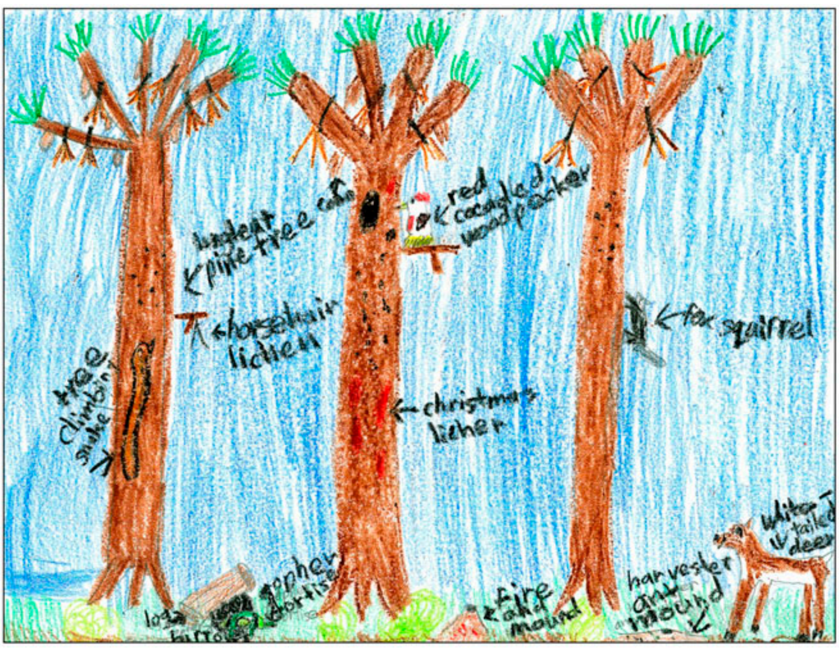

Figure 2. Post-drawing of same student as Figure 1.

Figure 3. Pre-drawing of student that attended the Center for 2 days.

Figure 4. Post-drawing of same student represented in Figure 3.

points for sparse shrub cover (6), appropriate ecosystem components (11) and widely spaced trees (14). Notice that with the structure of the rubric, the absence of alternative conceptions of communities and species helped to provide the score that

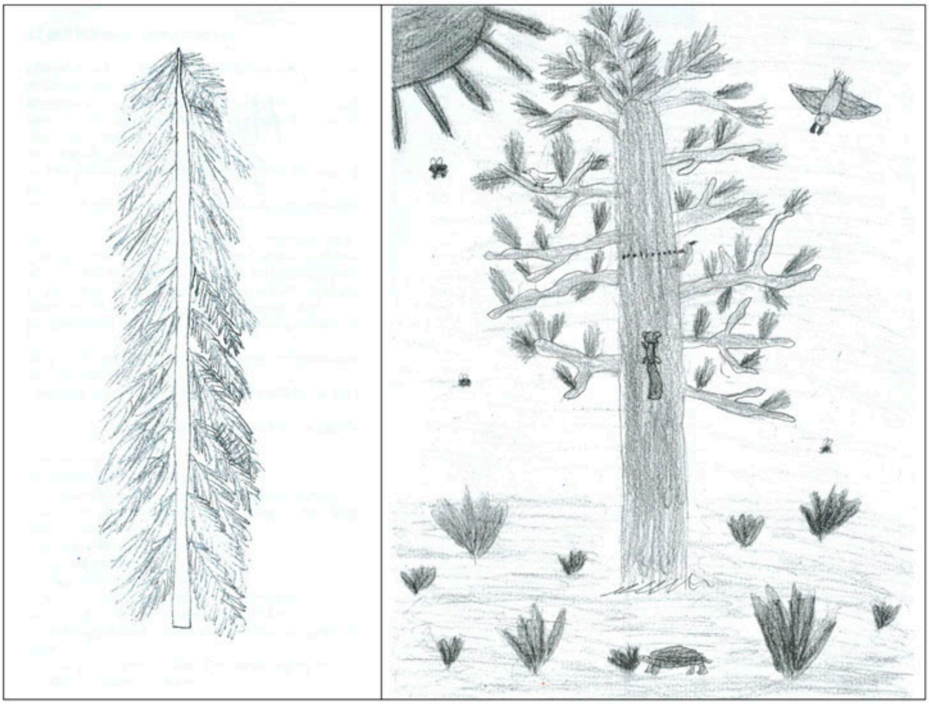

Figure 5. Pre-drawing (left) and post-drawing (right) showing a seven-point increase in scores using the rubric.

was received. The post-drawing (right) received a score of 10 for the inclusion of items 1, 3, 6, 7, 11–15 and 19. In this drawing, the details of the longleaf pine were evident and the community structure was improved.

Figure 6 is pre-drawing from a student in which the image was classified as a northern coniferous pine. This drawing received a score of three; one point for items 6, 11 and 14. The post-drawing (Figure 7) showed substantial gains and received a

Figure 6. Pre-drawing representing northern coniferous pines.

Figure 7. Post-drawing of student shown in Figure 6 in which community misconceptions have been corrected and details related to the instruction (pitcherplants) have been included.

score of 15 for items 1, 3, 4–9 and 11–17. The post-drawing demonstrated specificity to the ecosystem, iconic species and species diversity.

Figure 8 is a pre-drawing that received a score of two, with one point each for items 6 and 14. Compare that with the post-drawing in Figure 9 that was assigned a score of 12 for the inclusion of items 3–6, 8, 11–15, 18 and 19. The post-drawing included key characteristics of the longleaf pine, multiple life stages of the pine,

Figure 8. Pre-drawing that received a score of 2.

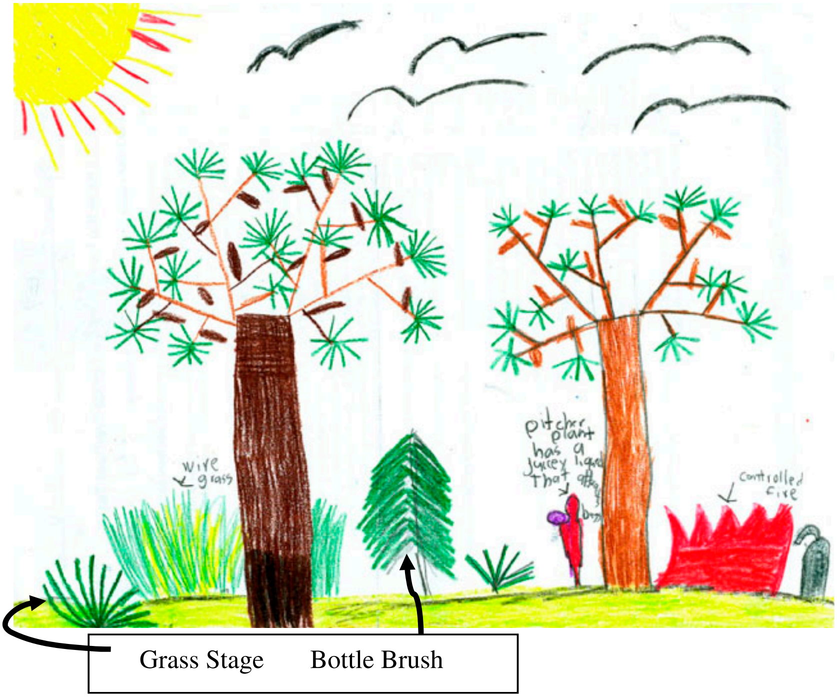

Figure 9. Post-drawing from same student represented in Figure 8 which received a score of 12.

important plant species (wiregrass), embedded communities (pitcherplants) and reference to prescribed fire.

Drawing rubric item analysis

The 20 items of the rubric were individually analyzed to look for pre- to post-shifts in occurrence. Table 5 provides the absolute frequency of occurrence of each rubric item pre and post ($N = 406$). Each item was analyzed using McNemar's Test in IBM SPSS 21 and the χ^2 calculations provided in Table 6. There was a significant increase in the frequency of occurrence between pre- and post-drawings for rubric items 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18 and 20. There was no statistically significant change in the frequency of occurrence for rubric items 5, 6, 16 and 19.

Rubric refinement

Based on data from item analysis from the First-Year data changes to the rubric were considered. The four items in which no significant increase was observed included:

- Ground cover is dense, covering > 50% of the substrate.
- Shrubs represent < 25% cover.
- Water cycle represented.
- Sun portrayed.

Table 5. Frequency of occurrence of rubric items pre and post for treatments combined.

	Item	Pre	Post
1	3 or more animals	174	238
2	Important species	21	138
3	All animals appropriate	291	354
4	3 or more plants	109	147
5	Groundcover dense	181	186
6	Shrubs sparse	389	399
7	All plants appropriate	362	394
8	2 or more communities	109	136
9	Burrows/mounds	53	193
10	Nests/cavities	180	225
11	All components appropriate	373	398
12	Longleaf characteristics	44	177
13	Longleaf life cycle	6	126
14	Trees widely spaced	326	366
15	Consistent with FL pines	209	336
16	Water cycle	156	179
17	Decomposition	57	127
18	Fire	2	66
19	Sun	159	175
20	Predator–prey	33	102

Table 6. Results of McNemar's test for each item on the rubric for all students combined.

Rubric item no.	χ^2 statistics	*p* value
1. 3 or more appropriate animal species	26.112	*<0.001**
2. Important animal species	99.674	*<0.001**
3. All animals appropriate (at least one present)	35.266	*<0.001**
4. 3 or more appropriate plant species	9.01	*0.003**
5. Dense groundcover	0.09	*0.761*
6. Sparse shrub cover[a]	NA	*0.064*
7. All plants appropriate (at least one present)	20.02	*<0.001**
8. 2 or more natural communities represented	5.08	*0.024**
9. Burrows or mounds	108.54	*<0.001**
10. Nests or cavities	11.73	*0.001**
11. All ecosystem components appropriate	14.05	*<0.001**
12. Longleaf pine characteristics	120.17	*<0.001**
13. Multiple stages of life cycle of longleaf pine	112.39	*<0.001**
14. Trees widely spaced	18.11	*<0.001**
15. All characteristics consistent with FL pines	99.85	*<0.001**
16. Water cycle	3.01	*0.083*
17. Decomposition	36.068	*<0.001**
18. Fire	62.02	*<0.001**
19. Sun	1.42	*0.233*
20. Predator–prey interactions	44.04	*<0.001**

Note: The Italics represents probability.
*Denotes significance at 0.05.
[a]SPSS used a binomial analysis instead of McNemar's test.

The first two items were grouped under the category of Flora and were intended to characterize the structure of the vegetation within the ecosystem, which depends on fire to define the forest into distinctly represented layers or strata. In the presence of a natural fire regime, a healthy longleaf pine forest has a sparse to moderately defined pine tree canopy, minimal young tree and shrub subcanopy, and a rich groundcover of grasses, herbs and sprouting woody material. Fire favors longleaf pine that has special adaptations at the expense of other pine species and large hardwoods.

The final two items showing no significant increase in occurrence are under the Forest Process subheading. The intent with this category was to provide consideration of the biotic and abiotic processes that occur in the forest, support the diversity of plants and animals, and enable the ecosystem to function effectively. While the sun is obviously a critical aspect of all communities, its role in the rubric is related to the requirement of grasses and herbs on the forest floor for adequate light to sustain healthy growth. With respect to the water cycle, it is undeniably essential to all ecosystems, and for that reason was included in the rubric. Since these categories were not statistically significant and since both represent an abiotic consideration, the collapsing of the items into a single item asking if the drawing acknowledged the role of abiotic factors was appropriate.

To evaluate the feasibility of revising the rubric the original items 5 and 6 were condensed as follows: ground cover is dense (>50% of the substrate) and/or shrubs are sparse (<25%). Similarly, items 16 and 19 were condensed to: an abiotic factor (sunlight, wind, rain, groundwater, clouds, etc.) is depicted. These revised 18 categories were re-evaluated using the original data from the three independent raters on the original rubric. Since these did not represent new categories as much as they represented a collapsing of categories, combining the original scores to accommodate this was straightforward and generated correlations for the three pairs of $r = 0.812$, 0.854 and 0.862, $\rho < 0.001$. This represents sufficient correlation between raters and suggested the revised rubric with 18 instead of 20 items is also reliable.

Group comparison of pre- vs. post-drawing scores in Second Year

In the Year 2 data, using the revised rubric, there was a significant increase in the incorporation of key ecological features of the longleaf pine ecosystem after completing the program at the Center (Table 7). There was a statistically significant average increase in the post-scores of 2.106 or 11.7%, and this change was considered meaningful as demonstrated by a large effect size. The Second-Year data were also accompanied by limited, self-reported demographic data which allowed additional comparisons to be evaluated. When gender was considered as a grouping variable, both females and males also individually demonstrated significant growth with large effect sizes (Table 7); however, when *the amount of change between the pre- and*

Table 7. Paired sample t-tests for pre- and post-drawing scores for all students based upon the 18 point rubric. Dominant and nondominant refer to individuals privileged, and not privileged, respectively, by the educational system.

	N	Mean change	SD	t	df	p	Cohen's d effect size	
All students	293	−2.106	2.963	−12.165	292	<0.001	0.837	Large
Female	131	−1.553	2.805	−8.317	130	<0.001	0.810	Large
Male	156	−1.616	3.118	−8.447	155	<0.001	0.849	Large
Dominant	199	−1.920	2.980	−9.086	198	<0.001	0.772	Large
Nondominant	60	−2.350	2.887	−6.306	59	<0.001	0.946	Large

post-scores was used with gender as a variable in independent t-tests, there was no significant difference in the amount of change between females and males ($t = 0.201$, $p = 0.841$). Therefore, the amount of growth was not different for the sexes.

Of the total students in the Second-Year data, 259 reported ethnicity as follows: 199 White/Caucasian, 25 African-American, 8 Hispanic/Latino/Latina, 4 Asian and 24 listed as 'Other'. Such variable sample sizes did not allow statistical comparisons between individual groups, yet in an effort to explore the data completely, it was delineated into 'dominant' and" nondominant" groups (Guitérrez and Rogoff 2003). Using this framework, dominant referred to those that have been privileged by the educational system, and who may or may not represent a numerical majority. Given the demographics of the area (US Department of Commerce, n.d.), it was reasonable to attribute dominant status to the Caucasian students. Each group demonstrated significant growth in understanding, and like the gender categories, there was no significant difference in the amount of change demonstrated by each group based upon an independent t-test ($t = –0.988$, $p = 0.324$).

Human representation in the drawings

As referenced in Table 3, the rubric identified that humans were to be considered as appropriate 'fauna' for the community but not necessarily as a 'keystone' or 'indicator' species for the ecosystem. While this may be an arguable point, the goal of the program was to focus on those species that require the longleaf forest ecosystem for their existence, such as gopher tortoise and red-cockaded woodpecker. For the most part, students did not include humans to a great extent in either the pre- or the post-drawings. When they did, they usually represented either the instructors they encountered at the Center, themselves engaged in an activity offered during their visits, or themselves with their class on the field trip (Figure 10).

Discussion and implications

It is first important to identify limitations associated with the methodology and study as implemented. We must consider that the restrictions of drawing size, the amount of time devoted to the task (which was not measured and would be expected to vary from teacher to teacher), the manner in which the task was introduced to the students (i.e. – verbal vs. written instructions, deviations from the 'script', etc.) and the student's attempt to 'make it look nice' could have made the exclusion of important ecosystem details an oversight. Therefore, the absence of an item should not be taken as a lack of understanding of its importance. With the absence of classroom observations, we were unable to ascertain the fidelity of implementation of the assessment. This is especially pertinent in the First-Year data where instructions were verbally provided to the teachers and no specifications for drawing size were stipulated. These issues were partially mitigated in the Second Year where the teachers were provided with a sheet for both the pre- and post-drawing assessments that contained the student instructions and a standardized drawing size. This, however, does not guarantee fidelity of implementation as evidenced by some drawings being submitted on paper other than provided to each teacher. More space could allow students to represent more information without feeling confined.

Consideration must be given to the ability of a fourth grade student to spatially represent some ecosystem functions such as the canopy, subcanopy and groundcover.

Figure 10. Example of human representation in student drawings.

Arnold, Sarge, and Worrall (1995, 639) in their review of student drawings concerning the earth and the gravitational field concluded that ‘the fact that a person understands a concept does not necessarily mean that they can draw it accurately’. Hurwitz and Day (1991) concluded that children have a propensity to draw features along a baseline which may make vertical stratification – in this case the differentiation between canopy, subcanopy and groundcover – a difficult concept.

We must also acknowledge that the length of time provided for the students to complete the assessments could have varied between classes and teachers depending upon a variety of factors, not the least of which could be a teacher’s level of commitment to the experience. Variable time could be a limiting factor in what was included or excluded from drawings. Time was also an uncontrolled variable when looking at the wide range of intervals between the pre- and post-drawings, which varied from approximately 30 days to as much as 180 days between each drawing. While we cannot rule out knowledge gains occurred that were independent of the experience – and very much welcomed – we can remain confident that these students were not gaining additional onsite experience at the Center. While the Center is currently open to the public on weekends and special events, it was not at all during the First Year, and only on a few Saturday’s during the end of the Second Year.

Some of the above limitations were supported by qualitative interview data, to be reported on more completely in a subsequent manuscript, of 41 students in the

Second Year of the study who consented to interviews four months after their last visit to the Center (Dentzau 2013). Several students offered insight that suggested that the absence of an element in a drawing should not necessarily be interpreted to reflect lack of understanding of a concept. The following exchanges documented this issue:

> I was going to draw a circle where the woodpecker was in there but we didn't have enough time. (Nancy, interview)

> I was gonna draw a deer … [but] it was too much. (David, interview)

Other students included items and features in the drawings simply because they were personally appealing.

> Oh, there um … tents … no they're mountains. Yeah, because since I like mountains because you know how they got … don't they have snow on top? (David, interview)

While interview data provided insight to study limitations, it also served the primaly function of helping to validate the instrument. Students were asked to clarify their drawings and to identify salient features, and these data demonstrated that researcher interpretation of images and student intent were well matched (Dentzau 2013).

It is important to recognize that a student did not need to be especially artistic in order to be able to represent depictions of species and ecosystems. Figure 11 shows

Figure 11. Drawing conveying important aspects of the longleaf pine forest ecosystem.

one such drawing that was able to convey important aspects of the longleaf pine ecosystem, including the role of fire and the gopher tortoise in the ecosystem, without noticeable artistic flair.

At the basic level 'drawings by elementary students include more details and realistic representations for subjects they know more about' and often 'omit drawing subjects they do not know much about' (Cronin-Jones 2005, 229).

The D-LLPFE and the associated rubric specifically targeted the characteristics that make the longleaf pine ecosystem unique and valuable. From the data presented we can conclude that the assessment and rubric are reliable, valid and useful in assessing learning gains concerning an ecological topic. Furthermore, the absence of differential gains between groups – male vs. female and dominant vs. nondominant – suggest that the assessment may transcend the limitations associated with more main stream and/or high-stakes accountability measures. However, it should be noted that the variable socioeconomic status was not factored in, and therefore assignment to dominant/nondominant status was based upon race. The analysis of the data also supports that the interpretation of the drawings was substantially aided by notations and labels provided by many students. These labels were more common in the post-drawings where students attempted to demonstrate their knowledge through the inclusion of specific species and structures (e.g. Figures 2, 7, and 9).

While the format used in the study was similar to others (e.g. Cainey et al. 2012), it differed in several key ways. First, the final version of our rubric included 18 items marked as either present or absent. This is compared to Cainey et al. (2012) who included one domain, detail used in the drawing, based on a more qualitative Likert-type scale. In our early considerations for this study, a similar rubric was considered, but comments from colleagues indicated that it was too subjective, especially for teachers with limited content knowledge on the ecosystem. Second, the Center for this study was largely inaccessible to students outside of the field trip opportunities, and no student had any prior experience at the facility before their first visit. This is in stark contrast with the context of the study referenced by Cainey et al. (2012), where a large portion of the sample population had previous exposure to the facility. Finally, unlike Cainey et al. (2012), we have documented inter-rater reliability, which we believe bolsters this methodology, and allows for application outside of the research team.

On first analysis of the drawings, the disconnect between humans and the environment as represented by the minimal representations of people in the drawings was slightly unsettling. Shepardson et al. (2007, 343) found similar results when evaluating students' mental models of the environment, where they placed 'humans apart from the environment' and viewed 'the environment as a resource for living organisms'. This absence of anthropogenic interaction led the authors to recommend that a more inclusive view of the environment in environmental education was needed. In this case, however, the focus of the experience at the Center did not revolve around such a comprehensive view of the environment (other than land management), but rather focused on the nonhuman biotic and abiotic factors of the ecosystem. With this understanding, the relative absence of humans in the drawings may be expected and should not be taken as a de facto indication of a deficit in understanding.

These results demonstrate the feasibility of designing an alternative assessment strategy for nonformal educational settings, and support the findings of others (Barraza 1999; Bowker 2007; Cronin-Jones 2005; Moseley, Desjean-Perrotta, and

Utley 2010; Shepardson et al. 2007, 2011; Weber 2008) that drawings can be an effective tool in ascertaining understanding and learning, especially when utilized in a pre-/post-manner (e.g. Cainey et al. 2012). Furthermore, the use of a pre-engagement drawing is an effective measure of prior knowledge. The current data demonstrated that few students entered into the experience with any substantive prior knowledge about the longleaf pine ecosystem. Combine this with the notion that traditional paper-and-pencil tests seldom accurately assess learning with respect to science concepts (McNair, Thomson, and Williams 1998), and the efficacy of such an approach becomes unambiguous. Such alternative assessment strategies should be further explored and conveyed to pre-service and in-service teachers in an effort to diversify the range of instruments available for assessing learning, and provide opportunities for those students that have difficulty with formal and high-stakes accountability to demonstrate growth. It is important, however, to remember that drawing as a means of assessment in our case was viable in part because of the pre-/post-format, the level and depth of the information being assessed and the context of the learning environment. It would be unreasonable to assume this methodology would work in all situations and for all content.

The results also demonstrate that, post attendance at the Center for both years, the understanding of the complex interactions and importance of the longleaf pine ecosystem increased for all students. While this study does not demonstrate causality, it is reasonable to assume that the intervention at the Center was the source, or at least the catalyst, for this growth. The detailed community information necessary to move students' understanding of the longleaf pine ecosystem forward would not be expected to fall under the general science content knowledge of most elementary grade teachers. Studies have consistently documented gaps in the basic science content of elementary school teachers (e.g. Burgoon, Heddle, and Duran 2011; Krall, Lott, and Wymer 2009), and ecological community interactions as represented in this study would typically fall outside of the purview of most pre-service teaching programs.

The implications for utilization outside of the current ecosystem framework are also clearly evident. In our attempts to understand and further enhance student learning, the use of a formative or summative assessment that feels less like high-stakes test and more of an expression of conceptual understanding is powerful. Adaptation of this design for other ecosystems could be straightforward with moderate understanding of the target ecosystem, with any attempt to gauge understanding of specific ecosystems following the basic outline of the rubric focusing on the flora, fauna, ecosystem diversity and ecosystem functions that are specific to that community. The category defined as longleaf pine could easily represent temperate hardwoods, seagrass, wetlands and countless others.

This study also focuses attention on the larger issue of the importance of the content covered by, and the context of, this out-of-school environmental education experience. According to the National Research Council [NRC] (2012), 'the continuing expansion of scientific knowledge makes it impossible to teach all the ideas related to a given scientific discipline in exhaustive detail in the K-12 years' (30). Yet, exposure to the diversity of a life should constitute foundational knowledge for students in grades K-12 (NRC 2012). Wagler (2010, 370) concluded that 'if students are not *exposed* to this foundational knowledge of animal biodiversity during their elementary years they will not *learn* and *understand* this knowledge'. Given the limited time for teaching and the complexity of the material, the historical trend toward biology on a micro scale (Yore and Boyer 1997) is in direct conflict with the need for early exposure to macro biological concepts such as ecology.

Research has converged on the reality that young people have generally low levels of factual knowledge relating to environmental issues (e.g. Rickinson 2001, 297). Harry Greene (2005) in his argument for study of natural history provided:

> Our ignorance of the lives of organisms in nature entails complex problems on a global scale, but, for many of us, the best places to start seeking solutions might be within local educational institutions. People will care more about, pay more about, and even sacrifice on behalf of things that they understand, so we need to establish biological diversity, ecology, behavior and conservation as among the core components of scientific literacy. (26)

This research has shown that young students are able to demonstrate ecological learning through a nontraditional assessment within an informal learning environment. While knowledge alone may not be sufficient for scientific literacy under Green's definition, it is clearly the cornerstone that needs to be set in order to ultimately achieve such literacy. However, it is also clear that we also need to look closely at the context in which the learning occurs, and opportunities such as those provided at the Center in this study are a promising place to start.

Acknowledgments

The authors would like to acknowledge the dedication and support of Mr. M.C. Davis and the staff of the E.O. Wilson Biophilia Center.

Notes on contributors

Michael W. Dentzau is an assistant professor at Columbus State University and the executive director of the Oxbow Meadows Environmental Learning Center, which is a cooperative venture between the university and Columbus Water Works. His research centers on understanding the impact of out-of-school environmental education programs and the importance of context in the teaching and learning of environmental science.

Alejandro José Gallard Martínez is a professor and Goizueta Distinguished Chair at Georgia Southern University in the Teaching and Learning Department. The platform for his research is to explore equity and social justice in education in general and in science education specifically. Through the lens of complexity his foci are to understand teaching and learning science and education policy in relation to differences associated with ethnicity, gender, race and SES. His frameworks include global perspectives on differences, otherness, polyphony of voices and meaning-making that reflects categories used to situate people in social life.

References

Alerby, E. 2000. "A Way of Visualising Children's and Young People's Thoughts about the Environment: A Study of Drawings." *Environmental Education Research* 6 (3): 205–222.

Arnold, P., A. Sarge, and L. Worrall. 1995. "Children's Knowledge of the Earth's Shape and Its Gravitational Field." *International Journal of Science Education* 17 (5): 635–641.

Barraza, L. 1999. "Children's Drawings about the Environment." *Environmental Education Research* 5 (1): 49–66.

Bennett, D. B. 1989. "Four Steps to Evaluating Environmental Education Learning Experiences." *The Journal of Environmental Education* 20 (2): 14–21.

Bowker, R. 2007. “Children’s Perceptions and Learning about Tropical Rainforests: An Analysis of Their Drawings.” *Environmental Education Research* 13 (1): 75–96.
Burgoon, J. N., M. L. Heddle, and E. Duran. 2011. “Re-examining the Similarities between Teacher and Student Conceptions about Physical Science.” *Journal of Science Teacher Education* 22: 101–114.
Cainey, J., R. Bowker, L. Humphrey, and N. Murray. 2012. “Assessing Informal Learning in an Aquarium Using Pre- and Post-visit Drawings.” *Educational Research and Evaluation* 18 (3): 265–281.
Chang, N. 2012. “The Role of Drawing in Young Children’s Construction of Science Concepts.” *Early Childhood Education Journal* 40 (3): 187–193. doi:10.1007/s10643-012-0511-3.
Cronin-Jones, L. 2005. “Using Drawings to Assess Student Perceptions of Schoolyard Habitats: A Case Study of Reform-based Research.” *Canadian Journal of Environmental Education* 10 (1): 224–240.
Dentzau, M. W. 2013. “Using Drawings to Understand Students’ Changing Conceptions of the Longleaf Pine Ecosystem.” Unpublished doctoral diss., The Florida State University, Tallahassee, FL.
E.O. Wilson Biophilia Center at Nokuse Plantation. n.d. http://www.eowilsoncenter.org/welcome.html
Ehrlén, K. 2009. “Drawings as Representations of Children’s Conceptions.” *International Journal of Science Education* 31 (1): 41–57.
Ellenbogen, K. M., and R. Stevens. 2005. “Informal Science Learning Environments: A Review of Research to Inform K-8 Schooling.” http://www7. nationalacademies.org/bose/Ellenbogen_Stevens_Commissioned_Paper.pdf
Emer, S., and J. Banks. 2012. “High Stakes Testing and Student Perspectives on Teaching and Learning in the Republic of Ireland.” *Educational Assessment, Evaluation and Accountability* 24 (4): 283–306.
Fello, S. E., K. R. Raquette, and M. R. Jalongo. 2006. “Talking Drawings: Improving Intermediate Students’ Comprehension of Expository Science Text.” *Childhood Education* 83 (2): 80–86.
Florida Department of Education. n.d. http://www.fldoe.org/bii/curriculum/SSS/
Frost, C. 1995. “Four Centuries of Changing Landscape Patterns in the Longleaf Pine Ecosystem.” In *Proceedings 18th Tall Timbers Fire Ecology Conference*, edited by S. I. Cerulean and R. T. Engstrom, May 30–June2, 1991, 17–43. Tallahassee, FL: Tall Timbers Research.
Greene, H. W. 2005. “Organisms in Nature as a Central Focus for Biology.” *Trends in Ecology and Evolution* 20 (1): 23–27.
Guillemin, M. 2004. “Understanding Illness: Using Drawings as a Research Method.” *Qualitative Health Research* 14 (2): 272–289.
Gutiérrez, K., and B. Rogoff. 2003. “Cultural Ways of Learning: Individual Traits or Repertoires of Practice.” *Educational Researcher* 32 (5): 19–25.
Hurwitz, A., and M. Day. 1991. *Children and Their Art*. New York: Harcourt Brace Jovanovich.
Judson, E. 2011. “The Impact of Field Trips and Family Involvement on Mntal Models of the Desert Environment.” *International Journal of Science Education* 33 (11): 1455–1472.
Kalvaitis, D., and R. M. Monhardt. 2012. “The Architecture of Children’s Relationships with Nature: A Phenomenographic Investigation Seen through Drawings and Written Narratives of Elementary Students.” *Environmental Education Research* 18 (2): 209–227.
Krall, R. M., K. H. Lott, and C. L. Wymer. 2009. “Inservice Elementary and Middle School Teachers’ Conceptions of Photosynthesis and Respiration.” *Journal of Science Teacher Education* 20: 41–55.
Lewis, D., and J. Greene. 1983. *Your Child’s Drawings: Their Hidden Meaning*. London: Hutchinson.
McConnell, S. 1992. “Talking Drawings: A Strategy for Assisting Learners.” *Journal of Reading* 36 (4): 260–269.
McNair, S., M. Thomson, and R. Williams. 1998. “Authentic Assessment of Young Children’s Developing Concepts in Mathematics and Science.” Paper Presented at the Australia and New Zealand Conference on the First Years of School, Canberra, Australia, January. ED 445 922.

Moseley, C., B. Desjean-Perrotta, and J. Utley. 2010. “The Draw-an-environment Test Rubric (DAET-R): Exploring Pre-service Teachers’ Mental Models of the Environment.” *Environmental Education Research* 16 (2): 189–208.

National Research Council (NRC). 2012. “A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.” Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press.

Nossiter, V., and G. Biberman. 1990. “Projective Drawings and Metaphor: Analysis of Organisational Culture.” *Journal of Managerial Psychology* 5 (3): 13–16.

Oosterhof, A. 2009. *Developing and Using Classroom Assessment*. Columbus, OH: Allyn & Bacon.

Rennie, L. J., and T. Jarvis. 1995. “Children’s Choice of Drawings to Communicate Their Ideas about Technology.” *Research in Science Education* 25 (3): 239–252.

Rickinson, M. 2001. “Learners and Learning in Environmental Education: A Critical Review of the Evidence.” *Environmental Education Research* 7 (3): 207–320.

Shepardson, D. P., S. Choi, D. Niyogi, and U. Charusombat. 2011. “Seventh Grade Students’ Mental Models of the Greenhouse Effect.” *Environmental Education Research* 17 (1): 1–17.

Shepardson, D. P., B. Wee, M. Priddy, and J. Harbor. 2007. “Students’ Mental Models of the Environment.” *Journal of Research in Science Teaching* 44 (2): 327–348.

Thomas, G. V., and A. M. J. Silk. 1990. *An Introduction to the Psychology of Children’s Drawings*. London: Harvester Wheatsheaf.

Tunnicliffe, S. D., and M. J. Reiss. 1999. “Students’ Understandings about Animal Skeletons.” *International Journal of Science Education* 21: 1187–1200.

U.S. Department of Commerce. n.d. http://quickfacts.census.gov/qfd/index.html

Vygotsky, L. S. 1971. *The Psychology of Art*. Cambridge, MA: The MIT Press.

Wagler, R. 2010. “The Association between Preservice Elementary Teacher Animal Attitude and Likelihood of Animal Incorporation in Future Science Curriculum.” *International Journal of Environmental & Science Education* 5 (3): 353–375.

Weber, N. R. 2008. “A Comparative Analysis of Locally Based Conservation Education Programs That Promote Issue Awareness and Community Solutions within Honduras and the United States.” Doctoral diss. http://web.me.com/weberphin/Weber/Research_files/Dissertation_Weber.pdf.

White, R. T., and R. F. Gunstone. 1992. *Probing Understanding*. London: Falmer.

Whitney, E., D. B. Means, and A. Rudloe. 2004. *Priceless Florida: Natural Ecosystems and Native Species*. Sarasota, FL: Pineapple Press.

Yore, L. B., and S. Boyer. 1997. “College Students’ Attitudes toward Living Organisms: The Influence of Experience and Knowledge.” *The American Biology Teacher* 59 (9): 558–563.

Zoldosova, K., and P. Prokop. 2006. “Education in the Field Influences Children’s Ideas and Interest toward Science.” *Journal of Science Education and Technology* 15 (3–4): 304–313.