Amy N. Spiegel, E. Margaret Evans,
Wendy Gram, and Judy Diamond

Museum Visitors' Understanding of Evolution

Abstract In spite of overwhelming scientific evidence supporting evolution, a large percentage of the American public does not understand or accept the fundamental principles of evolutionary theory. Museums have an important role in educating children and adults about evolution. This paper reviews recent museum visitor studies, which suggest that while visitors are interested in learning about and less likely to reject evolution than the general public, they tend to have a limited understanding of evolutionary concepts. A new conceptual framework, based on developmental research, indicates that visitors reason about evolution differently depending on the type of organism they are considering, applying evolutionary principles to some species-change scenarios, but not others. The use of a conceptual framework that builds on previous visitor research may lead to a deeper understanding of how visitors reason about evolution and how museums may use this understanding to improve the effectiveness of their exhibits.

> I don't believe in evolution. The dinosaurs live [sic] with Adam and Eve in the Garden of Eden 3,000 years ago. And then the Aliens came and gave us fire and the wheel.
> —Visitor's written comment at *Explore Evolution* Exhibition, September, 2005

Evolutionary theory is a well-supported, unifying construct guiding research in the biological sciences. Yet a large percentage of the American public does not accept or understand the central role of evolution in the

Museums & Social Issues, Volume 1, Number 1, Spring 2006, pp. 69–86.

life sciences (Newport 2004; National Science Board 2004). In the last three decades, public opinion polls, developmental and educational research, and museum evaluation studies have begun to shed some light on how people understand evolution and why this topic remains so controversial (Bishop & Anderson 1990; Brumby 1984; Evans 2000, 2001; Guisti 1994a; People for the American Way (PFAW) 2000; Stein & Storksdieck 2005). A brief summary of this research will provide a context for interpreting museum-based studies of visitors' understanding of evolution, which will be described in more detail.

Public opinion polls provide the most well-publicized information on the public's ideas about evolution. These polls have largely focused on people's understanding of human origins, and they find that public opinion on this issue has remained consistent for over twenty years (Gallup & Gallup 1999; Newport 2004). The Gallup polls indicate that almost half of Americans (45% in 2004) believe that "God created human beings pretty much in their present form at one time within the last 10,000 years or so," while slightly more than a third of Americans believe that humans developed from earlier life forms, with God guiding the process (Newport 2004). Other polls support these findings (National Science Board 2004), depending on the wording of the questions. In spite of the nearly universal agreement by scientists on the fundamental principles underlying evolution, between one-third and one-half of Americans think that the theory of evolution is not well-supported by evidence (Newport 2004; PFAW 2000).

These public opinion polls have focused on questions of phylogenetic change and the origin of species. In contrast, most of the educational research on evolution has concentrated on students' understanding of natural selection and other evolutionary principles (e.g., Anderson, Fisher, & Norman 2002; Banet & Ayuso 2003; Brumby 1979, 1984; Clough & Wood-Robinson 1985; Ferrari & Chi 1998; Settlage 1994). These studies illustrate the difficulties students have in understanding how the mechanisms of evolution work. Students' misconceptions about within-species change and adaptation have been found to be consistent and hard to modify. Typically, students endorse need-based or teleological concepts of adaptive change. For example, they are likely to reason that animals change because of the need to adapt to a novel environment and that such acquired characteristics can be inherited (e.g., Anderson, Fisher, & Norman 2002; Beardsley 2004; Bishop & Anderson 1990). Researchers have found that questions of origins, particularly of human origins, are the most likely to elicit creation-

ist reasoning. On the other hand, questions about adaptive change within a "species" are more likely to elicit teleological reasoning, such as students' beliefs that giraffes' long necks result from their habit of stretching their necks to reach into tall trees to obtain food.

Developmental Research on Understanding Evolution

Studies of the early emergence of evolutionary concepts indicate that younger elementary school children are quite resistant to the idea that one "kind" of animal could be the ancestor or descendent of a completely different kind (e.g., Evans 2000, 2001; Poling & Evans 2004a, 2004b; Samarapungavan & Wiers 1997). Moreover, this seems to be part of a broader pattern in that children generally do not even accept the idea of radical developmental change, such as metamorphosis, until about 8 years of age (Rosengren, Gelman, Kalish, & McCormick 1991). Interestingly, regardless of parental beliefs, U.S. 8- to 10-year-olds spontaneously endorse creationist (God made it) explanations for the origin of species (Evans 2000, 2001). By early adolescence, however, children reared in more religious contexts, such as Christian fundamentalist homes and schools, were more likely to maintain and extend their creationist ideas, whereas their non-fundamentalist counterparts were more likely to endorse evolutionist views. Early adolescents' endorsement of evolutionary origins is related to their understanding of metamorphosis and of fossils, as well as to their parents' beliefs. But, just like the older students, they propose need-based mechanisms of adaptive change operating at the level of the individual, not Darwinian natural selection mechanisms operating at the population level (Evans 2000, 2001, 2005).

This kind of evidence motivates the hypothesis that evolution is counterintuitive because of initial "constraints" on cognition (Evans 2000, 2001; Evans, Rosengren, Szymanowksi, & Smith 2005). These constraints give rise to cognitive biases or intuitive theories that appear to limit humans' view of nature: Species are separated by fixed boundaries in an unchanging world, and animate behavior is directed towards a goal that satisfies an organism's needs (Evans et al. 2006). Such intuitions appear early in childhood, and they seem to persist into adulthood.

These studies raise the question of the extent to which museum visitors are subject to the same ideas. What proportion endorse creationist explanations of human and non-human species origins? If evolutionist, do

they endorse Darwinian mechanisms of change? Nearly one-third (30%) of Americans visit museums every year (National Science Board 2004). Knowledge of museum visitors' reasoning about evolution can help in the improvement of museum exhibits and lead to greater public understanding of evolutionary concepts. How different museums exhibit evolution is addressed in Diamond and Scotchmoor's article in this issue, and how museums portray human evolution in particular is addressed in Scott and Guisti's article in this issue. This paper will address what is presently known about museum visitors' understanding of evolution from evaluation and research studies.

Museum Visitor Understanding of Evolution

> I don't believe in all the evolution. It seems to clash too much with religious beliefs, but I do believe in some of it. What do most scientists believe?
> —Visitor's written comment at *Explore Evolution* Exhibition, October 2005

Museums are one of the primary ways that both children and adults are exposed to evolutionary ideas. A number of natural history and science museums have undertaken studies to assess visitor interest in, understanding of, and acceptance of evolutionary ideas (see Table 1). Some were undertaken as front end evaluation or research studies without regard to a particular exhibition. Others were developed as evaluation tools within the specific context of an exhibition that included or focused on evolution (in several cases, the exhibits being evaluated are no longer on display). The majority of these studies have included large numbers of visitors to examine how long visitors attend to different exhibit components, what they remember and identify as main themes from different exhibits, the extent to which they agree with statements about evolution, and their level of interest in evolutionary topics or exhibits. In addition, some of these studies have looked in more depth at visitor explanations of evolutionary mechanisms and visitor familiarity with evolutionary topics and terms. These museum studies provide a foundation for future research on public understanding of evolution and give insight into typical visitor misconceptions and the distinction visitors make between the evolution of humans and the evolution of non-human animals.

Researchers with the recently created *Explore Evolution* exhibition have taken a somewhat different approach. Using the evolutionary sce-

narios presented in the exhibit as a research tool, these researchers take a more detailed look at visitor understanding of evolution. They applied a conceptual model based on the developmental research described earlier, to provide a framework for assessing visitors' reasoning about evolution. In particular they were interested in the consistency of visitor responses across different organisms. This study shows how more in-depth research and analysis can provide specific information on visitor reasoning patterns to illuminate how visitors think about evolution, which in turn can inform exhibit design.

Visitor Level of Interest in Evolution

In general, museum studies indicate a high level of interest in evolutionary topics by visitors. A study at the New York Hall of Science found that, when asked whether science museums should feature an exhibit on evolution, over half (59%) of the surveyed visitors thought they should and 84% indicated that they were interested in bringing children to an exhibition on evolution (Stein and Storksdieck 2005). A front-end study at the Smithsonian National Museum of Natural History found that, when visitors were asked to choose among topics to learn about the "earliest humans" in future exhibits, they expressed the most interest in long-term changes in the environment, early development of family life, and changes in brain size and capabilities (Pawlukiewicz, Doering, & Paasch 1996). An evaluation study of two temporary exhibitions on the early hominid Lucy at the California Academy of Sciences found that more than three-quarters (78%) of visitors rated their interest in human evolution as a four or five on a five point scale (Squire & Hubbell Mackinney 1996). Finally, a front-end study at the University of Pennsylvania Museum in preparation for a new exhibit titled *Being Human: A Design in Process* found that nearly all participants, both children and adults, said they were interested in attending an exhibit on human evolution (Borun 2002). While the term "evolution" was not seen as problematic by the adult participants, they did express the desire to see the exhibit address controversies and differences of opinion by scientists.

Visitor Understanding of Evolutionary Terms and Concepts

Visitor understanding of evolutionary terms, concepts, and mechanisms is less clear. Formative evaluation of the permanent exhibit *Life Over Time* at the Field Museum of Natural History indicated that nearly all of the visitors in their study understood that extinction refers to a species that no

Table 1. Summary of Museum Studies on Visitor Understanding of Evolution

Museum	Authors	Subjects	Focus
American Museum of Natural History	Guisti, 1994a, 1994b	137 museum visitors	An evaluation study of the exhibition, the *Hall of Human Biology and Evolution.* Included observations and structured and open-ended interviews.
California Academy of Sciences	Squire & Hubbell Mackinney, 1996	46 adult visitors	The evaluation study examined what visitors know and want to know about human evolution by interviewing visitors about two temporary exhibits on Lucy, an early hominid.
The Field Museum of Natural History	People, Places, and Design Research, 1992	74 visitors	Formative evaluation study examining visitors' understanding of and interest in learning more about scientific terms used in the exhibition *Life Over Time.*
The Field Museum of Natural History	Hayward, Hart, & Gyllenhaal, 1996	1355 adult visitors	The summative evaluation of the same exhibition *Life Over Time.* Included observations, interviews, and follow-up contacts with visitors.
Florida Museum of Natural History	Dunckel, et. al. 2005	329 adult participants at six natural history museums	In an interview format, visitors were asked to use principles of biological evolution to explain how scientists think the modern cheetah came to run so fast if it had a slower ancestor. Participants were provided with a relevant word bank and pictures to help them respond. After participants completed their responses, they were asked if they accepted their own explanation of biological change (whether accurate or not), and if not, to explain how their beliefs differed.
New York Hall of Science	Stein & Storksdieck, 2005	387 museum visitors at seven science museums	This survey study asked museum visitors identical questions asked of the general U.S. public in a recent nationwide survey on evolution (PFAW, 2000).

Table 1. Summary of Museum Studies on Visitor Understanding of Evolution (cont.)

Museum	Authors	Subjects	Focus
Smithsonian National Museum of Natural History	Pawlukiewicz, Doering, & Paasch, 1996	797 visitors, including both children and adults	Visitors were interviewed in 1989 at the museum in two areas, *Emergence of Man* and *Human Variation* to understand "the perspectives, experiences, and expectations visitors bring to the museum."
University of Pennsylvania Museum	Borun, 2002	37 adult and 10 child visitors	In preparation for a planned exhibit on human evolution (working title, *Being Human: A Design in Process*), this series of focus groups for a front-end evaluation was designed to assess museum audience members' knowledge, preferences, and feelings about the subject of human evolution.

longer exists. Visitors were familiar with the terms evolution, mutation, and adaptation, but their comprehension was rated as moderate or fair because their expressed depth of knowledge was limited, or included some misconceptions (People, Places, and Design Research 1992). Visitors rarely tied adaptation to change in species over generations, but instead referred to an individual "coping" with or changing in response to living conditions. Visitors also did not understand the term "common ancestor" and used this term in the more general vernacular to mean recent generations rather than awareness of this as the root of different species of animals. The majority of respondents (58%) did not know what natural selection was (People, Places, and Design Research 1992). When asked about specific evolution exhibits they had just visited, only a fraction of visitors could identify the main points of the *Adaptation Lab, Extinction Lab,* and *Origin of Species Lab* (Hayward, Hart, & Gyllenhaal 1996).

In the University of Pennsylvania front-end study (Borun 2002), few participants were able to explain the theory or the mechanisms of evolution. While many adults were aware of the ideas of natural selection and adaptation, these were poorly understood. Some participants thought that natural selection is no longer occurring with humans, and "none seemed to clearly understand how gradual changes in the frequency of adaptive traits

occurred in a population," (Borun 2002, 22). The children's responses also reflected misconceptions, including thinking that apes changed to humans and that evolutionary change occurs during an individual's lifetime.

In a collaborative study spearheaded by the Florida Museum of Natural History (Dunckel et al. 2005), approximately one-third of visitors in this study used natural selection to explain how cheetahs evolved from a slower ancestor. An additional 39% of visitors provided explanations that did not conflict with modern evolutionary theory, but did not reference natural selection specifically. For example, subjects said cheetahs "evolved" but could not explain further. One-quarter of the subjects provided clearly inaccurate accounts of the change. The majority of these were teleological explanations: The cheetah became a faster runner because it needed to. When asked if they believed the evolutionary account they had offered, nine percent of the participants explicitly rejected evolution as the explanation for the cheetahs' biological change. While a large majority of visitors recognize and agree with statements describing evolutionary theory and certain mechanisms of evolution (Pawluklewicz, Doering, & Paasch 1990), they appear less able to accurately describe the meaning of central terms such as natural selection, adaptation, and common ancestor (Borun 2002; People, Places and Design Research 1992). For example, findings from an evaluation study of the Hall of Human Biology and Evolution at the American Museum of Natural History indicate that visitors came away with the idea that evolution meant progression from simple to more complex life forms, with humans as the culmination. (Guisti 1994a, 1994b).

Visitor Acceptance of Evolutionary Ideas

Although they are more accepting of evolution than the public at large, many museum visitors expressed uncertainty or said they did not accept evolution when asked whether they agreed with statements about the accuracy of evolution. The New York Hall of Science study (Stein and Storksdieck 2005) found that nearly half (49%) of museum visitors agreed that evolution was a "completely or mostly accurate account of how humans were created and developed." This compares to one-quarter (27%) of the general public who agrees that evolution is an accurate account of human origins (PFAW 2000). One-third (30%) of museum visitors said it "might or might not be accurate, you can never know for sure," and 19% said it was "mostly inaccurate" or "completely inaccurate."

In studies that directly compared visitors' responses to questions about non-human evolution and human evolution, visitors were clearly more willing to accept non-human evolution (Hayward, Hart, & Gyllenhaal 1996; Pawluklewicz, Doering, & Paasch 1990). In the Smithsonian National Museum of Natural History study (Pawluklewicz, Doering, & Paasch 1990), over 85% of visitors agreed with factual statements about animal evolution describing concepts such as inheritance and adaptation (e.g., "Different kinds of animals may look alike because they inherited characteristics from a common ancestor"). However, far fewer (less than 65%) agreed with statements specific to human evolution (e.g., "Humans, monkeys and apes all evolved from a common ancestor"). Nearly one-third (31%) either believed or were not sure if humans and dinosaurs co-existed.

In a summative evaluation of the *Life Over Time* exhibit at the Field Museum of Natural History (Hayward, Hart, and Gyllenhaal 1996), researchers found that nearly half (47%) of visitors interviewed or surveyed thought the main idea of the whole exhibit was to "teach people about evolution." When asked, "Do you believe in the facts of evolution?" 82% of visitors said they did and 12% said they did not. Overall, 61% said they believed in evolution and that humans descended from animals; 21% believed in evolution but not in human descent; and 17% did not believe in or were not sure about the facts of evolution. Asked about their belief in God, 87% of respondents were believers.

In the study on the display of Lucy, an early hominid, over half of the respondents (52%) felt "fine" comparing themselves to Lucy, while 4% (2 people) responded that they did not believe in evolution (Squire & Hubbell MacKinney 1996). Over three-quarters (78%) agreed that humans evolved from creatures like Lucy, and 15% did not agree.

Other Factors Related to Visitor Understanding of Evolution

Some studies found a positive correlation between level of education and familiarity with and understanding of evolution (Pawlukiewicz, Doering, & Paasch 1996; Stein and Storksdeick 2005). Interestingly, in Dunckel, et al.'s study of visitors' explanation of how cheetahs came from a slower ancestor, younger adults were more likely than older adults to offer a correct evolutionary explanation, even though they had less formal education than their older counterparts.

Conclusions

Overall, visitors show great interest in evolutionary topics, are familiar with evolutionary terms and agree with statements that describe evolutionary mechanisms (Pawlukiewicz, Doering, & Paasch 1996; Stein & Storksdieck 2005). However, visitors demonstrate a limited understanding of evolutionary terms and concepts (People, Places, and Design Research 1992). In addition, a significant proportion of visitors express some uncertainty or do not accept evolution, and this was especially true when applied to human evolution (Hayward, Hart, & Gyllenhaal 1996; Pawlukiewicz, Doering, & Paasch 1996).

Explore Evolution Exhibition

Building on this extensive body of work, researchers working with the *Explore Evolution* exhibition proposed a model of visitor understanding of evolution, one that builds directly on the developmental research described earlier, and takes into account visitors' "intuitive theories" (Evans, Spiegel, Gram, Frazier, Cover, Tare, & Diamond 2006). The *Explore Evolution* team identified cognitive and cultural sources likely to inform museum visitors' reasoning about evolution. *Intuitive* or commonsense reasoning comprises the everyday explanations that most easily come to mind when humans solve problems. From studies in cognitive development, several intuitive reasoning modes have been identified that appear to underlie human reasoning about the natural world, including an everyday or intuitive biology and an intuitive psychology (e.g., Evans 2001; Carey 1985; Keil 1994; Medin & Atran 2004; Wellman & Gelman 1998). As described in the earlier section on developmental research on understanding evolution, these reasoning modes are associated with distinct cognitive biases that appear to make evolutionary ideas particularly difficult to assimilate: that living things are separate, stable, and unchanging (*essentialism*) and that animate behavior is goal directed (*teleology*) and intentional (*theory of mind*). At the same time, the *scientific* and *religious* communities provide cultural sources of information about the origins of species, which should reinforce or modify these basic intuitions. Using this theoretical perspective, the researchers profiled visitors' use of three different reasoning patterns, intuitive, scientific, and religious, to explain the evolution of seven diverse organisms, featured in *Explore Evolution*.

Explore Evolution is a major exhibition on permanent display at six Midwestern museums (Diamond, Spiegel, Meier, Disbrow 2004). Developed by a consortium of museums led by the University of Nebraska State Museum, the focus of the project is seven current research projects that make major contributions to our understanding of evolution. These seven research projects were selected in part because they focus on different organisms (virus, diatom, ant/fungus, fly, finch, human, and whale), which range from the smallest to the largest, and yet they all illustrate common evolutionary principles (Diamond 2005). The evolutionary concepts of *variation, inheritance, selection*, and *time* (VIST provided by the University of California Museum of Paleontology) provided a cognitive organizer for the exhibition.

The initial front end survey included questions about visitor understanding of and interest in the seven organisms featured in the exhibit and in the VIST concepts (Evans et al. 2006). Sixty visitors from three Midwestern natural history museums responded to the questions, "What would you expect to see when I say [variation, inheritance, selection, time, evolution]?" The majority of subjects associated biological organisms with the words variation (72%), inheritance (60%), selection (58%), and evolution (82%). A typical response to the word *evolution* included references to fossils, evolution of humans, or VIST terms. For example, *"[I'd expect to see] mutation, natural selection, as well as examples of them."* Visitors indicated a greater interest in learning more about whales, humans, viruses, and diatoms than the other organisms, and about two-thirds of visitors (60%) indicated they would be somewhat or very likely to go to a museum exhibit entitled, *Explore Evolution*. As expected, visitors' level of knowledge about the seven organisms, their recognition of the evolution concepts, and their level of formal education were significantly, positively correlated with one another ($p < .01$).

To learn how museum visitors reason about evolutionary problems, visitors were asked to explain the evolution of the seven organisms in the *Explore Evolution* exhibit. Unlike the first study and prior research, visitors were not told that these were evolutionary problems, nor was the term evolution used (IRB permission was obtained for all studies). From the 32 visitors' responses, 601 conceptual units were identified that expressed themes relevant to evolution. Visitors' responses were individually coded for these themes, which corresponded to different reasoning patterns. Responses fell into the following reasoning patterns: (1) *Informed naturalistic*

reasoning (INR), in which one or more core Darwinian evolutionary concepts or VIST terms was referenced, though the visitors were not "experts." (2) *Novice naturalistic reasoning (NNR)*, in which the intuitive modes of reasoning, described earlier, were used to explain evolutionary change. (3) C*reationist reasoning*, in which supernatural rather than natural explanations were invoked, in particular, God's direct role in the origin of species (CR). (4) *Mixed Reasoning*, using more than one of the above reasoning patterns.

Each question presented a set of observations on evolutionary change that were based on the core issues addressed by the scientists featured in the *Explore Evolution* exhibition. All of the visitors endorsed mixed patterns of reasoning. The majority of responses (72%) used a combination of informed naturalistic reasoning (INR) and novice naturalistic reasoning (NNR) to explain these evolutionary events. Some visitors (28%) used a combination of creationist reasoning with one or both of the naturalistic reasoning patterns. However, the majority of visitors did have a dominant reasoning mode, which they used most frequently. Overall, the most frequently used reasoning pattern, used by 53% of the respondents, was novice naturalistic reasoning (NNR), followed by 34% using informed naturalistic reasoning (INR), and 6% using predominately creationist reasoning (CR).

This finch question will be described in more detail to give a sense of the variation in visitors' understanding. The question was as follows:

> During one year, scientists measured the beaks of one kind of finch on a remote island. They found that most of these finch beaks were small. In the following year, a drought wiped out almost all the plants that produce small seeds. Only the plants that make large tough seeds remained. A few years later, the scientists returned to the island and measured finch beaks again. This time they found that more of the finches had bigger beaks. How would you explain why more of the finches had bigger beaks?

Table 2 provides examples of visitor responses from each of the different reasoning patterns. It is interesting to note that the mixed reasoner shows both creationist and informed natural reasoning, simultaneously denying evolutionary origins, while providing a reasonable description of natural selection.

Of the seven organisms, the finch question was the most likely to invoke an evolutionary term and least likely to invoke a novice reasoning

Table 2. Visitor Responses to Finch Question that Typify the Different Reasoning Patterns

Type of Reasoning Used	Example of Visitor Responses
Informed Naturalistic Reasoning (INR)	Well, the large-beaked birds were the only ones that survived because they could eat the seeds, and therefore they were the only ones that reproduced, and the ones with the small beaks lost out.
Novice Naturalistic Reasoner (NNR)	Evolution for survival. . . .Well, in order to survive, their body parts had to adjust to certain things, similar to the way giraffes' necks probably grew long as they reached for the plants at the top of the trees, so the beak grew longer in order to deal with the tougher seeds..
Creationist Reasoner (CR)	I would just explain it as God being the creator with infinite wisdom, and he designed and created every organism, down to most minute detail.
CR/INR Mixed Reasoning	But like I said, I don't believe in evolution. So I don't believe that they evolved because it takes too long. There are too many failures before they evolve into something that finally works, so I just reject that view. Um, my guess would be that there probably were larger beaked finches but there weren't as many of them and the small beaked ones would have died out because they couldn't get the food.

pattern. The fly, ant, diatom, and virus were more likely than the finch, human, and whale to invoke novice reasoning. The finch, human, and whale questions were more likely to elicit evolutionary reasoning than the other organisms, and the human was also more likely to elicit creationist reasoning. Creationist reasoners fell into two groups. One rejected most references to evolution and explained variation as part of God's plan ("built into the DNA"). The other group, which comprised the majority of the creationist reasoners in this sample, applied creationist reasoning primarily to one organism: Humans were created by God, even though the other organisms change over time.

In sum, this study suggests that museum visitors have some knowledge about evolution, but they often combine it with intuitive reasoning and less often, with creationist reasoning. The majority of visitors in this study accurately described at least one evolutionary mechanism for

one or more organisms. But in their other responses, most subjects (65%) displayed a very limited understanding of evolution. Visitors reasoning patterns differed depending on which organism they discussed. Evolutionary explanations were more common when discussing the Galápagos finches, while creationist responses were more common when discussing humans and chimps. Visitors' explanations also differed depending on their prior museum experience. Subjects who visited museums more often were more likely to use evolutionary terms in their responses ($p < .05$).

Discussion

> It's obvious that evolution exists. What do you tell people who say it doesn't?
> —Visitor's written comment at *Explore Evolution* Exhibition, October, 2005

In comparison with the general public, museum visitors are more likely to endorse evolution as the explanation of human origins (Squire & Hubbell Mackinney 1996; Stein & Storksdieck 2005). However, visitors are still more likely to endorse creationist origins for humans as opposed to non-human species. Moreover, the majority of museum visitors continue to hold misconceptions about evolution (Guisti 1994a) and most have difficulty accurately explaining fundamental evolutionary mechanisms, such natural selection, adaptation and variation (Evans et al. 2006; Borun 2002; Dunckel, et. al., 2005; People, Places and Design Research 1992).

Applying a conceptual framework to the study of visitors provides additional insight. Museum visitors appear to reason about evolution differently depending on the organism. Their level of interest in and understanding of the evolution of one type of organism does not necessarily transfer to other types, although the same biological principles apply. Museum visitors are not solely creationist, novice naturalistic, or evolutionary reasoners, but rather they combine elements of these different reasoning patterns depending on the situation.

Deciphering how visitors apply their reasoning patterns can help determine how best to scaffold visitor learning in an exhibit. Already, many museum visitors apply evolutionary principles to some organisms. This result suggests that museums may be able to play a role in shifting visitors' perspectives from novice naturalistic or creationist reasoning patterns to become more informed naturalistic reasoners. Additional visitor research

based on a coherent conceptual framework may eventually produce new principles of exhibit design and lead the way to a greater public understanding and acceptance of core evolutionary ideas.

References

Anderson, D. L., K. M. Fisher, & G. J. Norman. 2002. Development and evaluation of the conceptual inventory of natural selection. *Journal of Research of Science Teaching,* 39(10): 952–978.

Banet, E., and G. E. Ayuso. 2003. Teaching of biological inheritance and evolution of living beings in secondary school. *International Journal of Science Education* 25: 373–407.

Beardsley, P. M. 2004. Middle school student learning in evolution: Are current standards achievable? *The American Biology Teacher* 66(9): 604–613.

Bishop, B. A., & C. W. Anderson. 1990. Student conceptions of natural selection and its role in evolution. *Journal of Research in Science Teaching,* 27: 415–428.

Borun, M. 2002. *Being human: A design in process, four focus groups.* University of Pennsylvania Museum: Museum Solutions.

Brumby, M. 1979. Problems in learning the concept of natural selection. *Journal of Biological Education,* 13: 119–122.

Brumby, M. N. 1984. Misconceptions about the concept of natural selection by medical biology students. *Science Education,* 68(4): 493–503.

Carey, S. 1985. *Conceptual change in childhood*. Cambridge. MA: MIT Press.

Clough, E. E., & C. Wood-Robinson. 1985. How secondary students interpret instances of biological adaptation. *Journal of Biological Education,* 19: 125–130.

Diamond, J. (Ed.) 2005. *The Virus and the Whale: Exploring Evolution in Creatures Small and Large.* Arlington, VA: National Science Teachers Association (NSTA) Press.

Diamond, J., A. Spiegel, D. Meier, & S. Disbrow. 2004. The virus and the whale: Exploring evolution in a museum collaboration. *Proceedings of the Third Conference of the International Museum and Collections (UMAC):* 7–11.

Dunckel, B.A., S. Ellis, B. J. MacFadden, L. D. Dierking, L. Abraham-Silver, J. Kisiel, & J. Koke. September 2005. *Natural history museum visitors' understanding of evolution by natural selection: Florida Museum of Natural History Evolution Project Report.* Gainesville, FL: Florida Museum of Natural History, University of Florida.

Evans, E. M. 2000. The emergence of beliefs about the origins of species in school-age children. *Merrill-Palmer Quarterly,* 46(2): 221–254.

———. 2001. Cognitive and contextual factors in the emergence of diverse belief systems: Creation versus evolution. *Cognitive Psychology* 42: 217–266.

———. 2005. Teaching and learning about evolution. In *The Virus and the Whale:*

Exploring Evolution in Creatures Small and Large, Diamond, J. (Ed.) Arlington, VA: National Science Teachers Association (NSTA) Press.

Evans, E. M., K. S. Rosengren, K. Szymanowksi, & P. H. Smith. December 2005. *From metamorphosis to evolution: A developmental constraints perspective*. Division of Research, Evaluation, and Communication, Principal Investigators Annual Meeting, National Science Foundation, Washington, DC.

Evans, E. M., A. Spiegel, W. Gram, B. F. Frazier, S. Thompson, M. Tare, & J. Diamond. April, 2006. *A conceptual guide to museum visitors' understanding of evolution.* Paper presented at the Annual Meeting of the American Education Research Association, San Francisco.

Ferrari, M., & M. T. H. Chi. 1998. The nature of naive explanations of natural selection. *International Journal of Science Education,* 20(10): 1231–1256.

Gallup, A., & G. Gallup. 1999. *The Gallup Poll cumulative index: Public opinion 1935-1997.* Lanham, MD: SR Books.

Guisti, E. 1994a. *Summative evaluation of the Hall of Human Biology and Evolution. What can we learn from visitors.* New York, NY: American Museum of Natural History.

Guisti, E. 1994b. Visitors evaluate evolution hall. *Exhibitionist* (Fall 1994): 15–18.

Hayward, J., J. Hart, & E. Gyllenhaal. 1996. *Summative evaluation of the 'Life Over Time' exhibit at the Field Museum.* Northhampton, MA: People, Places and Design Research.

Keil, F. C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In *Mapping the mind: Domain specificity in cognition and culture,* L. A. Hirschfeld & S. A. Gelman (Eds.). Cambridge: CUP. 234–254.

Medin, D. L., & S. Atran. 2004. The native mind: Biological categorization and reasoning in development and across cultures. *Psychological Review* 111(4): 960-983.

National Science Board (2004). Science and Engineering Indicators 2004. (NSB-04-1). www.nsf.gov/statistics/seind04/toc.htm. Arlington, VA: National Science Foundation.

Newport, F. November 19, 2004. *Gallup Poll: Third of Americans say evidence has supported Darwin's evolution theory.* Princeton, NJ: Gallup Organization.

Pawlukiewicz, J. D., Z. Doering, & K. Paasch. May 1990. Views from the Audience: Planning a new exhibition on human evolution. *Current Trends in Audience Research and Evalution: Papers Presented at a Poster Session.* Washington, DC: AAM Visitor Research and Evaluation Committee.

People for the American Way. 2000. *Evolution and creationism in public education: An in-depth reading of public opinion: Results of a comprehensive, national survey.* www.pfaw.org/pfaw/general/default.aspz?oid=2095.

People, Places, and Design Research. 1992. *Life Over Time, Formative evaluation study #3: Visitors' understanding of scientific terms.* Northhampton, MA: People, Places, and Design Research.

Poling, D. A., and E. M. Evans. 2004a. Are dinosaurs the rule or the exception? Developing concepts of death and extinction. *Cognitive Development* 19: 363–383.

Poling, D. A., and E. M. Evans. 2004b. Religious belief, scientific expertise, and folk ecology. *Journal of Cognition and Culture: Studies in Cognitive Anthropology of Science* 4: 485–524.,

Rosengren, K. S., S. A. Gelman, C. W. Kalish, & M. McCormick. 1991. As time goes by: Children's early understanding of growth in animals. *Child Development* 62: 1302–1320.

Samarapungavan, A., & R. W. Wiers. 1997. Children's thoughts on the origin of species: A study of explanatory coherence. *Cognitive Science* 21: 147–177.

Settlage Jr., J. 1994. Conceptions of natural selection: A snapshot of the sense-making process. *Journal of Research in Science Teaching* 31: 449–457.

Squire, J., & L. Hubbell Mackinney. 1996. *Learning from Lucy: What visitors want to know about human evolution. An evaluation study of the Lucy skeleton in the "Creatures of the Ice Age" exhibit the California Academy of Sciences.* San Francisco, CA: California Academy of Sciences.

Stein, J. K., &M. Storksdieck. 2005. *Life changes museum visitor survey: Summary of results.* Annapolis, MD: Institute for Learning Innovation.

Wellman, H. M., & S. A. Gelman. 1998. Knowledge acquisition in foundational domains. In *Handbook of Child Psychology: Vol. 2. Cognition, Perception and Language. (5th ed.)* W. Damon, D. Kuhn & R. Siegler (Eds.). 523–574. New York: Wiley.

About the Authors

Amy N. Spiegel, Ph.D., is an evaluator and a Research Associate Professor at the Center for Instructional Innovation, University of Nebraska-Lincoln.

E. Margaret Evans, Ph.D., is a developmental psychologist at the Center for Human Growth and Development, University of Michigan.

Wendy Gram is Head of Education at the University of Oklahoma (OU) Sam Noble Oklahoma Museum of Natural History and an Adjunct Assistant Professor in the OU Department of Zoology.

Judy Diamond, Ph.D., is Professor and Curator at the University of Nebraska State Museum, the creator of the *Explore Evolution* project, and the author of a book about the evolution of behavior in parrots.