Life Changes Summative Evaluation

February, 2011

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New York Hall of Science

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Executive Summary

Life Changes: Communicating pre-evolutionary concepts to young children in informal settings is an education and research effort designed to address the lack of basic understanding of the biology of evolution and the challenges to teaching this complex content in both formal and informal learning environments. Exhibit designers from the New York Hall of Science, Miami Science Museum, and North Museum of Natural History & Science worked closely with researchers from the University of Michigan to devise an educational intervention that could meet this critical public science need. This project explored how educational principles can be extracted from theory and applied to exhibit development. Informed by research in developmental and cognitive psychology on how children reason about biological change and evolution, the project team identified a set of educational principles that could support children's developing understanding of pre-evolutionary concepts. Exhibit components were designed to introduce pre-evolutionary concepts that included: variation, inheritance, selection, time, and adaptation (VISTA). Informed by these concepts, the *Life Changes* team developed *Charlie and Kiwi's Evolutionary Adventure*—a research-based 1000sf traveling exhibition that functions as an educational intervention for informal learning settings.

The summative evaluation explored the degree to which a one-time family visit to an exhibition is capable of influencing children's reasoning about biological change—defined in this context as pre-evolutionary VISTA concepts. The evaluation investigated whether informal settings can help young children develop the reasoning skills and a sufficient understanding of pre-evolutionary concepts to prepare them for learning about evolution. The development process and the exhibition product have provided a much needed opportunity to test basic research principles about how people reason and make sense of the world. In additional, this project also tested the power and limits of learning from museums. It asked what we can reasonably expect visitors to learn from a museum experience, and whether museum experiences can be used to develop or adjust mental models of biological change. The summative evaluation was conducted at the New York Hall of Science (NySci) and the Miami Science Museum (MiaSci). Three data collection approaches were utilized: Timing and tracking, child interviews, and parent surveys. The key findings from each are summarized below.

Timing & Tracking

Timing and tracking established the level of engagement of children and families ages 5 to 12 in the exhibition as well as providing important information about the use of the exhibition in different configurations. A total of 80 un-cued timing and tracking cases were collected.

Exhibit success: There were two exhibits that were consistently most successful at capturing and holding visitor attention, and engaging interest: the Fossil Dig and Honeycreeper Puzzle. Both of these exhibits were hands-on activities that could support multiple simultaneous users. This provided opportunities for interaction within family groups and between unrelated visitors. This added social facilitation may have supported the increased number of visitor stops, time invested, and level engagement.

Differences by age: Data were analyzed by age, comparing younger (5-8 yrs old) and older (9-12 yrs old) children to see if there were differences in use of the exhibits, time spent and engagement levels. While there was a statistically significant difference in overall time spent in the exhibition, there were no differences comparing which exhibits children stopped at, and no differences comparing how long they stayed when they did stop. This suggested that while younger children stay longer, the two age groups were equally attracted to exhibits, and distributed their time in similar ways during their visits.

Child Interviews

Child Interviews were designed to measure the effect of the exhibition on visitors between the ages of 5 and 12 engaged in a short educational intervention. The design used unmatched pre and post tests with the experience of the exhibition as a treatment. Participants included one-time family visitors at NySci and MiaSci. A total of 174 child interviews were collected.

Understanding evolutionary relationships: Child interviews explored participants' recognition of the evolutionary relationships between animals. Participants were asked to identify an image of an *Archyopteryx* fossil and describe how this provides evidence of a relationship between dinosaurs and birds. Analysis revealed a significant difference between pre test and post test responses. On the post test, 64% of responses identified salient features of dinosaurs and birds that were present in the fossil image, compared to 28% of the pre-test responses (X^2=4.72, p<.05).

In addition, analysis revealed a significant difference between pretest and post test responses to a question about the origin of the first birds. On the post test, 57% of responses provided evolutionary explanations for the origins of birds as compared to only 29% of pretest responses (X^2=4.38, p<.05). The largest percentage of responses indicated that birds evolved from other animals 32%.

Understanding evolutionary concepts: One of the areas that the child interviews investigated was participants' level of understanding of evolutionary concepts. Children's open ended responses to a question about natural selection were coded for the inclusion of pre-evolutionary concepts including variation, inheritance, selection, time, and adaptation (VISTA). Differences between pre and post test responses did not reveal significant changes in level of understandings, however, an analysis of age groups revealed that older participants produced significantly more responses focused on adaptation (58%) compared to younger participants' responses (32%) (X^2=11.45, p<.001).

Parent Surveys

Parent surveys were designed to measure demographics, patterns of museum visitation, visitor agendas, and level of agreement with the theory of evolution. Parents of the children who participated in child interviews completed the survey. A total of 168 parent surveys were collected.

Beliefs about evolution: Respondent rating of *how important is religion in your life* was negatively correlated with ratings of all other belief items. This suggests that those who rated religion as having more importance in their lives subsequently rated evolution as being less compatible with their beliefs. For these visitors, the theory of evolution is less likely to explain the origin of insects, birds, and humans, or that birds evolved from dinosaurs. Conversely, parents that rated religion as having less importance in their lives rated evolution as being more compatible with their beliefs. For these visitors, there were significant positive correlations between belief statements regarding the origins of insects, birds, and humans and the belief that birds evolved from dinosaurs.

Evolutionary relationships*:* Adults who participated in the parent survey demonstrated a relatively sophisticated understanding the relationship between dinosaurs and birds. Responses to the question "*Do you think birds evolved from dinosaurs? (Scale 1-5)* revealed no statistically significant difference on the rating, pre- versus post-test. The majority (approximately 66%) of visitors agreed with this statement in both pre and post samples.

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Introduction

Life Changes: Communicating pre-evolutionary concepts to young children in informal settings is an important education and research effort to address the growing concerns in US science education of the lack of basic understanding of the biology of evolution (Lerner, 2000). This project provided an opportunity to explore how educational principles can be extracted from theory and applied to exhibits and other educational interventions. Informed by research in developmental and cognitive psychology on how children reason about biological change and evolution, the project team identified a set of educational principles that could support children's developing understanding of pre-evolutionary concepts. These educational principles were tested extensively and translated into *Charlie and Kiwi's Evolutionary Adventure,* a 1000sf traveling exhibition. Exhibit components were designed to introduce pre-evolutionary concepts that included: variation, inheritance, selection, time, and adaptation (VISTA). The research question at the core of this project was: *Can an informal, museum-based intervention effectively introduce pre-evolutionary concepts to children in a way that prepares them to understand the scientific concepts that support evolutionary theory?*

The summative evaluation was designed to ascertain the degree to which this application of research to practice was successful. Evaluation procedures investigated whether a one-time family experience in the exhibit environment was capable of affecting children's reasoning about biological change as defined by VISTA concepts. The combined evaluation and research efforts supported by this project tested the power and limits of learning from museums by asking what we can reasonably expect visitors to learn from a museum visit and whether museum experiences can be used to cultivate mental models of complex scientific concepts like biological change over time.

Summative evaluation procedures were designed to explore the following questions:

- How do family visitors typically experience the exhibition?
- Is the educational intervention of sufficient quality to achieve the stated goals?
- Are learning outcomes achieved for children ages 5 to 12 who experienced *Charlie & Kiwi's Evolutionary Adventure* as part of a family visit to New York Hall of Science (NySci) and Miami Science Museum (MiaSci)?
- In what ways does the exhibition align with visitor agendas?

Methods

The target audience for this exhibition was family visitors with children between the ages of five and twelve years old. This population was chosen to align with previous research on children's misconceptions about biological change and educational interventions that have been designed to support the development of understanding pre-evolutionary concepts in informal education contexts (Diamond & Evans, 2007; Evans, 2001; Evans, 2008; Evans, Spiegel, Gram, & Diamond, 2009). Three approaches were used to measure visitor experience and outcomes at NySci and MiaSci: Timing and tracking observations; Child interviews collected before and after experiencing the exhibition; Parent surveys. See table A for a summary of data collected by location.

Timing and tracking:

Timing and tracking established the level of engagement of children and families in the exhibition as well as providing important information about the use of the exhibition in different configurations. Timing and tracking data was collected independent of the child interview and parent survey data. Visitors were selected randomly as they entered the exhibition and were unobtrusively observed until they exited. Observation measures included: total time spent in the exhibition, which exhibits were visited, time spent at each exhibit, and level of engagement at each exhibit. Pathways through the exhibit were also captured. Timing and tracking data was collected on weekends at the beginning of each data collection period. A total of 80 timing and tracking cases were collected: 50 family groups at NySci and 30 family groups at MiaSci in November and early December, 2009. The Instrument is included in appendix 1.

Child interviews:

Child interviews measured the effect of a one-time visit to the exhibition (short educational intervention) on children's level of understanding of pre-evolutionary concepts. The design was an unmatched pre and post interview with the experience of the exhibition as a treatment. Participants were recruited from family visitors at NySci and MiaSci. The final instrument was developed in collaboration with University of Michigan (UM) researchers led by Dr. Margaret Evans. The research and evaluation teams decided against a traditional matched pre/post design because the detailed assessment procedure used by Evans and adapted by ILI would cue children too strongly and provide an experience that might influence behavior in the exhibition and subsequent learning outcomes. Family visitors with at least one child in the target age group of 5-12 were randomly assigned pre or post status and approached for interviews on the periphery of the exhibition. The sample was monitored for demographics and adapted (when visiting population allowed) from random to stratified sampling to ensure that both age groups (5-8 and 9-12 years old) were represented. Cognitive measures for the summative evaluation were supplemented by open-ended and Likert-like questions focused on benefits derived from the exhibition visit, enjoyment, and visitor agenda or expectations.

Child interviews were conducted at tables at the edges of the exhibition. In each location there were two to three tables for researchers to sit with child visitors and their parents. Interviews were conducted using images in a binder to illustrate questions and all were digitally recorded. The majority of interviews were conducted on weekends when visitation numbers were higher, however, when possible weekday afternoons were also used for data collection. A total of 174 child interviews were collected. The interview Instrument is included in appendix 2.

Parent Surveys:

Parent surveys were designed to measure demographics, patterns of museum visitation, visitor agendas, and level of agreement with the theory of evolution. Parents of the children who participated in child interviews completed the parent surveys. This short, paper based instrument was a combination of open ended questions and belief statements associated with agreement rating scales. The survey required approximately 10 minutes to complete. A total of 168 parent surveys were collected. The parent survey Instrument is included in appendix 3.

Table A: Summary of sample data by location

	NySci	MiaSci	Total
Timing and Tracking	50	30	80
Child Interviews	128	46	174
Parent Surveys[1]	122	46	168

Exhibition context and implementation

The installation of *Charlie and Kiwi's Evolutionary Adventure* at NySci and MiaSci reflected the opportunities and constraints defined by the gallery space and staff at each institution (see appendix X for floor plans). The majority of exhibition components were identical (see below for exceptions), however differences in crowd levels, component placement, and frequency of staff facilitation may have had an impact on visitor experience and outcomes.

Additional components in Miami:

The MiaSci installation featured three cases with models of early birds and dinosaurs with feathers that were placed on the edge of the exhibition space and acted as an added visual attractor for *Charlie & Kiwi's Evolutionary Adventure.* The cases and the reproductions were labeled in a font and style consistent with the rest of the exhibition. In the report these are referred to as "Cases (Miami only)" and are listed at the bottom of tables comparing the two locations. In addition, project team members at MiaSci developed the "Kiwi Box". This table top activity housed a kiwi bird skeleton mounted in a clear box with a rotating platform. Labeled information panels could be lifted to reveal the three bones shared in both dinosaurs and birds.

Crowd level:

There was a significant difference in crowd levels present during data collection. This may be explained by a combination of the average daily visitation at the two sites as well as when the timing and tracking occurred. New York data were gathered in August, 2009 while Miami data were gathered in November, 2009. In New York, 44% of the observations occurred when the exhibition was at least moderately crowded while in Miami, only 17% were collected with similar crowd levels. Moderate crowd levels are defined as approximately half of the exhibits in the traveling exhibition area being used by visitor(s). Likewise, only 10% of the tracked cases in New York had an empty exhibition, while this was the case for 57% of the cases in Miami. Empty crowd levels are defined as less than two visitors in the traveling exhibition area in addition to the group being observed. Seasonal differences may have also contributed to visit group variations consistent with institutional visitation patterns.

Discovery boxes:

The exhibition included one Discovery Box storage table as well as two tables to be used to explore discovery box activities. These three tables were used differently at each of the museums. At NySci one of the discovery tables had books about evolution on it while the second

[1] Parent surveys were collected for each child interview, however, 4 were discarded from the sample as a result of incomplete data (due to language challenges), or because they were completed by a person other than a parent (e.g. grandparent).

table had two discovery box activities displayed on the surface that were occasionally changed. In contrast, at MiaSci books were never observed as a feature of the exhibition, one of the tables was dedicated to the Kiwi Box, and the remaining table featured rotating activities.

Exhibition Staffing:

During weekday afternoons and on weekends at NySci discovery boxes were facilitated by teen explainers who presented activities to visitors on the larger Discovery Box Storage table. Throughout summative data collection teen explainers were present in the exhibition facilitating the discovery box experience, resetting puzzles when they had been completed, and answering questions about exhibit elements. During summative data collection at MiaSci, facilitation of the discovery boxes by staff occurred approximately 1 to 2 hours per day.

Findings

Timing and Tracking

A total of 80 un-cued timing and tracking cases were conducted: 50 in New York and 30 in Miami. Only those ages 5 to 12 were included in the sample. To record visitor behavior in the exhibition, visitors' paths and the amount of time they spent at specific exhibit components was recorded by the observer. The observation started when they entered the space and concluded when they left the space. The next group that included a child between the ages of 5 to 12 was selected for participation. The groups were observed unobtrusively.

Characteristics of the sample

Age: Only visitors between the ages of 5 and 12 were observed for the summative timing and tracking study. Age was estimated and not asked of visitors. Two age groups were created: younger (ages 5 to 8) and older (ages 9 to 12). Overall there were 55% in the younger category and 45% in the older category. In New York there were 58% in the younger group and 42% in the older group. In Miami there were 47% in the younger group and 52% in the older group. There were no statistically significant differences in the children's age between locations (see appendix 4, table 1).

Gender: Overall the sample included 56% males and 44% females. In New York gender was evenly split (50% male, 50% female) while in Miami the sample included more males (67%) than females (33%). There were no statistically significant differences in gender between locations (see appendix 4, table 2)

Race/ ethnicity: Since the timing and tracking was done unobtrusively and the groups were not interviewed, race/ethnicity was estimated by the observer. It is understood that there are issues with the accuracy of estimating race/ethnicity, including the fact that it cannot capture multiple ethnicities. This should be taken into account when interpreting the findings. Overall, the tracking sample appeared to include Caucasian visitors (41%) as the largest single group. This was followed by Hispanic (29%), African American (14%), Asian (11%) and Middle Eastern (4%). However, there was a statistically significant difference in the perceived racial/ethnic breakdown in comparing the two locations. In New York the majority of visitors in the sample appeared to be Caucasian (50%, n=25) while in Miami the majority of visitors appeared to be Hispanic/Latino (57%, n=17) (see appendix 4, table 3).

Crowd Level : Crowd level was separated into 4 categories: empty, sparse, moderately crowded and very crowded. The crowd level categories were defined as follows: empty meant that there were fewer than two other visitors in the space, sparse meant that there were between three to ten people in the exhibit only occupying a few exhibit components, moderately crowded meant that approximately half of the exhibit elements were occupied and very crowded meant that nearly all of the exhibit elements were occupied. For purposes of analysis these were then collapsed into less crowded (empty and sparse) and more crowded (moderately crowded and very crowded). Overall the exhibition space was less crowded (66%, n=52) rather than more crowded (36%, n=28) when data were being collected. This was likely the result of the time of year during which data were collected. In New York the exhibition was more evenly distributed in terms of crowd level with the space being less crowded (54%, n=27) slightly more than more crowded (48%, n=23). In Miami the majority if observations were conducted when the space was considered to be essentially empty (57%, n=17) (see appendix 4, table 4).

Visitor Behavior explored by location

In looking at the time groups spent in the exhibition the median time overall was slightly more than three minutes, with times ranging from 9 seconds to 1 hour, 7 minutes. While the median time was slightly higher in Miami, there was not a statistically significant difference in comparing time at the two locations.

Table B: Summary of time spent in exhibition by location[2]

	Overall (n=80)	NySci (n=50)	MiaSci(n=30)
Median time spent (min:sec)	3:01	2:45	3:05
Mean time spent (min:sec)	7:47	8:22	6:49
Standard Deviation (min:sec)	11:34	12:39	9:38
Range – low (hr:min:sec) Range – high (hr:min:sec)	0:00:09 to 1:07:00	0:00:09 to 1:07:00	0:00:21 to 0:42:22

Percentage of Visitors Stopping at Each Exhibit

Overall the Fossil Dig exhibit was stopped at the most (69%) followed by the Live Budgies (55%), the Homologous Features Comparison (33%), the Honeycreeper Puzzle (31%), the Homologies Puzzle (26%), Discovery Boxes (25%) and Story Theater/Video (25%). The exhibits that were stopped at the least were the Life Size Charlie cutouts (1%), the Intro Panel (3%), the Theater Title Panel (4%), which were all title panels or non-exhibit display (See table C).

[2] Both means and medians are reported in this table. Means are most appropriate when you have a standard distribution, with few or no outliers. Medians are more appropriate when the distribution is not standard. Since the times for this study were not a normal distribution and the sample size was modest, medians are the most accurate measure of central tendency (e.g., mean, median, mode).

The location, NySci or MiaSci, had very little impact on the proportion of visitors stopping at each of the elements. The exceptions were the Homologies Puzzle (18% NY, 40% Miami) and the Discovery Table 2 (26% NY, 3% Miami). It is possible that the orientation of the homologies puzzle in NY (facing into the exhibition and directly across from the live budgies) accounted for the reduced percentage of stops made by visitors in NY. The increased number of stops at Discovery Table 2 in NY may be the result of explainers being present in the exhibition and generally facilitating engagement with the table top activities.

Table C: Percentage stopping at each exhibit

Rank	Exhibit	Overall	NySci	MiaSci
1	Fossil Dig	69% (n=55)	66% (n=33)	73% (n=22)
2	Live Budgies	55% (n=44)	60% (n=30)	47% (n=14)
3	Homologous Features Comparison	33% (n=26)	32% (n=16)	30% (n=10)
4	Honeycreeper Puzzle	31% (n=25)	26% (n=13)	40% (n=12)
5	Homologies Puzzle *	26% (n=21)	18% (n=9)	40% (n=12)
6	Discovery Boxes	25% (n=20)	32% (n=16)	13% (n=4)
6	Story Theater/Video	25% (n=20)	26% (n=13)	23% (n=7)
8	Natural Selection Computer Interactive	21% (n=17)	18% (n=9)	27% (n=8)
9	Dino to Bird Computer Interactive	20% (n=16)	16% (n=8)	27% (n=8)
9	How Evolution Works Panel	20% (n=16)	14% (n=7)	30% (n=9)
11	Kiwi Vignette	19% (n=15)	20% (n=10)	17% (n=5)
12	Discovery Table 2 *	18% (n=14)	26% (n=13)	3% (n=1)
13	Discovery Table 1	13% (n=10)	8% (n=4)	20% (n=6)
14	Theater Title Panel	4% (n=3)	2% (n=1)	7% (n=2)
15	Entry/Intro Panel	3% (n=2)	4% (n=2)	0% (n=0)
16	Life Size Charlie	1% (n=1)	2% (n=1)	0% (n=0)
	Cases (Miami only)	N/A	N/A	43% (n=13)

* Statistically significant difference between locations (NY or Miami)

Of the top 5 exhibits stopped at for each location, four were the same in both New York and Miami: Fossil Dig, Live Budgies, Honeycreeper Puzzle and the Homologous Features Comparison. This pattern of engagement is consistent with expectations that hands-on activities would attract larger percentages of visitors. Of the bottom 5 exhibits stopped at three were the same in New York and Miami: they were all text panel exhibits including the Intro Panel, Life Size Charlie cutouts and the Theater Title panel.

Median Time Spent at each Exhibit

Overall visitors spent the <u>most</u> <u>time</u> at the Story Theater/Video (3:12) followed by the Natural Selection Computer Interactive (2:23), the Discovery Boxes (1:23), the Honeycreeper Puzzle (1:12), and the Fossil Dig (0:58). This pattern of visitor time investment is encouraging as these components include some of the most conceptually rich learning experiences in the exhibition. Overall visitors spent the <u>least</u> <u>time</u> at the Theater Title Panel (0:09), the Life-size Charlie Cut-outs (0:09), the Intro Panel (0:10), and the Kiwi Vignette (0:10). There were no statistically significant differences between the two locations when comparing the amount of time visitors spent at each exhibit component.

Table D: Median time spent at each exhibit, only those who stopped

Rank	Exhibit	Overall (n=80)	NySci (n=50)	MiaSci (n=30)
1	Story Theater/Video	3:12 (n=19)	4:44 (n=12)	0:38 (n=7)
2	Natural Selection Computer Interactive	2:23 (n=16)	1:30 (n=9)	2:38 (n=7)
3	Discovery Boxes	1:23 (n=18)	2:17 (n=15)	0:04 (n=3)
4	Honeycreeper Puzzle	1:12 (n=22)	1:16 (n=13)	1:03 (n=9)
5	Fossil Dig	0:58 (n=47)	0:58 (n=32)	1:10 (n=15)
6	Dino to Bird Computer Interactive	0:37 (n=12)	0:39 (n=7)	0:35 (n=5)
7	Homologies Puzzle	0:21 (n=10)	0:30 (n=9)	0:16 (n=10)
8	Discovery Table 2	0:20 (n=12)	0:20 (n=12)	0:00 (n=0)
9	Live Budgies	0:18 (n=40)	0:21 (n=29)	0:15 (n=11)
9	Homologous Features Comparison	0:18 (n=24)	0:13 (n=15)	0:22 (n=9)
9	Discovery Table 1	0:18 (n=7)	0:30 (n=4)	0:18 (n=3)
12	How Evolution Works Panel	0:16 (n=13)	0:13 (n=7)	0:24 (n=6)
13	Kiwi Vignette	0:10 (n=14)	0:13 (n=9)	0:07 (n=5)
13	Entry/Intro Panel	0:10 (n=2)	0:10 (n=2)	0:00 (n=0)
15	Life Size Charlie	0:09 (n=1)	0:09 (n=1)	0:00 (n=0)
16	Theater Title Panel	0:09 (n=3)	0:09 (n=1)	0:07 (n=2)
	Cases (Miami only)	N/A	N/A	0:38 (n=13)

NOTE: Three MiaSci elements did not have people stop at them. There is no median time to report.

Mean Engagement Level at each Exhibit

Engagement levels were recorded on a four point scale and defined as:
1 = Visitor spends 3 seconds or less looking at an exhibit element
2 = Visitor spends 3 seconds or more looking at exhibit element, might touch something, but does not "do" activity
3 = Visitor does activity, is moderately engaged but does not complete everything or spend a long time at the element
4 = Visitor does whole activity, reads labels, spends an extended length of time

Overall engagement was observed the highest at the Fossil Dig (3.0) and the Story Theater/Video (3.0), followed by the Honeycreeper Puzzle (2.9). These top three were closely followed by the Dino to Bird Computer Interactive, Natural Selection Computer Interactive (each 2.8), and the Discovery Boxes (2.8). The lowest engagement overall was observed at the Entry/Intro Panel (1.5), the Life-Size Charlie Cut-outs (2.0), Theater Title Panel (2.0) and Kiwi Vignette (2.2). The most popular components tended to be hands-on or computer interactive elements, while the least popular tended to be static, text-based displays. This is consistent with findings from other timing and tracking studies. None of the differences comparing NySci to MiaSci were statistically significant.

Table E. Mean engagement level at each exhibit

Rank	Exhibit	Overall (n=80)	NySci (n=50)	MiaSci (n=30)
1	Fossil Dig	3.0	3.1	2.9
1	Story Theater/Video	3.0	3.2	2.6
3	Honeycreeper Puzzle	2.9	2.9	2.8
4	Dino to Bird Computer Interactive	2.8	2.9	2.7
4	Natural Selection Computer Interactive	2.8	2.8	2.8
4	Discovery Boxes	2.8	2.9	2.5
7	Live Budgies	2.6	2.6	2.5
7	How Evolution Works Panel	2.6	2.3	2.9
9	Homologies Puzzle	2.5	2.3	2.6
9	Discovery Table 1	2.5	2.5	2.5
11	Homologous Features Comparison	2.4	2.5	2.3
11	Discovery Table 2	2.4	2.4	---
13	Kiwi Vignette	2.2	2.3	2.1
14	Theater Title Panel	2.0	2.0	2.0
14	Life Size Charlie	2.0	2.0	---
16	Entry/Intro Panel	1.5	1.5	---
	Cases (Miami only)	N/A	N/A	43% (n=13)

NOTES: None of the comparisons yielded statistically significant differences. ; Three MiaSci elements did not have people stop at them. There are no mean engagement levels.

Top Exhibits in each Category and Bottom Exhibits in each Category

When examining the overall success of each exhibit, related to how many visitors stopped, time spent and engagement level, two rose to the top, in both locations: the Fossil Dig and Honeycreeper Puzzle. Both of these exhibits were hands-on activities that could support multiple simultaneous use—providing opportunities for interaction within family groups and between unrelated visitors. This added social facilitation may have supported increased visitor stops, time invested, and level of engagement. When looking at the same variables, there was one exhibit that tended to rate lowest across these measures—the Theater Title Panel—which is a static, non-interactive exhibit.

Visitor Behavior explored by age

Data were also analyzed by age, comparing younger (5-8 yrs old) and older (9-12 yrs old) children to see if there were differences in use of the exhibits, time spent and engagement levels. While there was a statistically significant difference in overall time spent in the exhibition, there were no differences comparing which exhibits children stopped at, and no differences comparing how long they stayed when they did stop. There was only one exhibit where the average level of engagement was different. This suggest that while younger children stay longer, the two groups seems to be rather equally attracted to the various exhibits, and do not differ much in terms of how they distribute their time in the exhibition.

Median Time Spent in Exhibition

When looking at median time spent, younger visitors tended to spend more time in the exhibition overall (8:39) compared to older visitors (5:00). One cannot run a statistical comparison on medians, so a comparison (t-test) was run comparing the mean time spent in the exhibition by younger (13:42) and older (7:45) children. This difference was statistically significant $p<.05$. There is evidence that younger children spend more time in the exhibition than older children.

Percentage Stopping at Each Exhibit

There were no statistically significant differences in the percentage of children stopping at the specific elements, when comparing younger and older children. While this does not address whether or not the experiences at the specific elements are different, it suggests that younger and older children within the target age group are attracted equally to the various elements.

Table F: Percentage stopping at each exhibit, by age

Rank	Exhibit	5 to 12 years (n=80)	5 to 8 years (n=43)	9 to 12 years (n=37)
1	Fossil Dig	69% (n=55)	63% (n=27)	76% (n=28)
2	Live Budgies	55% (n=44	60% (n=26)	49% (n=18)
3	Homologous Features Comp	33% (n=26)	37% (n=16)	27% (n=10)
4	Honeycreeper Puzzle	31% (n=25)	37% (n=16)	24% (n=9)
5	Homologies Puzzle	26% (n=21)	28% (n=12)	24% (n=9)
6	Discovery Boxes	25% (n=20)	23%(n=10)	27% (n=10)
6	Story Theater/Video	25% (n=20)	30% (n=13)	19% (n=7)
8	Natural Selection Interactive	21% (n=17)	28% (n=12)	14% (n=5)
9	Dino to Bird Interactive	20% (n=16)	19% (n=8)	22% (n=8)
9	How Evolution Works Panel	20% (n=16)	19% (n=8)	22% (n=8)
11	Kiwi Vignette	19% (n=15)	21% (n=9)	16% (n=6)
12	Discovery Table	18% (n=14)	19% (n=8)	16% (n=6)
13	Discovery Table 1	13% (n=10)	14% (n=6)	11% (n=4)
14	Theater Title Panel	4% (n=3)	0% (n=0)	8% (n=3)
15	Entry/Intro Panel	3% (n=2)	5% (n=2)	0% (n=0)
16	Life Size Charlie	1% (n=1)	2% (n=1)	0% (n=0)
	Cases (Miami only)	38% (n=14)	14% (n=6)	22% (n=8)

Mean Time Spent at Each Exhibit

While younger visitors spent more time at nearly all exhibits compared to the older visitors, none of these differences were statistically significant.

Table G: Mean time spent at each exhibit, by age

Rank	Exhibit	5 to 12 years (n=80)	5 to 8 years (n=43)	9 to12 years (n=37)
1	Story Theater/Video	6:19	7:52	3:40
2	Discovery Boxes	3:18	4:40	1:36
3	Natural Selection Interactive	2:36	2:53	1:55
4	Fossil Dig	1:26	1:59	0:57
5	Honeycreeper Puzzle	1:40	1:48	1:26
6	Dino to Bird Interactive	1:03	1:11	0:56
7	Discovery Table 2	0:52	1:15	0:29
8	Discovery Table 1	0:51	1:18	0:12
9	Live Budgies	0:34	0:38	0:29
10	Kiwi Vignette	0:26	0:17	0:35
11	Homologous Features Comp	0:31	0:22	0:44
12	How Evolution Works Panel	0:23	0:28	0:17
13	Homologies Puzzle	0:36	0:39	0:35
14	Entry/Intro Panel	0:11	0:11	N/A
15	Life Size Charlie	0:09	0:09	N/A
15	Theater Title Panel	0:08	N/A	0:08
	Cases (Miami only)	0:37	0:52	0:23

Mean Engagement Level at Each Exhibit, by Age

While there were differences in mean level of engagement based on age, only one element yielded a statistically significant difference. At the Cases in Miami (they were not included in New York); younger children had a higher average level of engagement.

Table H: Engagement level at each exhibit, by age

Rank	Exhibit	5 to 12 years (n=80)	5 to 8 years (n=43)	9 to 12 years (n=37)
1	Story Theater/Video	3.0	3.2	2.8
1	Fossil Dig	3.0	3.0	3.0
3	Honeycreeper Puzzle	2.9	2.9	2.7
4	Discovery Boxes	2.8	3.0	2.6
4	Dino to Bird Computer Interactive	2.8	2.8	2.8
4	Natural Selection Interactive	2.8	2.7	2.9
7	How Evolution Works Panel	2.6	2.8	2.4
7	Live Budgies	2.6	2.6	2.5
9	Homologies Puzzle	2.5	2.3	2.8
10	Discovery Table 1	2.4	2.4	2.7
10	Homologous Features Comparison	2.4	2.3	2.5
10	Discovery Table 2	2.4	2.4	2.3
11	Kiwi Vignette	2.2	2.2	2.3

12	Theater Title Panel	2.0	N/A	2.0
12	Life Size Charlie	2.0	2.0	N/A
13	Entry/Intro Panel	1.5	1.5	N/A
	Cases (Miami only) *	2.6	2.8	2.3

* Statistically significant difference

The younger age group stopped at approximately a third more exhibits than the older age group, spent more time at every exhibit save for one and had higher levels of engagement at over two-thirds of the exhibits.

Child Interviews

Child interviews explored the effect of a one-time visit to the exhibition in the context of a casual family museum experience. The study design was an unmatched pre and post interview with the experience of the exhibition as a treatment or educational intervention. Cognitive measures for the summative evaluation were supplemented by open-ended and Likert-like questions focused on benefits derived from the exhibition visit, level of enjoyment, and visitor agenda or expectations. The average length of the child interview was approximately 10 minutes (NySci: M=10 minutes, 43 seconds and MiaSci: 9 minutes, 58 seconds).

Characteristics of the sample

All participants were family visitors at NySci and MiaSci. A total of 174 child interviews were collected: 128 at NySci and 46 at Miami. Approximately half of the participants completed pre test interviews (n= 82) and post test interviews (n=91). Table I summarizes the distribution of pre and post test interviews by location.

Table I: Summary of collected pre and post-test interviews

	Location of interview					
	NySci		**MiaSci**		**Total**	
	n	%	N	%	n	%
Pre	62	49	20	43	82	47
Post	65	51	26	57	91	53
Total	127	100	46	100	173	100

Participants were children between the ages of 5 and 12. For the purpose of analysis, two age groups were created: younger (ages 5 to 8) and older (ages 9 to 12). Overall there were 54% in the younger category and 46% in the older category. In New York there were 52% in the younger group and 48% in the older group. In Miami there were 61% in the younger group and 39% in the older group. There were no statistically significant differences in the children's age between locations. Table J summarizes the distribution of children's ages by location. Overall the sample included 49% males and 51% females. In New York gender was evenly split (50% male, 50% female) while in Miami the sample included fewer males (46%) than females (54%). There were no statistically significant differences in gender between locations (see appendix 4, table 5).

Table J: Summary of age by location

	Location of interview					
	NySci		**MiaSci**		**Total**	
Ages	n	%	N	%	n	%
5-8	66	52	28	61	94	54
9-14	61	48	18	39	79	46
Total	127	100	46	100	173	100

Item Analysis

The child interview instrument was a combination of agreement scales and open-ended questions designed to measure the level of evolutionary understanding of child visitors. These questions were adapted from an instrument developed by University of Michigan researchers for a simultaneous research project (Evans personal communication). The decision to share a subset of items across research and evaluation instruments will allow us to potentially pursue additional analyses across data sets in subsequent publications and presentations. Post test interviews also included items that explored exhibition expectations, enjoyment, and levels of engagement. Analysis indicated that there were no differences between the patterns of responses observed at NySci and MiaSci, therefore, data were collapsed across location. Results are presented in two sections: cognitive items and affective/engagement items.

Cognitive Items: These items were designed to explore participants' level of understanding of evolutionary concepts. For several items of these items, the interviewer presented a short story and participants used a rating scale to indicate level of agreement or disagreement with a set of statements. The rating scale was a 1 to 5 instrument grounded by images of faces that reflected levels of disagreement and agreement. For some items rating scales were paired with open-ended questions that addressed the target concept from the story (full instrument, appendix 2).

Inheritance—One of the evolutionary concepts the child interview explored was inheritance. After hearing a short story about two dogs with a family of offspring, participants were shown five pictures of adult animals and asked whether each of the pictured animals could be the offspring of the two parents. The majority of participants demonstrated a basic understanding of the concept of inheritance. Approximately 85% correctly agreed that a yellow lab could be an offspring, 77% that a black lab could be an offspring, and 99% correctly disagreed that a black bear could be an offspring of the two dogs. In addition, the majority correctly answered the more challenging cases—66% disagreed that the rust colored dog could be an offspring and 52% disagreed that the Dalmatian could be an offspring. However, children expressed the most uncertainly about the Dalmatian which suggested that their understanding of inheritance may be based on similarity of surface features, in this case fur color.

There were no significant differences between responses collected on pre test or post test. However, analysis indicated that younger children (M=2.86, SD=1.58) were significantly more likely than older children (M=2.38, SD=1.29) to agree that the Dalmatian could be an offspring of the parents (t_{171}=2.17, p=.03). See appendix D, table 6 for additional means and standard deviations. The absence of pre-post change for the concept of inheritance may be related to the limited opportunities to engage specifically with this concept in the exhibition. While inheritance was an embedded concept in both the natural selection interactive and the storybook theater, participants may not have focused sufficient attention on this aspect of the process to support the transfer of understanding from the dinosaur and bird examples to the dog case presented during the interview. In addition, inheritance was addressed in detail in Discovery Box activities however these experiences were under utilized by the majority of visitors.

Natural Selection—A story about guppies was used to illustrate the process of natural selection. Responses were coded for the presence of components of evolutionary concepts including variation, inheritance, selection, time, and adaptation (VISTA). Coding of the total number of open ended responses to the question "Why were there so many plain colored guppies" revealed that 44% of participants provided explanations consistent with the concept of adaptation. The majority of these adaptive answers focused on the differential survival of the plain colored fish (e.g. the bigger fish ate all the colored ones, so only the plain ones were left). Descriptions of variation among the fish accounted for 15% of explanations (e.g. there were bigger ones and smaller ones) while ideas about inheritance accounted for 13% (e.g. maybe the plain ones had more babies so there were more of them). Ideas about intentional change accounted for 10% of responses (e.g. they needed to be less colorful to hide from the big fish), change caused by an external agent for another 6% (e.g. God or "they" wanted there to be more plain ones). The remaining 11% of responses were coded as uninformative (e.g. I don't know or off topic). This pattern of responses suggested that language focused on adaptation may have been more accessible to participants and may be one of the more easily understood components of natural selection.

No significant differences were found between the open ended responses collected from participants in the pre or post test conditions. However, an analysis of age groups revealed that older participants produced significantly more responses focused on adaptation (58%) compared to younger participants' responses (32%) ($X^2=11.45$, $p<.001$). This finding suggested that older children were able to more frequently identify and describe how adaptation might have been related to the changes in the guppy population.

Following the open ended question, children were asked to use the agreement scale to evaluate a set of statements about the natural selection story. Results indicated that younger children ($M=3.55$, $SD=1.39$) were significantly more likely than older children ($M=2.81$, $SD=1.54$) to agree that the guppies color changed because they needed protection ($t_{171}=3.11$, $p=.002$). In addition, younger children ($M=3.12$, $SD=1.77$) were significantly more likely than older children ($M=2.16$, $SD=1.39$) to agree that the guppies wanted to be plain colored ($t_{171}=3.91$, $p=.000$). See appendix D, table 7 for additional means and standard deviations. A complete presentation of natural selection was provided in the computer interactive about Darwin's finches and the storybook theater that featured Charlie and Kiwi's adventure. The lack of pre and post visit change on this item may be related to participants' inability to transfer this complex idea from the dinosaur and bird examples to the story of the guppies. While participants may not have understood this process completely enough register significant change after seeing the exhibition, the pattern of responses suggested a movement towards evolutionary explanations. The finding that younger children were more likely than older children to agree with explanations that highlighted the intentionality of the guppies may suggest these children are taking an early step towards a more sophisticated understanding of the processes of natural selection by recognizing the advantages related to change before being able to articulate scientifically how that change might occur.

Adaptation—To explore understanding of adaptation, participants were asked to choose an animal from a set of pictures that would be best at hiding from a predator and then to explain their selection. Over 90% of the participants selected the green frog pictured on a green leaf. The majority of open ended responses (79%) indicated that a green frog would be most successful at blending into the leaves around it. Another 13% of responses included behaviors and features (like agility) that would help it to survive, 6% listed specific senses (excellent hearing) that would keep it alive, and 2% of responses were unsure. Further analysis revealed no significant differences in responses between pre and post tests or the age groups of participants. The strong consensus among responses suggests that participants understand the relationship between the ability to use camouflage and survival.

In a follow up question, participants were asked to choose an environment from a set of images where the frog could best hide from the same predator. Over 90% selected the green, forested image. Consistent with the previous question, the highest percentage of open ended responses (43%) focused on the importance of blending into the environment for survival and provided explicit descriptions of the frog and the environment that would allow for successful camouflage. In addition, 29% were more implicit about this relationship and described features of the environment without indicating why those features would help the frog to survive. Other responses included 14% that focused on behaviors or features that would help the frog to survive, 10% that emphasized how the environment would provide resources like food and water for the frog, and 4% that stated that the environment was a place where frogs could survive.

There was an encouraging trend between pre and post test responses (X^2=3.72, $p<.06$). On the posttest, 53% of responses indicated specific features of the frog that would allow it to blend with features of the environment while only 32% of responses on the pretest provided this same level of explanatory detail. One of the most popular components in the exhibition, the honeycreeper puzzle, presented and reinforced the importance of birds being adapted to their environments. The direction of this pattern of responses suggests that the experience with adaptation in the exhibition plus the accessibility of this concept to participants may be beginning to support a more refined understanding of this concept.

Understanding evidence: Bird-Dinosaur Link—Participants were shown a picture of an *Archaeopteryx* fossil and asked to identify the image. Approximately a third of the participants indicated that the image was familiar to them (38%), while the remaining two thirds (62%) did not recognize this image despite the fact that a reproduction of this fossil was included in the exhibition. Though the majority of participants reported being unfamiliar with the specific image, they were able to generate many reasonable interpretations: 28% identified it as a fossil, 23% as a dinosaur, 16% as a bird, 15% as other (e.g. maps, prehistoric cave painting, or rocks), 9% as another animal (e.g. frog or other reptile), 9% were unsure. The comparison of pre-post open-ended responses revealed no significant differences. However, there were consistently more responses in the posttest that indicated that the image was a fossil, a dinosaur, or bird and fewer that described it as other or were unsure. In addition, the only participants to identify the *Archaeopteryx* by name (n=3) were in the post test.

Exploration of age groups revealed that significantly more of the older participants' responses (37%) identified the image as a fossil than younger participants' responses (27%) (X^2=3.79, p=.05). This suggests that older participants might have been more familiar than younger participants with representations of fossils in 2-dimensional forms. In addition, older participants (24%) were more likely to identify the image as a bird than younger participants

(9%) (X^2=5.64, p<.02). This suggests that features of the *Archaeopteryx* like wings and feathers most frequently associated with modern birds might have encouraged older participants to make this identification. Younger participants were consistently more likely than older to identify the image as a dinosaur, but this difference was not significant.

Following their open ended responses, participants were asked to indicate how much they agreed that the image was a fossil, a dinosaur or a bird. When presented with possible labels, 84% agreed that the image was a fossil, 56% agreed that it was a dinosaur and 43% agreed that it was a bird. There were no significant pre to post test or age differences for the level of agreement with the fossil or dinosaur labels. However, on the post test (M=3.27, SD=1.59) there was greater agreement that the image was a bird than on the pre test (M=2.78, SD=1.50). In addition, older children (M=3.32, SD=1.40) expressed significantly more agreement that the image was a bird that younger children (M=2.81, SD=1.60). See appendix D, tables 9 and 10 for more details). Not surprisingly, participants were able to more consistently recognize and agree that the image was a fossil as opposed to generating that label on their own as an open ended response. The increased agreement that the image could be a bird on the post test and among older participants suggests that participants might be recognizing the relationship between the two species as opposed to seeing them as mutually exclusive categories.

Participants were also asked to describe how the image of the *Archaeopteryx* fossil showed that dinosaurs and birds are related. The majority of responses focused on salient features as evidence that dinosaurs and birds are related. Specifically, 28% referenced dinosaur and bird features, 27% referenced bird features alone, and 12% referenced dinosaur features alone. The remaining responses were equally divided where 5% explained an evolutionary relationship, 5% stated that dinosaurs and birds are related without elaboration, 5% stated that dinosaurs and birds were alive at the same time, and 5% suggested that the fossil record provided evidence of the relationship between dinosaurs and birds. Only 5% of responses suggested that dinosaurs and birds are not related. The remaining 7% indicated that they were “not sure”.

Further analysis of these explanations revealed that 64% of post test responses provided an explanation that identified salient features of dinosaurs and birds that were present in the fossil image compared to 28% of the pre-test responses (X^2=4.72, p<.05). In addition, more posttest responses described evolutionary relationships between dinosaurs and birds though the numbers were too few to be significant. Responses to this question on the pre-test often indicated that birds and dinosaurs were related without elaborating on any evidence for that relationship. In addition, more pre-test responses suggested that there was no relationship between dinosaurs and birds. This change in the pattern of responses suggests that the exhibit experience succeeded in introducing child visitors to features that provide evidence for a relationship between dinosaurs and birds and supported their ability to articulate these connections.

Understanding Origins—In order to explore participants’ understanding of the origins of species discussed in the exhibit they were asked to explain where the very first bird came from and where the very first dinosaur came from. Analysis suggested that these were challenging questions for the participants. In several cases participants specifically remarked that these were “very tough questions” before they provided their answers.

The largest percentage of responses (32%) indicated that birds evolved from other animals. However, 27% indicated that they did not know the answer to this question. Only 21% indicated that birds were created by God or Jesus. The remaining responses reflected a range of naïve theories about the origins of animals including: came from somewhere else (8%), that they appeared (6%), were created by a nonspecific agent (4%) or were born (2%).

Additional analysis revealed that 57% of post test responses provided evolutionary explanations for the origins of birds as compared to only 29% of pretest responses (X^2=4.38, p<.05). In addition, 53% of older participants' responses included the idea that birds evolved from other animals as compared to 33% of younger participants responses (X^2=5.60, p<.02). Creation based explanations also decreased from pre to post test, though this change was not significant.

The analysis of responses for the origins of the first dinosaur reflected similar patterns. While 22% indicated that dinosaurs evolved from other animals, the frequency of that response was lower for this question than for the replies about birds. Participants were less certain about their answers to this question, with 32% of responses stating they did not know the origin of the first dinosaurs. There were 20% of responses that suggested God created dinosaurs, consistent with responses to the origins of birds. The remaining responses reflected a range of naïve theories about the origins of animals –that they appeared (9%), came from somewhere else (8%), that they were created by a non specific agent(3%) or were born (6%).

Comparison of responses from the pretest and posttest suggested that there were no significant differences in how participants responded to this question despite an increase in evolution based explanations recorded on the posttest. In addition, posttest responses also demonstrated a decrease in creation based explanations, though this change was also not significant. Age group analysis revealed that 59% of older participants' responses included the idea that dinosaurs evolved from other animals as compared to 34% of younger participants responses (X^2=4.55, p<.04).Younger participants also provided more creation-based explanations for the origin of dinosaurs though the difference was not significant. Given that the exhibition did not directly address the origins of dinosaurs, it is encouraging that the majority of older participants provided an explanation that was consistent with the evolutionary perspective illustrated by the dinosaur – bird relationship. And without an explicit presentation about the origins of dinosaurs it is not surprising that many in the younger age group were uncertain about how to answer this question.

Affective/ Engagement Items: The items described in this section were designed to measure children's expectations, enjoyment, and engagement with the exhibition. Understanding these characteristics of the experience provides additional insight into the quality and impact of the exhibition.

What is this exhibit about? Children in the pre-test group (n=82) were asked what they thought the exhibit was about and to describe how they could tell. Eighteen children suggested the exhibit was about time travel and adventure. Seventeen said it had to do with evolution and how living things were made. Fifteen children described the exhibit as being about dinosaurs, and 11 said it was about other animals. Others said that it was about Charlie and Kiwi (n=9), science and observation (n=9), birds (n=8), bones or fossils (n=7), or people in general (n=3).

When asked how they could tell, most pre test children explained that they used the title of the exhibition to figure it out. Other participants said that they could see parts of the exhibit, such as fossils or pictures of dinosaurs and birds. The location of the interview tables on the borders of the exhibition account for children's ability to read the title and observe components.

How much did you enjoy the exhibit? Exhibit visitors were asked to rate their level of enjoyment in the exhibit as well as discuss their favorite components. Overwhelmingly, participants indicated that they enjoyed the exhibition, with the average score rating of 4.61 on a 5 point agreement scale. Older children expressed a higher rate of agreement than younger children. Based on the sample of children who elaborated on their experience, older children were more likely than younger children to say their favorite components were the Natural Selection Interactive, the story theater, or the Dino to Bird Computer Interactive. In contrast, a slightly greater number of younger participants identified the Fossil Dig as their favorite part of the exhibit. The two age groups appeared to equally enjoy seeing the live birds and the Homologies Comparison. Other favorite items mentioned were the Discovery Boxes, Stuffed animals, and the Honeycreeper Puzzle. This pattern of responses provides some additional insight into why older participants might have demonstrated more instances of change on cognitive items. If it were the case that older children preferred the most conceptually rich components of the exhibition, they might have had more opportunities to iteratively engage with the range of pre evolutionary concepts available.

Participants were asked to recall elements of the exhibit that they experienced. Participants were encouraged to list as many as they could recall. In general, the pattern of responses was consistent with the patterns of visitor behavior observed during the timing and tracking studies. Not surprisingly, participants most frequently recalled the live birds and the fossil dig, followed by the homologous features case and the honeycreeper puzzle. These elements were all highly attractive and rarely missed by visitors to the exhibition. A complete summary of total responses is included in the table K (below). See appendix D, Table 11 for a summary of the frequency of recalled exhibits by location.

Table K: Summary of responses to *"Tell me a little bit about what you saw and did in the exhibit"*

Exhibit	Totals
Live Budgies	58
Fossil Dig	52
Homologous Features Comparison	28
Honeycreeper puzzle	22
Story theater/video	19
Natural Selection computer interactive	18
Dino to Bird computer interactive	16
Homologies Puzzle	13
Discovery Boxes	13
Kiwi vignette	7
Discovery Table 1- middle of the room	2
How Evolution Works panel	2
Entry/Intro panel	1
Life-size Charlie	0
Discovery Table 2- By Wall	0
Theater title panel	0

How did participants make sense of the more conceptually rich components? Components in the exhibition were designed to support the communication and understanding of evolutionary concepts. However, a subset of experiences provided more elaborate explanations and opportunities for learning concepts like natural selection. Participants were asked specifically about whether they visited the story theater, computer interactives, and discovery boxes and to indicate their level of interest and enjoyment in response to these components on a five point interest scale. Tables L through O summarize mean responses by location.

Table L: Summary of story theater ratings by location

Story Theater	NySci (n=15)		MiaSci (n=10)	
	Mean	*Std dev*	*Mean*	*Std dev*
How interesting was	4.07	0.799	4.50	0.707
How much did you enjoy	4.20	1.014	4.70	0.675

Table M: Summary of natural selection computer interactive ratings by location

Natural Selection Computer Interactive	NySci (n=16)		MiaSci (n=9)	
	Mean	*Std dev*	*Mean*	*Std dev*
How interesting was	4.44	0.629	4.89	0.333

How much did you enjoy	4.50	1.033	4.78	0.441

Table N: Summary of dinosaur to bird computer interactive ratings by location

Dinosaur to Bird Computer Interactive	NySci (n=15)		MiaSci (n=10)	
	Mean	*Std dev*	*Mean*	*Std dev*
How interesting was	3.93	1.335	4.60	0.516
How much did you enjoy	4.27	1.10	4.70	0.483

Table O: Summary of Discovery Box ratings by location

Discovery Boxes	NySci (n=13)		MiaSci (n=4)	
	Mean	*Std dev*	*Mean*	*Std dev*
How interesting were	4.54	1.127	4.75	0.500
How much did you enjoy	4.69	0.855	5.00	0.000

*1-5 Scale

For each of the more elaborate components they visited, participants were asked to describe the experience. Analysis suggested that age may have been a factor in being able to interpret and express the concepts that were presented. For example, a younger child describing the natural selection interactive said "'Cause the birds that had the big beaks were alive, but the birds who had the little beaks, they died." An older child who used the same interactive described it as, "Oh, it was about [how] Charles Darwin thought of the thing [evolution], thought just like these birds on this one island, and he thought they were just like regular everyday birds, but they weren't because they all had different size beaks. And the ones with the larger beaks, when the drought came, the ones with the small beaks died out 'cause they couldn't break open the hard shells. And then the ones with the larger beaks, during the summer, had eggs and then most of the birds had large beaks." Both children noticed that the population of birds in the story experienced selective pressure and that the result of that pressure changed the natural variation of beak sizes for that population of birds. However, the language used by the younger participant suggested a less developed understanding of the implications of selective pressure on patterns of inheritance. In contrast the older participant articulates change at the population level and the implications for inheritance of an adaptive feature. While there are conceptual gaps in the older participants' response like the passage of time during which the change occurred, the response provided by the older participant suggests some encouraging first steps towards understanding natural selection.

A very small number of interviewed children used the Discovery Boxes (n=9) and two-thirds who described these experiences were younger children. One commented about the inheritance game, stating, "It was a mother and a father cat, and she [explainer] put different kind of animals, and she [explainer] said, 'what do you think the baby would look like?'" Another younger child commented, "You have to match the beaks with the birds, and with what the birds [can] do." While their recall of the activities is good, their ability to articulate the concepts underlying the activities seems less developed.

Making the dinosaur-bird connection Overall, participants were able to make connections between dinosaurs and birds within the exhibit. When asked how they would explain the exhibit to their friends, about a third of the respondents (33%) said it was about evolution, how birds were created, or how birds could be related to dinosaurs. Over half of those who saw the Story

Theater (53%) said that the movie was about dinosaurs turning into birds, or otherwise described evolution. About one-third of those who discussed the Natural Selection Interactive (27%) said that it was about evolution and Darwin, and another third (33%) recognized its message to be studying how birds live, how birds are different from each other, and how the type of beak a bird has will impact survival. Only 27% reported that the Dino to Bird interactive was about dinosaurs evolving into birds.

When asked, "What does the exhibit tell you about birds and dinosaurs," half of the children (51%) said dinosaurs and birds can be related or be from the same ancestor, there are similarities between them, and dinosaurs have evolved into birds. The visual components of the exhibit seemed to be important in conveying the relationship between birds and dinosaurs. Many children referenced specific features as they described the relationships between dinosaurs and birds. This exciting trend that suggests that participants might be adopting some of the evidence based explanation style modeled throughout the exhibition. Selected responses are included below that illustrate this pattern.

- "How dinosaurs and birds are related, I think. They had the same beak, and their claws looked like dinosaur claws."
- "That the scientists' believe that birds came from dinosaurs. And they have a lot of bones and stuff in common, like their hip bone."
- "Because evolution, because like some pterodactyls and some other flying dinosaurs started out, it was evolution and they turn into birds...because those legs look like bird's legs."
- "Because it looks like a small dinosaur, but because parts of it looks like a small dinosaur and parts of it looks like a bird. Like well, kind of like the tail definitely would be a dinosaur, and the feet look more like a bird's."
- "Because some dinosaurs had feathers and there are feathers on birds, and there are feathers on this dinosaur. And also it looks like it had a bird-related beak."
- "Because the little meat-eaters have the same leg as a bird."
- "It explains that dinosaurs and birds could be related somehow even by a few body parts."
- "It told me about fossils and how the two creatures could be related. Because of their appearances and their structure like their bone structures."
- "It told me that they are very similar and not completely different. It's kind of hard to believe that a Tyrannosaurus Rex turned into a chicken, but they have the same figure, the same simple little figure."

Consistent with existing literature, there seemed to be developmental differences in how children reasoned about the transformation from bird to dinosaur. For example, a six-year old identified a connection between dinosaurs and birds through the identification of a single shared feature, stating, "I think that that told me that a chicken and a *T.rex* are related 'cause they have the same type of eye." In contrast, a twelve-year old also included shared features as evidence of a relationship between dinosaurs and birds, but included additional complexity stating, "Maybe because, maybe some dinosaurs, they might have had like arms and they started to grow feathers, have feathers, and they turn into wings, and their bodies start to adjust." Both children recognized a relationship, and provided feature based evidence, however, the older child described incremental changes more consistent with evolution over time.

The difference in the concept of time is also reflected in the children's comments. A seven-year old said, "I like think like, like the dinosaur, like, like dinosaurs stays like a dinosaur for a few days, but like overnight it becomes a, it changes into a bird" whereas an 11- year old explained, "Because dinosaurs can slowly evolve into birds." Younger children do not have a strongly developed sense of time and therefore, to this child, "overnight" may seem to accurately reflect the long period of time that the child senses but cannot articulate.

Parent Surveys

Parent surveys were designed to measure demographics, patterns of museum visitation, visitor agendas, and level of agreement with the theory of evolution. Parent survey data were collected from families at two locations: Miami Science Museum (MiaSci) and the New York Hall of Science (NySci). There were 168 total survey respondents. One hundred twenty-two were surveyed at the NySci and 46 were surveyed at the Miami. Almost three-quarters of the questionnaire responses were received from NySci (73%). The parent survey instrument was the same regardless of whether it was completed prior to visiting the exhibit or after visiting the exhibit. Data from the 84 pre-tests and 84 post-tests are summarized below.

Characteristics of the sample

Adult Gender, Age, and Ethnicity

Respondents provided demographic information including age, education, ethnicity, gender, and information regarding museum visitation. Overall, the majority of the people who completed the survey were Caucasian (46%), women (63%), ages 34-45 (59%).

At both locations, two-thirds of the adult respondents were female. The most commonly reported age range in both locations was 34-45. In New York, 16% of respondents were ages 18-33, and 14% of respondents were ages 46-55. In Miami, approximately 24% of respondents were ages 18-33, and about 12% were ages 46-55. Overall, less than 10% of the sample was over 56 years old, and the majority of these individuals were in New York.

The majority of respondents (46%) described themselves as White (Caucasian), followed by Other Latin American (17%), and Black or African American (15%). Those respondents describing themselves as Latin American were more commonly represented in Miami, while those respondents describing themselves as Black/African American or Asian were more commonly represented in New York.

The independent t-test was used to determine whether there were significant differences in parent ages according to location. The results show a statistically significant difference in *age* ($t_{(df=155)}$=2.738; p <.05) between those individuals surveyed in New York and those surveyed in Miami. The chi-square test of association was run to examine the association between *ethnicity* and *location.* The results show a significant association between the two variables ($x^2_{(df=6)}$= 29.66; p <.05) based on location. There are no significant differences in *gender* based on *location*.

Adult Education

Respondents were asked to report their highest academic grade completed and the highest grade completed by another adult living in their home. At both museums, almost half of all respondents stated that they and the other adult in their home, if applicable, had attended graduate school. Overall, 90% of respondents and 87% of other adults had reportedly attended at least some college. The variable *respondents' education level* was significantly correlated with the variable of *education level for other adult at home* ($r(122)=.442$, $p=.000$), suggesting that adults in the home shared a similar level of education.

Adult Museum Visitation

Most respondents (74%) were not members of the museum they were visiting. In Miami, almost half of the respondents reported low museum visitation to date. Respondents from New York (26%) were almost twice as likely to say that they had been to any museum more than seven times than were Miami respondents (15%). About a third of the respondents were on their first visit to either NySci or MiaSci. Almost all respondents were visiting with children under the age of 18. The independent t-test examined the variable *visited this museum* based on *location*. The results show a statistically significant difference ($t_{(df=158)}=2.717$; $p<.05$) between location and whether respondents had visited the museum where the survey took place. The New York population of the study appeared to visit the science museum more frequently than the Miami population.

See Appendix 4, Tables 12-16 for additional detail about the characteristics of the sample.

Belief Statements

Respondents were asked six belief statements about evolution. These statements were:

- How important is religion in your life?
- Are your religious beliefs compatible with the theory of evolution?
- Do you think the theory of evolution explains the origin of insects?
- Do you think the theory of evolution explains the origin of humans?
- Do you think the theory of evolution explains the origin of birds?
- Do you think birds evolved from dinosaurs?

The independent t-test was used to examine each of these belief statement variables based on *location*. There were significant differences identified for four belief statements: Are your religious beliefs compatible with the theory of evolution?; Do you think the theory of evolution explains the origin of insects?; Do you think the theory of evolution explains the origin of humans?; Do you think the theory of evolution explains the origin of birds? Respondents from Miami had slightly lower rates of agreement with evolutionary beliefs than those from New York ($p<.05$).

Belief statements were examined against demographic variables to determine the relationships between variables. There were no statistically significant differences in mean scores between age groups or academic level groups for these statements. To examine the relationship between respondents' ratings of the belief statements, the Pearson-product moment correlation coefficient was utilized. Respondent rating of *how important is religion in your life* was negatively correlated with ratings of all other belief items. This suggests that those who rated religion as having more importance in their lives subsequently rated evolution as being less compatible with their beliefs. As a result they are less likely to agree that the theory of evolution explains the origin of insects, birds, and humans and less likely to accept that birds evolved from dinosaurs.

Conversely, the lower respondents rated the importance of religion in their lives, the higher they rated the other belief items. The belief statements regarding the origins of insects, birds, and humans and the belief that birds evolved from dinosaurs were all significantly and positively correlated. Respondents' beliefs regarding these items related to the theory of evolution were internally consistent.

The nonparametric test Spearman Rho was used to examine the relationships between respondents' belief statements and demographic variables. Education level was significantly correlated with participant response to *How important is religion in your life*, rho=(160)= -.216, p=.006. The correlation between these two variables is negative, suggesting that respondents who had a higher level of education placed less importance on religion in their life. See Appendix 4, Tables 17-19 for additional detail about these comparisons.

<u>Origins Measurement</u>

The three items measuring belief in origins of insects, birds, and humans were combined to make an overall measurement of parents' origin beliefs. Analysis revealed that respondents from New York are significantly more likely than those from Miami to believe that the theory of evolution explains the origins of a wide range of living thing $t(154)=3.00$, p=.003 (Table O). There was not a significant difference in origin belief between pre- and post-test groups.

Table O. Summary of origins belief ratings by location

	Overall $\bar{x}$	Miami $\bar{x}$	New York $\bar{x}$
N=	156	42	114
%	100	26.9	73.1
Origins belief measure	3.82	3.33	4.01

Open-Ended Responses Regarding Belief Statements

All respondents were asked to rate how strongly they agree or disagree with the item "Do you think birds evolved from dinosaurs" with 1 being disagree and 5 being agree. The mean for this item was 3.84. Respondents were then asked to explain their rating. The responses were coded so that frequency and type of response could be identified. There were a total of 61 statements coded. Approximately 54% indicated that they agree that birds evolved from dinosaurs. Table P summarizes the responses and shows that 20% of responses included evolution or adaptation and another 20% mentioned that fossils or skeletons provide evidence for the relationship between birds and dinosaurs. However, 18% responded that there is no relationship and explained that religion or that God created all things. Another 10% of coded responses did not answer the question and were coded as off topic (n=6)

Table P. Frequency and percent for coded responses: "Do you think birds evolved from dinosaurs?"

Code	#	%
Yes – Evolution/adaptation; Darwin	12	20%
Yes – Fossils/Skeletons as evidence	12	20%
No – Religion/God created all things	11	18%
More research/proof is necessary	6	10%
Yes – Mention science or scientific evidence	5	8%
Mention religion and evolution as being compatible	3	5%
Yes – Both could fly	2	3%
All animals are related somehow	2	3%
No – No evidence	1	1%

Respondents who went through the exhibit were asked what kinds of evidence was presented that may support dinosaurs and birds are related. The responses were coded so that frequency and type of response could be identified, with a total of 31 statements coded. As shown in Table Q, the most frequently coded response was that fossils, skeletons, or bones were used in the exhibit as evidence for this relationship. Only 3 responses (10%) asserted that evolution is an unproven theory and did not mention evidence included in the exhibition.

Table Q. Frequency and percent for coded responses: "Thinking about the exhibit, what kinds of evidence were presented that might support that dinosaurs and birds are related?"

Code	#	%
Fossils, skeletons, bones	13	42%
Movie/video from the exhibit	4	13%
The exhibit itself	4	13%
Not true – Evolution is theory, unproven, not true	3	10%
Pictures/books	2	7%
Unsure	2	7%
Similar physical characteristics (e.g. feathers)	2	7%
Natural selection/evolution	1	3%

Respondents who went through the exhibit were asked what they had expected the exhibition to be about. The responses were coded so that frequency and type of response could be identified, with a total of 31 statements coded. Evolution was the most frequently coded expectation, followed by birds and dinosaurs.

Table R. Frequency and percent for coded responses: “What did you expect the exhibition to be about?”

Code	#	%
Evolution	10	32%
Birds and dinosaurs	6	19%
To learn something	5	16%
No expectations	5	16%
Biology/science	2	7%
Archeology/fossils	2	7%
Endangered species	1	3%

Reactions to Exhibit

Respondents who went through the exhibit were asked to what degree the exhibit met their expectations. The overall mean for this item was 3.91 on a 5- point scale. On average, this suggested that the exhibition met parents’ expectations. There were no differences mean by location, member status or demographic variables measured. Respondents were also asked what might have made the exhibit exceed their expectations. The responses were coded so that frequency and type of response could be identified. A total of 18 statements were coded. As shown in Table S the most frequently coded response (33%) indicated that the exhibition was well done and parents did not have any specific suggestions for improvement. The most frequent specific suggestion (28%) was for the exhibit to offer more hands on or interactive opportunities.

Table S. Frequency and percent for coded responses: “What would have made the exhibit exceed your expectations?”

Code	#	%
Nothing/No suggestions/Great job	6	33%
More hands on/interactive opportunities	5	28%
Less text more pictures	4	22%
More specific info.	2	11%
More explainers/docents	1	5%

After visiting the exhibition, parents were also asked whether they would think about birds and dinosaurs differently. The overall Yes/No responses were almost equal (Yes 53%, No 47%), with slightly more visitors agreeing they would think differently about birds and dinosaurs. A total of 31 statements explaining these responses were coded. As shown in Table T the most common response (32%) was that their thoughts were not changed because they already knew the information. For the 29% who expected that they would think differently, they attributed the change to information received in the exhibit.

Table T. Frequency and percent for coded responses: "Will you think about birds and dinosaurs differently next time you see them?"

Code	#	%
No – I already knew/believed this information	10	32%
Yes – mention information from the exhibit	9	29%
Yes – I now see the relationship between birds and dinosaurs/more evidence was provided	5	16%
No – I still don't believe in evolution	2	7%
No – I need more information	2	7%
I will look at relationships between animals closer	1	3%
Yes – They are NOT related	1	3%
Other	1	3%

Sharing the Exhibit with Children

Respondents who went through the exhibit were asked whether they planned to explore the exhibit's science topics with their children. Fifty-two parents stated they plan to explore science topics from the exhibition with their children. A total of 30 statements explaining these responses were coded. As shown in Table U the most commonly reported answers were that they would explore science topics with their children by reading books and newspapers, visiting museums and science centers, and talking about science. Approximately 20% reported that they planned to follow up on these topics without including how they would do so.

Table U. Frequency and percent for coded responses: Do you plan to explore science topics from this exhibition with your child after you leave the museum?"

Code	#	%
Visit museums, science centers, libraries	5	16%
Reading (books, news)	4	13%
Talk about science	4	13%
Use the internet	3	10%
Television programs	2	7%
Look at/learn about fossils	2	7%
Talk about how evolution is wrong	1	3%
Doing science experiments	1	3%

All parents were asked how they explore science with their children. As shown in Table V the most frequently reported response was visiting museums, science centers, and libraries. The second most common response was reading. Other frequent responses include watching television programs and doing science experiments, observations, or hands-on activities.

Table V. Frequency and percent for coded responses: "How do you and your child explore science together?"

Code	#	%
Visit museums, science centers, libraries	66	26%
Reading	43	17%
Television programs	38	15%
Science experiments or hands on activities	35	14%
Talk about science	17	7%
Parks, outdoor play, outdoor exploration	17	7%
Use the internet	14	6%
Not specific	11	4%
School assignments	9	4%
Other/Unrelated to question	6	2%

Conclusions

The *Life Changes* project proposed to identify educational principles that could be successfully applied to exhibition design and development. Informed by the research and evaluation studies embedded in this project, *Charlie and Kiwi's Evolutionary Adventure* was designed to communicate the concept that species change over time. Summative evaluation determined that children's pre-evolutionary thinking and reasoning were influenced by exposure to this concept in a museum context. Following their experiences in the exhibition, children were more aware that species can change overtime, that there are relationships between dinosaurs and birds and that there are evolutionary explanations for these relationships. In contrast, parent beliefs and understanding regarding species change over time was not influenced by their experiences in the exhibition. These findings suggest that museum learning experiences have the potential to support young children's awareness of pre-evolutionary concepts and their ability to recognize relationships between species. Future research will be needed to explore the broader learning implications of these experiences.

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