City Science: Understanding the Relationship between Ecological Exhibits and Urban Planning

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Abstract

With the suite of environmental challenges faced by today's society growing ever more imminent, the potential role of science and natural history museums as social institutions to promote environmental stewardship is being realized. A recent collaborative effort between the EcoTarium in Worcester, MA and six other institutions across the country, the NSF funded City Science exhibit serves to introduce the public to new research on human-ecology interactions in urban settings. The project also supports the inclusion of Public Participation in Science Research (PPSR) elements in museum exhibits, and tests the use of a spatial neighborhood design interactive as a tool to understand the relationship between the exposure to ecological exhibits and neighborhood design. This paper describes and analyzes results from a 2014 study carried out at the EcoTarium exploring the relationship between visitor's use of urban ecology exhibits and their conceptual frameworks for urban planning and design. Initial results indicate a correlation between use of ecological exhibits and subsequent neighborhood design. In particular, interactions with exhibits focused on land use change and urban biodiversity appear to have the strongest potential influences on neighborhood design.

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1 Introduction

PATHWAYS: From the Lab to the Neighborhood

Perhaps the most important question faced by the contemporary museum is: *How can natural history and science museums best encourage the use of their collections and research in order to engage the next generation of citizen-minded scientists and science-minded citizens in taking ownership for solutions to the environmental crisis that threatens human civilization?* (Watson & Werb, 2013). Work underway at the EcoTarium, an indoor-outdoor science museum located in Worcester, MA is currently attempting to find solutions to this primary query. Aided by a recent grant from the National Science Foundation (NSF), the purpose of the PATHWAYS project is to develop a nationally-replicable model for integrating the newly-emerging science on urban systems into exhibits in urban science museums through: (1) establishing a partnership between the EcoTarium, two existing NSF-funded networks, and teachers; (2) integrating urban ecology

research and K-12 curriculum work from these two existing networks with four new prototypes for the City Science exhibit set to open at the EcoTarium and; (3) establishing a collaborative effort between scientists and professors from the University of Massachusetts Amherst, Clark University, Loyola Maramount University, and six other museums in New England and California to review prototypes, provide feedback, and begin plans to introduce these or similar exhibits to their museums and beyond. The achievement of these goals will help to develop a model that delivers NSF funded ULTRA-Ex (Urban Long-Term Research Area Exploratory) research to science museums nationwide, informs discussion, and encourages engagement with science by local residents to understand the implications of environmental policies and decisions.

The greater PATHWAYS project also supports the inclusion of Public Participation in Science Research (PPSR) elements in museum exhibits. The application of a "research-exhibit" feedback loop allows museum visitors to contribute to projects as research subjects, while also learning about the larger goals of the research and the scientific process. The main goal of the PPSR project is to integrate research experiments and findings (ULTRA-Ex research) and exhibit prototypes (City Science at the EcoTarium) in an effort to increase informal learning about scientific concepts, processes, and methods of inquiry to promote increased interest in the sciences and a heightened sense of environmental stewardship. The project also serves to integrate PPSR research into prototypes whereby information and visitors' responses are gathered, analyzed, compared, and reported back to museum visitors to link them with project researchers and the research process itself. The objective of this paper is to detail visitor study carried out at the EcoTarium in 2014 that explores the potential impact of urban ecology exhibits on visitor perception and understanding toward urban planning and design.

1.1 Background

Exploring, documenting, and communicating the history of the planet and the science behind it have been the essential work of natural history and science museums for over a century (Watson & Werb, 2013). With rapid climate change, the challenges of providing energy, food, and water to an exponentially growing population, increasing levels of pollution, the exploitation of natural resources, and the degradation of the planet (Turner, Lambin, & Reenberg, 2007), the tasks of the contemporary museum have taken on a new urgency. The untapped knowledge and information present in both science and natural history museums may become irrelevant without novel communication and engagement strategies inviting visitors to an essential and comprehensive dialogue concerning today's most pressing scientific challenges (Watson & Werb, 2013). Research has indicated that the general public has a distinct lack of familiarity with, and understanding of current research in the scientific field (Selvakumar & Storksdieck, 2013). Many citizens fail to grasp the purpose, importance, or relevance of contemporary science to their daily lives (ibid). Rethinking the role of the museum as a social institution with goals of promoting a sustainable future will require a reinvented museum, an organization that incorporates traditional museum values with a sense of environmental stewardship and social responsibility (Janes, 2010). The contemporary museum has the opportunity to play a major role in creating visitor experiences that relate to current issues in science. In the face of a worsening

global ecological crisis, a novel institution could serve as a tool for engaging and involving the public in ongoing debates and policy-making decisions, and ensuring a more sustainable future.

Urban ecology and the study of urban systems are at the forefront of scientific inquiry, addressing both the complex interconnection of human and natural systems, and the potential harmful effects faced by city dwelling citizens (Grimm, Faeth, Golubiewski, et al. 2008). With an ever-increasing number of challenges introduced by urban sprawl, landscape and land-use changes, and a growing human population, there is a pressing need to create a relevant link between scientific knowledge, processes, and methods of inquiry, and the lives of urban and suburban residents. Informed citizens are responsible for addressing the complex issues facing urban areas, for fostering environmentally responsible behavior at the household and neighborhood level, and for encouraging informed decision making on government policies. The informal learning opportunities afforded by science museums promote life-long and family-centered learning that research suggests can influence environmental attitudes (National Research Council, 2009). Furthermore, research indicates the creation of highly dynamic, interactive, hands-on learning environments that bridge the gap between experts and the layperson promote engagement, understanding, and recall of exhibits and their content (Falk & Dierking, 1992; Allen & Gutwill, 2004). With up to 95% of science learning occurring outside of classrooms (Falk & Dierking, 2010), museums that are capable of inspiring the next generation of environmentally conscious citizens will be vital to ensuring the realization of a sustainable future. Very few science education programs or urban exhibits in today's science and natural history museums, however, have integrated the emerging research on dynamic land-use change, climate change, and coupled human-natural systems in urban settings.

1.2 City Science

The EcoTarium is an innovative indoor-outdoor science museum located in Worcester, MA with over 130,000 visitors per year. As an integral part of an NSF funded collaborative research effort, the EcoTarium is scheduled to launch a new exhibition in 2016. "City Science" will incorporate the emerging research on urban systems and serve as a beta-test site to integrate ULTRA-Ex research into exhibits focused on urban ecosystems. The proposed set of exhibits will delve into the hidden science stories embedded within city ecosystems. These exhibits will serve as a hands-on exploration of the science encountered in everyday life. With seven different thematic areas, this collection of interactive exhibits will allow visitors to experiment with topics ranging from civil engineering and city planning, to issues in urban ecology. City Science ultimately serves to encourage the design of more sustainable cities, and to understand how science museums may be able to assist in decision-making processes that shape a sustainable future. By integrating ULTRA-Ex research into City Science interactives, this project seeks to increase public understanding of emerging issues in contemporary science, and spark dialogue surrounding the types of futures citizens envision for their communities.

As part of the greater NSF PATHWAYS project, the purpose of this study is to explicate how visitors' exposure to ecological exhibits focusing on urban biodiversity ('Best Nest'), land use change ('Turtle's Eye View'), and urban heat islands ('City Hot Zones') influences

neighborhood design ('Magnetic Neighborhood'). We hypothesize that the number and type of ecological exhibits visited will influence neighborhood design. More specifically, we anticipate that: (1) the Turtle's Eye View interactive will influence green space connectivity in neighborhood construction, (2) the Best Nest interactive will influence green space variety in neighborhood construction, and (3) the City Hot Zones interactive will influence the way visitors conceptualize health risks faced by city dwelling citizens.

2 Methods

2.1 Front end and formative evaluation

As part of the initial planning process for the City Science exhibition, EcoTarium staff conducted a number of preliminary front-end research activities. These activities took place between 2000 and 2012 and included facilitated and non-facilitated brainstorming with museum visitors, school and community groups, educators, and other stakeholders. This process served to identify topics of public interest to aid the selection of initial content for stage 1 City Science exhibit component prototypes. The resulting stage 1 prototypes were rigorously tested with visitors between 2013 and 2014. These assessment efforts served as formative evaluations to feed back into iterative improvement and inform future direction and expansion of each exhibit component. This formative evaluation process focused on usability, science process skills, concept understanding, and ability of visitors to apply the concepts to their lives. Two basic methods of data procurement were employed: (1) naturalistic observation of visitors interacting with each prototype on the museum floor, and (2) brief semi-structured interviews conducted with the visitor upon completing the interactive component of each exhibit.

2.2 Exhibit areas

As described below, although the proposed City Science exhibit areas cover a variety of topics addressed by ULTRA-Ex research, four exhibit areas (Neighborhood Design, Land Use Change, Urban Biodiversity, and Urban Heat Islands) were chosen based on their strong connection to ULTRA-Ex research topics.

2.2.1 Land Use Change

The Turtle's Eye View (TEV) interactive (Figure 1a) addresses land use changes and specifically focuses on the message that anthropogenic activity facilitates landscape changes that may potentially alter and fragment species' habitats. In this interactive, participants are provided with a set of houses (small, medium, and large) and rubber road pieces, and are asked to build a neighborhood. Each house is attached to a lawn featuring threats to turtle survival (raccoons and lawnmowers). Upon completion, visitors flip a switch to turn on a projection that appears over their neighborhood. The projection features dispersal corridors between four different habitats necessary for the survival of the species (mating, hibernation, nesting, and feeding). Participants are then afforded the opportunity to rezone their neighborhood, making it safe for turtles. This interactive serves to illustrate the effects of urban development on an animal species, and educates visitors on how their choices may fragment a species' habitat, restrict dispersal patterns,

and disrupt life cycles. Turtle's Eye View serves to spark discussion around topics such as conservation, urban planning, and the importance of striking a balance between humans and nature.

2.2.2 Urban Biodiversity

In the Best Nest (BN) interactive (Figure 1b), visitors encounter birds they might observe around their homes and learn that not every bird can live in the same nest. This interactive asks visitors to place five different species of stuffed birds (sparrow, wood thrush, crow, pigeon, and cardinal) in different nests based on provided clues that tell the visitor which type of habitat each bird prefers. Each nest features a corresponding cue card with a picture of the habitat and text asking, "Who lives here?" Visitors are instructed to place each bird in its preferred forest habitat and the analogous city environment. Upon placing each bird, participants are able flip the cue card in order to reveal the answer. For each location (forest and city) there is a species that cannot find a home there. Best Nest serves to spark discussion on the importance of preserving a variety of habitats for effective conservation efforts and serves to educate visitors on urban biodiversity issues.

Figure 1: Stage 1 exhibit prototypes used in the study. Clockwise from left (a) Turtle's Eye View; (b) Best Nest; (c) City Hot Zones and; (d) Magnetic Neighborhood

2.2.3 Urban Heat Islands

City Hot Zones (CHZ) (Figure 1c) focuses on the message that urban heat islands can affect the quality of life for city dwelling citizens. In this interactive visitors are asked to build a city using a variety of black and white foam and plastic blocks. Once they are finished, visitors have the opportunity to 'turn on the sun' by turning on an infrared (IR) camera. Visitors are able to watch their city heat up on a computer screen and identify hot spots. Visitors are then afforded the opportunity to redesign in order to mitigate urban heat islands effects and create a healthier city. City Hot Zones educates visitors on the effects of urban development and serves to facilitate discussion surrounding urban planning decisions, human health issues, and the quality of life for city dwellers.

2.2.4 Neighborhood Design

Magnetic Neighborhood (MN) (Figure 1d; Figure 2) serves to help visitors understand that city planning involves compromise and cost-benefit analysis. This interactive asks visitors to build their ideal neighborhood on a 13" x 9" cookie tray using magnetic pieces (For a list of available pieces see Appendix H). After completion facilitators ask participants where they would like their ideal neighborhood to be located: the city, the country, or the suburbs. Magnetic Neighborhood serves to spark dialogue surrounding the type of ideal neighborhoods citizens envision for themselves.

2.3 Project design

In order to uncover evidence of a potential relationship between interaction with ecological exhibits and neighborhood design, EcoTarium staff and volunteers conducted three prototyping sessions that simulated a finalized City Science exhibit. These sessions took place on the museum floor over the course of three days (8/13/14, 8/14/14, and 8/20/14), and during each session, three ecological exhibits (Turtle's Eye View, Best Nest, and City Hot Zones) were run concurrently with Magnetic Neighborhood. During each session, participants were free to visit as many exhibits as they wished in whichever order they desired, ensuring that exhibit visitation was random. This served to mimic natural visitor-exhibit interactions and traffic patterns on the museum floor. Additionally, the locations of the interactives on the museum floor were rotated between the first two prototyping sessions. This was done to increase the variation in visitation patterns, and prevent repetitive visitation order caused by architectural flow patterns.

During each session, participants were given a 'passport' (Appendix F) at the first exhibit they visited, and were informed that they were free to visit as many or as few of the exhibits as they wished. At each exhibit, facilitators stamped the passports of participants, enabling researchers to track their progress. EcoTarium staff recorded visitor observations for each of the three ecological exhibits. (City Hot Zones, Turtle's Eye View, and Best Nest). This information was used to track participant interaction at each exhibit and support the usability of interviews conducted at Magnetic Neighborhood. Interviews were conducted only at Magnetic Neighborhood to reduce any potential influence that interactions with facilitators might have on neighborhood design. Those participants who visited Magnetic Neighborhood first served as the control group, and after visitors completed this activity, EcoTarium staff and volunteers noted

the quantity and order of visitation for each participant by referencing their passport and recording the information on the 'passport tracker' (Appendix G).

In an effort to capture data from visitors across age groups, two observation and interview tools (Appendix A) were developed to target two distinct cognitive groups: less than age 5, and greater than age 5. Protocols were developed and pilot tested prior to the field-testing of all interactives. The appropriate interview was conducted for each participant in order to clarify responses, and help understand *why* participants built their neighborhood a particular way. Pictures were taken of the neighborhood each participant had created for later data analysis (Appendix I). Furthermore, in order to capture visitors from the 12-25 age group, a demographic that does not typically frequent the museum, EcoTarium staff specifically reached out to youth groups in the Worcester area. Participants in the 12-25 age group were granted free admission to visit the museum and were invited to participate in the study with a signed consent form (Appendix L; Appendix M).

Due to the complexity of the study, a large number of researchers were required to run each prototyping session (a total of eight required for the first two sessions). All staff, interns, partners, and volunteers involved in the study participated in a pre-survey training session in order to ensure consistency during interview sessions, and to prepare those less familiar with the form of evaluation practiced during the prototyping sessions. A facilitator script was also developed to ensure consistency in data collection and visitor-facilitator interaction (Appendix E). Furthermore, although each of the four activities (Turtle's Eye View, Best Nest, City Hot Zones, and Magnetic Neighborhood) were analogous to what they may be as a final interactive exhibit, staff and volunteers facilitated instructions, as the exhibit prototypes were not yet at a complete stand-alone stage.

Based on the method of analysis, and the nature of several questions where time spent with the interviewer could increase depth of answers and potentially skew results, interviews from the third prototyping session were removed from the sample. Review of these interviews revealed that those conducted during the third session were more in-depth than those conducted during the original two prototyping sessions. We believe that this was due in part to the higher experience levels of these evaluators and the reduction in the volume of traffic on the museum floor, allowing each facilitator to spend more time with the subject. In addition, many of the interviews conducted for participants who visited Magnetic Neighborhood third and fourth were missing information, as the interview questions were not asked due to interviewer error and/or visitor sessions where participants left before full completion. To account for this, these interviews were removed from the dataset and the total sample size was adjusted accordingly for each category during final analysis. This was to ensure that each sample had interviews yielding a full set of participant information. Lastly, in order to account for the potential influence of 'drive-by' interactions (i.e. instances where visitors did not fully interact with the exhibit), observation sheets, on which observers recorded the level of participant engagement, were reviewed for the three ecological interactives. The interviews of participants who visited ecological exhibits yet did not engage with the activity were excluded from the final dataset. The total sample size for

this study was n=56; 18 of the study participants visited Magnetic Neighborhood first, 10 visited second, 11 visited third, and 17 visited fourth, interacting with all three ecological exhibits.

2.4 Data analysis & evaluation materials

During prototyping sessions, pictures were taken of the neighborhood each participant had created (Figure 2) and matched up with the corresponding interview responses. Neighborhoods were analyzed based on the pieces participants included, and focused on percentage of green space, green space variety, and green space connectivity. Green space percentage was calculated by assigning each piece a numerical value based on the proportion of square area it occupied on the available neighborhood construction area (Appendix H). Green space variety is a sum of the unique green spaces included, and green space connectivity a sum of the connected patches of green spaces.

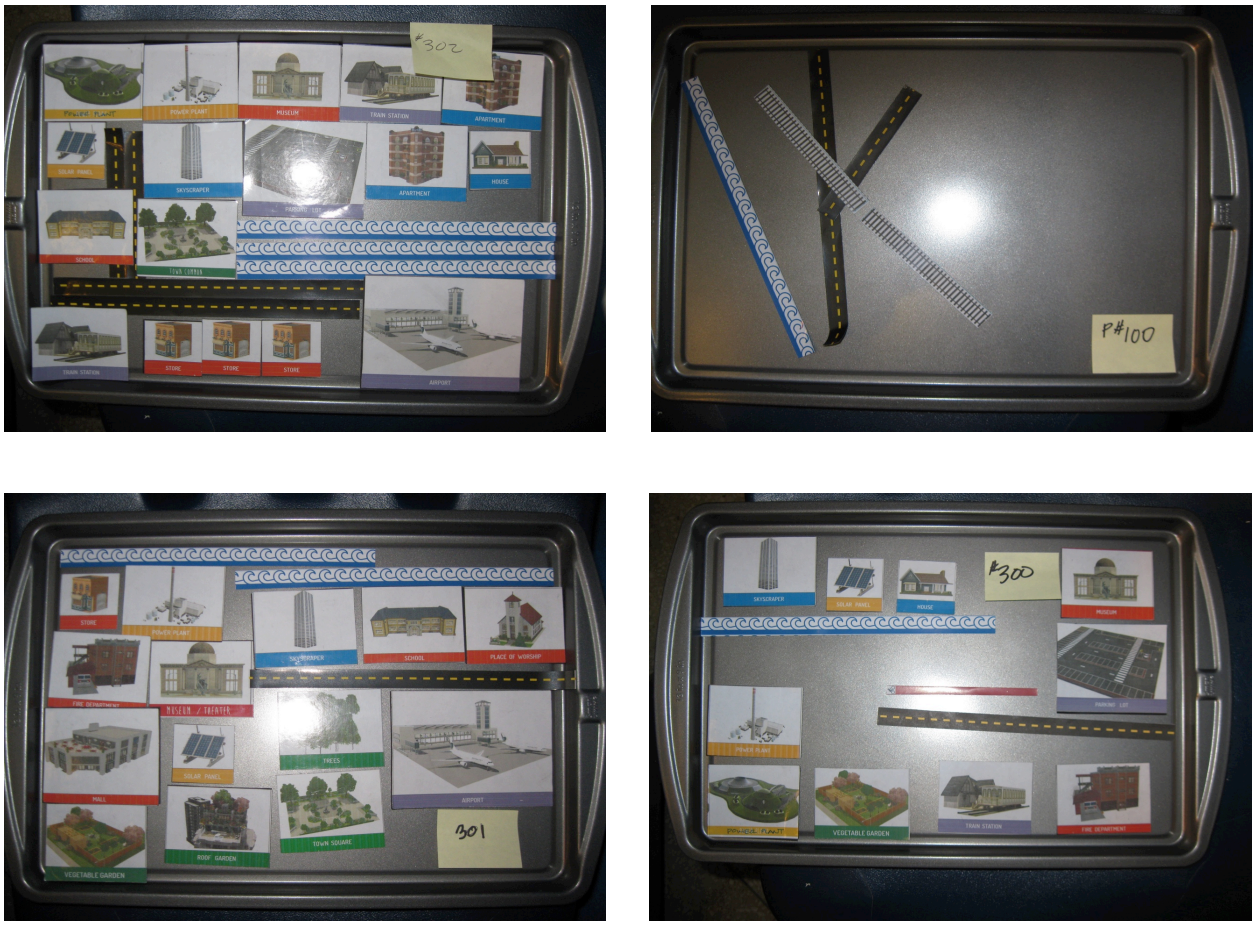

Figure 2: Sample neighborhoods created by study participants

After building their ideal neighborhoods, facilitators conducted interviews with participants (Appendix A) to uncover evidence of a potential link between ecological exhibits and

neighborhood design, and to parse out trends between interactives. Interview responses were coded to convert open-ended responses into quantifiable values (Appendix I). Two separate evaluators completed the coding process for open-ended responses. This final coding was crosschecked and any answers coded differently by separate evaluators were subsequently reviewed and recoded.

Results from interviews and neighborhood design were analyzed based on those aspects that we expected to be most influenced by exposure to the three urban ecology exhibits being tested in conjunction with Magnetic Neighborhood (see hypothesis above in Section 1.2). Analysis focused on the effects of specific prototypes to test for major differences between groups who visited one interactive versus another before visiting Magnetic Neighborhood (i.e. participants who visited Turtle's Eye View versus those who visited City Hot Zones). The neighborhoods of participants who visited Turtle's Eye View were analyzed based on changes in green space connectivity, the number of animals participants believed could reside in their neighborhoods, and whether participants included green space in their neighborhood based on benefits provided to the environment and wildlife. Best Nest focused on similar expected changes in neighborhood design, in addition to differences in green space variety. Lastly, City Hot Zones focused on pollution and human health as reasons given for the inclusion of green space. Neighborhoods were also analyzed based on expected changes between groups that visited a different number of ecological exhibits (as also hypothesized in Section 1.2). Additional factors analyzed included discussion of participants' ideal neighborhood, discussion of the inclusion or exclusion of green spaces, discussion surrounding what participants categorized the blank space in their neighborhoods as, and comments revealing urban planning decisions in neighborhood design, including those that indicated consideration of tradeoffs and consideration of quality of human and animal life.

3 Results

Neighborhood design

Results obtained from the analysis of neighborhood design included green space variety, green space connectivity, and percentage of green space. Comparisons between the numbers of ecological exhibits visited before Magnetic Neighborhood indicates minor differences in green space variety and green space connectivity. Although green space variety appears highest in groups that visited Magnetic Neighborhood (MN) first (4.82), there appears to be an increasing trend for groups where Magnetic Neighborhood was visited second, third, and fourth (2.10, 4.00, and 4.12 respectively). Green space connectivity follows the same trend with a value of 2.55 for the MN first group, 2.10 for the MN second group, 2.73 for the MN third group, and 2.94 for the MN fourth group. There was no discernable trend for percentage of green space between groups (Table 1).

Analyzing neighborhoods based on which ecological exhibits participants visited before Magnetic Neighborhood (i.e. City Hot Zones and Best Nest, or Best Nest and Turtle's Eye View) indicates that Turtle's Eye View (TEV) may have had the largest influence on green space

connectivity, which was highest for participants that visited TEV; 2.88 versus 2.71 for BN and 2.57 for CHZ (Table 2); and 3.00 for participants that visited TEV&BN versus 2.75 for CHZ&TEV, and 2.33 for CHZ&BN (Table 3). Results also indicate that Best Nest may have had the largest influence on green space variety. These values were highest for participants that visited BN; 4.29 versus 3.88 for TEV and 3.86 for CHZ (Table 2); and 4.33 for participants that visited CHZ&BN, 4.25 for TEV&BN, and 3.50 for CHZ&TEV (Table 3). Lastly results indicate that TEV and BN may have had the largest influence on percentage of green space. This value

Table 1: Comparison of results based on how many ecological exhibits were visited. MN First represents the control group; those visitors that did not visit any other ecological exhibits prior to Magnetic Neighborhood. The remaining columns indicate the number of ecological exhibits visited before MN, but does not distinguish which of the three ecology exhibits was visited, or the order of visitation. The first column indicates characteristics of neighborhood design and interview sessions that are aligned with each of the three ecological interactives.

	MN First	MN Second	MN Third	MN Fourth
n=	18	10	11	17
Turtle's Eye View (TEV) & Best Nest (BN)				
# of animals mentioned	1.82	1.75	1.33	2.07
Mentioned animals that couldn't live there?	9.09%	0.00%	14.29%	0.00%
Mentioned Exotic animals?	0.00%	25.00%	0.00%	7.14%
Animals/environment/habitat	0.45	0.10	0.36	0.24
Green space connectivity (number of connected patches)	2.55	2.10	2.73	2.94
Green space variety	4.82	2.10	4.00	4.12
City Hot Zones (CHZ)				
Pollution	0.00	0.20	0.00	0.18
Human health	0.73	0.30	0.91	0.88
ALL				
% green space	25.69%	9.56%	18.63%	22.30%
% green space w/o blanks	33.11%	16.73%	34.64%	30.76%
Green blank space	60.00%	20.00%	50.00%	46.15%
# of reasons for green space	1.27	0.50	0.91	1.06
Cost benefit decisions	27.27%	10.00%	18.18%	52.94%
Value of green space	45.45%	20.00%	18.18%	35.29%

was highest for participants who visited BN (20.73%) and TEV (17.72%) compared to those who visited CHZ (17.56%) (Table 2).

3.1 Interviews

Information gathered from interviews included: (1) the number of animals participants believed could reside in their neighborhood; (2) the mention of animals participants did not think could survive in their neighborhoods; (3) the mention of exotic versus local animals; (4) different reasons given for the inclusion of green space (i.e. human health, habitat, environmental benefits, etc.); (5) comments revealing that participants regarded the empty space in their neighborhood as green space and; (6) actions revealing cost-benefit decision making.

The number of animals participants believed could reside in their neighborhoods was found to be highest in groups that visited MN fourth. This indicates a potential influence of ecological

Table 2: Comparison of results based on which ecological exhibit was visited (TEV, BN, or CHZ). In each column visitors may have visited only the specified interactive, or that interactive in addition to another ecological exhibit. The first column indicates characteristics of neighborhood design and interview sessions that are aligned with each of the three ecological interactives.

	TEV&BN	CHZ&BN	CHZ&TEV
n=	4	3	4
Turtle's Eye View (TEV) & Best Nest (BN)			
# of animals mentioned	1.67	1.50	1.00
Mentioned animals that couldn't live there?	0.00%	0.00%	25.00%
Mentioned Exotic animals?	0.00%	0.00%	0.00%
Animals/environment/habitat	0.50	0.00	0.50
Green space connectivity (number of connected patches)	3.00	2.33	2.75
Green Space Variety	4.25	4.33	3.50
City Hot Zones (CHZ)			
Pollution	0.00	0.00	0.00
Human health	0.25	0.33	2.00
ALL			
% green space	20.49%	21.06%	14.94%
% green space w/o blanks	32.78%	37.69%	34.22%
Green blank space	50.00%	100.00%	33.33%
# of reasons for green space	1.00	0.33	1.25
Cost benefit decisions	25.00%	0.00%	25.00%
Value of green space	0.00%	0.00%	50.00%

Table 3: Comparison of results based on the combination of ecological exhibits that were visited (TEV&BN, CHZ&BN, or CHZ&TEV). Participants in these categories visited MN third and results are anaylzed based on which two interactives were visited. The first column indicates characteristics of neighborhood design and interview sessions that are aligned with each of the three ecological interactives.

	TEV	BN	CHZ
n=	8	7	7
Turtle's Eye View (TEV) & Best Nest (BN)			
# of animals mentioned	1.29	1.60	1.17
Mentioned animals that couldn't live there?	14.29%	0.00%	16.67%
Mentioned Exotic animals?	0.00%	0.00%	0.00%
Animals/environment/habitat	0.50	0.29	0.29
Green space connectivity (number of connected patches)	2.88	2.71	2.57
Green Space Variety	3.88	4.29	3.86
City Hot Zones (CHZ)			
Pollution	0.00	0.00	0.00
Human health	1.13	0.29	1.29
ALL			
% green space	17.72%	20.73%	17.56%
% green space w/o blanks	33.50%	34.89%	35.71%
Green blank space	40.00%	66.67%	50.00%
# of reasons for green space	1.13	0.71	0.86
Cost benefit decisions	25.00%	14.29%	14.29%
Value of green space	25.00%	14.29%	14.29%

exhibits on the way in which visitors conceptualize urban biodiversity and the importance of striking a balance between humans and nature (Table 1). This value was also highest for participants who visited TEV and BN (1.29 and 1.60 respectively) (Table 2) and those who visited *both* TEV&BN, the highest at (1.67) (Table 3). Additionally, whether or not a visitor went to TEV seemed to have the largest influence on the inclusion of green space based on benefits provided to the environment and wildlife (0.50 for TEV alone (Table 2), and 0.50 for TEV&BN and TEV&CHZ (Table 3)). City Hot Zones appears to have the least influence in this category. There is no observable trend for participants stating pollution or human health concerns as reasons for the inclusion of green space. In addition, there is no discernable trend for blank space as green space, and comments revealing the value of green space; however cost-benefit decisions were highest in the MN fourth group (52.94%) compared to the MN first, second and third groups (27.27%, 10.00%, and 18.18% respectively) (Table 1).

4 Discussion

Our results indicate a possible correlation between exposure to ecological exhibits and the way participants think about urban planning and design, as recorded through visitor neighborhoods. The content and number of ecological exhibits participants visited appears to influence the inclusion and spatial representation of design elements. Turtle's Eye View appears to have had the strongest relationship to green space connectivity, and whether participants included green space in their neighborhood based on benefits provided to the environment and wildlife. The focus of this interactive is land use change and habitat fragmentation. Results thus support the preliminary hypothesis that Turtle's Eye View would have the largest observable influences in these categories. The Best Nest interactive presents the message that not all birds can live in the same home. In this interactive, participants learn that a variety of green spaces are required in their neighborhoods in order to support bird diversity. Best Nest appears to have the largest impact on green space variety, also supporting our preliminary hypothesis.

Overall, the content, rather than the quantity of ecological exhibits visited, appears to create a stronger link to the types of neighborhoods participants create. This becomes evident when parsing out trends between exhibits. There appears a general trend of higher values for those that visited Magnetic Neighborhood first followed by a decrease for those who visited Magnetic Neighborhood second, then an increase for groups who visited Magnetic Neighborhood third and fourth respectively when comparing groups based on how many ecological interactives were visited before Magnetic Neighborhood. This observed trend of initially high values is potentially due to the exclusion of results and a reduced sample size in our MN third and fourth groups.

A potential limitation of this study is the focus on short-term effects. An issue with most educational tracking studies relates to the way humans process events and experiences. This occurs on several timescales and is highly affected by how it relates to each individual's cumulative experience. A lesson learned may have immediate effects causing direct observable behavioral changes, but will likely also be part of that individual's collective understanding, causing changes further than we are able to observe or draw correlations from in this type of study. It is also important to note that the sample sizes used in the latter analyses (Tables 2 and 3)

were significantly smaller than our total sample size. Replicating the study in the future with a larger sample size would serve to strengthen the validity of our results. Additionally, testing with stand-alone exhibits further along in the development process will reduce variability introduced by the need for facilitators in early phase 1 prototypes.

5 Conclusion

Confronted with the constellation of issues that threaten the planet and global civilization, 21st century museums have begun to undergo a fundamental transformation. As stated by Alberch:

> "Natural history museums are at a turning point in their history. They can now play a central and critical role in the development of research leading towards the understanding, conservation and sustainable use of biodiversity. To achieve this goal, however, they must radically change their mode of operation and public image, to clearly define goals, objectives, and new research strategies." (Alberch, 1993, pg. 372)

The historical approach to ecological studies and natural history exhibits has emphasized a separation from anthropogenic influence. Many classical exhibitions were essentially 19th century trophy halls; collections that provided a snapshot of a pristine natural scene unaffected by human activity (Krishtalka & Humphrey, 2000). The City Science project and the greater NSF PATHWAYS research transcend the boundaries of traditional museum studies to help the next generation of scholars, students, and citizens understand that the science of ecology is a profoundly human endeavor. As a collaborative effort that utilizes multiform interactive exhibits to engage visitors in today's most pressing issues in science, the City Science exhibition serves to knit together the social and biophysical aspects of understanding ecology in an urban context. These learning activities set the stage for a generation of people committed to understanding the ecology of their neighborhoods and empowered to participate in decision-making about the future of their environments.

As the self-proclaimed custodians of posterity, museums may serve to aid in the impending environmental crisis. The untapped knowledge and information inherent to these institutions however, may become irrelevant without novel communication and engagement strategies inviting visitors to an essential and comprehensive dialogue concerning today's most pressing environmental and social challenges. Interactive exhibits that improve recall of content, and inspire a sense of awe and wonder for the natural world are valuable in understanding the way individuals process and conceptualize information presented in informal learning environments. Our study has identified a possible correlation between exposure to ecological exhibits and decision-making behaviors as recorded through neighborhood design. In addition, this study highlights the potential role of science museums in addressing the suite of environmental challenges characteristic of the 21st century. Overall, the content rather than the quantity of ecological exhibits appears to have a stronger influence on visitor's conceptual frameworks for urban planning, and exhibits focused on land use change and urban biodiversity have the greatest influence on neighborhood design. This study does not in itself prove a direct correlation

between the two; however, our hope is that it will begin to help researchers understand what types of visitor behaviors might be related and suggest productive avenues of research for future studies.

5.1 Future studies

The greatest limitation of this study is the low sample size, due to the number of work hours required for data collection and analysis. The EcoTarium is currently in the process of developing a secondary study in an attempt to reduce these restrictions, and enable a larger capture rate. New developments include the finalizing of instructions, and the testing of each interactive through to a finalized exhibit prototype. This will both eliminate the need for staff to act as a facilitator at each exhibit station, and reduce variability in visitor experience. The second area of improvement will be the use of spatial scanning technology to allow for automatic computer analysis of neighborhood composition and visitor interview responses, again allowing for a reduction in facilitator introduced variability, and an increase in capture rate and data analysis.

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Appendix A
Magnetic Neighborhood OSIS

City Science – Magnetic Neighborhood – NSF
Observation Sheet

Version#: _____

Observation #: _____
Observer: _____
Date: _____

Start: _____

Finish: _____

Age:	<4	5-11	12-18	18-25	26-65	66+
F						
M						

Group Type:

Family School Group Other: _____

Visitor Actions

- ☐ Placed a piece on the board and then removed it
- ☐ Looked at unrelated visitors' neighborhood
- ☐ Worked alone
- ☐ Worked with adult
- ☐ Worked with child

Notes…

Usability
Comments…

Visitor Conversation

☐ Comments on proximity relationships between elements (*I put this next to this because…)*

☐ Assigns value to different aspects of the neighborhood (*I am putting this in because it is important, or I like x activity so I need this in my neighborhood)*

☐ Makes a comment revealing cost benefit analysis *(I will leave this out so I can fit in x)*

Notes…

City Science – Magnetic Neighborhood – NSF
Observation Sheet
***Circle which question was asked (<5 or >5)**

Version#: _____ Observation #: _____
Observer: _____
Date: _____

(<5) *Where you live are there a lot of...* ☐ *houses & lawns* ☐ *forests & animals* ☐ *cars& buildings*
(>5) **Do you live in the…** ☐ **city** ☐ **suburbs** ☐ **country**

(<5) *Can you tell me what you put in your neighborhood? What do you think about the pieces you chose?*
(>5) **Can you briefly describe what you put in your ideal neighborhood and why? Is there anything else that you would have liked to include?**

(<5) *What do you think about the trees and parks you put in your neighborhood? Can you tell me if they are important?*
(>5) **What green spaces** (point to pieces board) **did you include in your ideal neighborhood and why?**

(All) **What animals do you think could live in your neighborhood?**

If applicable:
(<5) *What is in this blank space?* (point to blank space in neighborhood) *Is it empty? Or is something there?*
(>5) **What does the empty space you left in your neighborhood represent?**

Appendix B
Turtle's Eye View OS

City Science – Turtle's Eye View
Observation Sheet

Version#: _____

Observation #: _____
Observer: _____
Date: _____

Start: _____

Finish: _____

Age:	<4	5-11	12-18	18-25	26-65	66+
F						
M						

Group Type:

Family School Group Other: _____

Visitor Actions

☐ Changed zoning of neighborhood

☐ Made cost benefit decisions (i.e. removing pieces, selecting smaller houses, etc)

Other…

Usability Comments…

Visitor Conversation

☐ Makes a comment about how their neighborhood affects the turtle

☐ Makes comment about different turtle habitats

☐ Makes a comment about turtle threats (raccoon, lawnmowers, cars)

☐ Asks questions

Other…

Appendix C
Best Nest OS

City Science – Best Nest
Observation Sheet

Version#: _____

Observation #: _____
Observer: _____
Date: _____

Start: _____

Finish: _____

Age:	<4	5-11	12-18	18-25	26-65	66+
F						
M						

Group Type:

Family School Group Other: _____

Visitor Actions

□ Looked at flip labels before placing bird

□ Looked at flip after placing bird

□ Attempted to place a bird in a nest

□ Places a bird in the correct nest

□ Squeezed the birds to hear a sound

□ Able to self reset exhibit

Other…

Usability
Comments…

Visitor Conversation

□ Makes a comment that different birds have different homes

□ Makes a comment about a bird not being able to live in a home

□ Makes a comment about birds they have seen

□ Makes a comment about analogous habitats, (*this habitat is like that one because…*)

Other…

Appendix D
City Hot Zones OS

City Science – City Hot Zones
Observation Sheet

Version#: _____

Observation #: _____
Observer: _____
Date: _____

Start: _____

Finish: _____

Age:	<4	5-11	12-18	18-25	26-65	66+
F						
M						

Group Type:

Family School Group Other: _____

Visitor Actions
□ Attempted to build a neighborhood □ Looked at neighborhood through IR camera

□ Attempted to redesign neighborhood

Other…

Usability
Comments…

Visitor Conversation

□ Makes a comment that certain colors are hotter than others

□ Makes a comment about real world constructions associated with specific colors

□ Makes a comment about something that would make the city cooler

□ Makes a comment about health and heat

Other…

Appendix E
Facilitator Script

Introduction: All exhibits

"Hello, would you like to help us test an exhibit?"
"These are the first stages of a new exhibit we want to open in the museum and we need your help to make it better."

*If asked, explain IRB sign.

*"We are testing to see how exposure to ecological exhibits affects urban planning decisions. The feedback we get from you or your child is going to be part of a collaborative research effort and will be used in our study. If you would like to learn more you may take one of these *(hand visitor IRB information sheet)* and feel free to ask if you have any questions."

Magnetic Neighborhood

"At this station, we would like you to make the best neighborhood to live in using these magnets. This sign shows you all of the choices you have. You can place the magnets anywhere you would like on this cookie tray, there are only two rules: No overlapping, and it must fit inside the tray"
"If you can, talk aloud while you build your neighborhood and let me know what you are thinking as you place different pieces around the board."
"Feel free to stop whenever you want, let us know when you are done, we would like to ask you a few questions."

*Interviews will be conducted for Magnetic Neighborhood

Best Nest

"This station is all about bird homes, there are directions to the activity here [point]."
"Feel free to stop whenever you want, we are just going to take a few notes, let us know when you are finished."

*Ecological exhibits are observation only

Turtle's Eye View

"This station is about turtle habitats, where turtles live. There are the directions [point]."

"Feel free to stop whenever you want, we are just going to take a few notes, let us know when you are finished."

*Ecological exhibits are observation only

City Hot Zones

"At this station you can use these pieces to build a neighborhood. When you are done building your neighborhood we can turn on the sun and see how your neighborhood heats up in the summer. Can you make your neighborhood cooler?"

"Feel free to stop whenever you want, we are just going to take a few notes, let us know when you are finished."

*Ecological exhibits are observation only

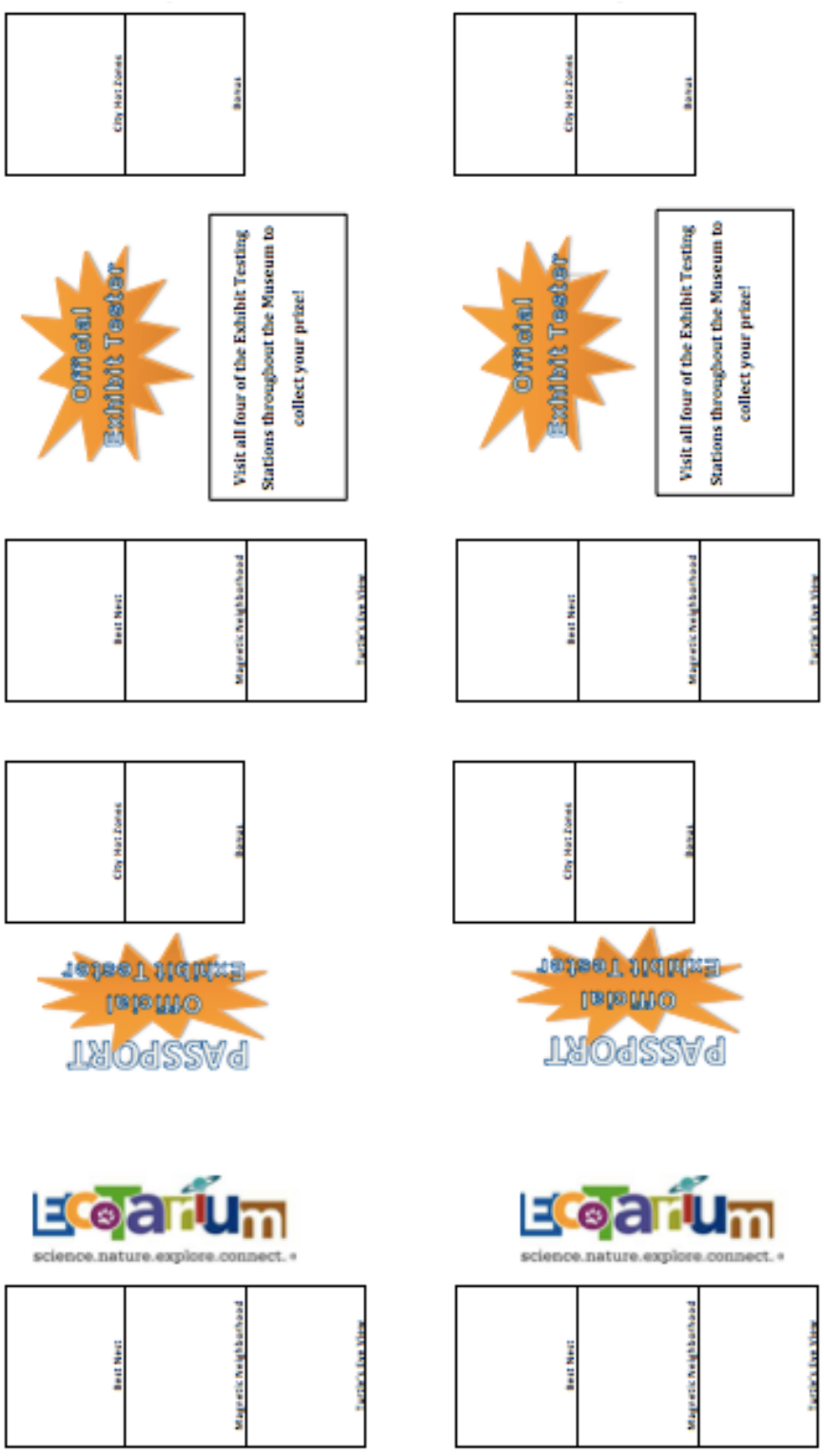
Closing: All exhibits

"Thank you for your help. Do you have a passport yet?"

No – "Ok well let's get you started. For each of these exhibits [points to passport] you visit throughout the museum you will get a stamp on your passport. Feel free to go to as many or as few as you would like. If you visit all four and fill up your passport you will get a special bonus prize. Your bonus prize can be picked up at the Magnetic Neighborhood exhibit after you have collected all of your stamps.

Yes – "Ok let me stamp it for you."

Appendix F
Passport



Appendix G
Passport Checklist

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

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Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Passport # ______

☐ Best Nest

☐ Turtle's Eye View

☐ City Hot Zones

Appendix H
Dimensions of magnets available for neighborhood construction

Piece	Size	Dimensions	Units	Category
Tray	N/A	13”x9”	468.5	N/A
Small trees	XS	1”x1”	4	Green Spaces
Solar panels	S	1.5”x1.5”	9	Buildings, Services & Utilities
Wind turbines	S	1.5”x1.5”	9	Buildings, Services & Utilities
House	S	1.5”x1.5”	9	Buildings, Services & Utilities
Store	S	1.5”x1.5”	9	Buildings, Services & Utilities
Museum	M	2.5”x2”	20	Buildings, Services & Utilities
Apartment	M	2.5”x2”	20	Buildings, Services & Utilities
Skyscraper	M	2.5”x2”	20	Buildings, Services & Utilities
Power plant	M	2.5”x2”	20	Buildings, Services & Utilities
School	M	2.5”x2”	20	Buildings, Services & Utilities
Fire department	M	2.5”x2”	20	Buildings, Services & Utilities
Place of worship	M	2.5”x2”	20	Buildings, Services & Utilities
Cemetery	M	2.5”x2”	20	Green Spaces
Flower Garden	M	2.5”x2”	20	Green Spaces
Lake/Pond	M	2.5”x2”	20	Green Spaces
Park	M	2.5”x2”	20	Green Spaces
Playground	M	2.5”x2”	20	Green Spaces
Roof garden	M	2.5”x2”	20	Green Spaces
Town square	M	2.5”x2”	20	Green Spaces
Vacant lot	M	2.5”x2”	20	Green Spaces
Vegetable garden	M	2.5”x2”	20	Green Spaces
Train station	M	2.5”x2”	20	Transportation
Parking lot	L	3”x2.5”	30	Transportation
Mall	L	3”x2.5”	30	Buildings, Services & Utilities
Hospital	L	3”x2.5”	30	Buildings, Services & Utilities
Airport	XL	4”x3”	48	Transportation
Small road	Strip M	4” x 0.5	8	Transportation
Large road	Strip L	8” x 0.5”	16	Transportation
Small sidewalk	Strip S	4” x 0.25”	4	Transportation
Large sidewalk	Strip M	8” x 0.25”	8	Transportation
Small bike path	Strip S	4” x 0.25”	4	Transportation
Large bike path	Strip M	8” x 0.25”	8	Transportation
Small river	Strip M	4” x 0.5	8	Green Spaces
Large river	Strip L	8” x 0.5”	16	Green Spaces

Appendix I
Summary and coding of data analyzed from neighborhoods and interview sessions

Neighborhood Design

- Volume of Buildings, Services & Utilities; Green Spaces and; Transportation
    - Each magnet has a specified value or number of units based on how much space it takes up on the board. The units for each category will be summed.
- Total space used
    - Total volume of all categories; Buildings, Services & Utilities; Green Spaces and; Transportation.
- Percentage green space (different than green space %)
    - The volume of green space will be divided by the total space used to quantify what percentage of total space used on the board is green space.
- Green space connectivity
    - This looks at whether or not green spaces are touching one another. If the neighborhood has 12 green spaces, how many connected clumps do they occur in?
- Green space variety
    - Number of unique elements used

Interview

- Do you live in the …?
    - City (CT)
    - Suburbs (S)
    - Country (C)
- What does the empty space you left in your neighborhood represent?
    - Green space (G)
    - Any man-made structure such as roads, buildings, houses, etc. (M)
    - Empty, or nothing (E)
    - Inconclusive or didn't answer the question (I)
    - No empty space left (N/A)
    - Visitor mentions both manmade and green as being in space (B)
    - Are participants that visited other ecological exhibits recognizing empty space as green space more often than those who did not?
- Type of green space
    - Does the participant make comments about green spaces being important for the environment/animals/habitat? (E)
    - Does the participant make comments about green spaces being important for human health/happiness/fitness/food source (H)
    - Inconclusive answer (Participant says they do not know or shrugs) (I)
    - Did not answer question (N/A)

    - Relates to interactives; participants who visit CHZ may list human health benefits; participants who visit TEV or BN may list environmental benefits. Is there a trend between interactives visited and these responses?
- # of reasons given for the inclusion of green spaces
    - How many distinct reasons do participants give for including green spaces?
- What animals do you think could live in your neighborhood?
    - Number of animals mentioned
        - Are participants that visited other ecological exhibits thinking more about wildlife in urban settings?
    - Local vs. Exotic
        - Local (L)
        - Exotic (E)
        - Both (B)
        - Are participants that visited other ecological exhibits listing more local animals?
    - Animals that couldn't live there
        - Did the participant list any animals that could *not* live in their neighborhood? (Y or N)
        - Are participants that visited other ecological exhibits recognizing that not all animals can live in a particular environment?

Actions/Conversation

- Made cost/benefit decisions
    - Picked pieces up and removed them, made comments about picking certain pieces over others, etc.
    - Are participants that visited other ecological exhibits displaying more thoughtful/planning behaviors?
- Comments on value of green space
    - Makes comments revealing the importance of green space

Appendix K
IRB notice accompanying all exhibits during August testing sessions

This Activity
is also part of a

Research Project*

about the kind of city people want in the future.

If you do not want your or your child's city design included in this research, please let us know.

Thank You for Your Help!

*National Science Foundation (NSF) Project DRL-1323168.

Appendix L
Informed Consent Form

Participation in a Joint EcoTarium/National Science Foundation Study
INFORMED CONSENT FORM

Principal Investigator:	Robert L. Ryan, University of Massachusetts Amherst
Grant Partner:	EcoTarium, Worcester, MA
Study Title:	Pathways: From the Lab to the Neighborhood: An Interactive Living Exhibit for Advancing STEM Engagement with Urban Systems in Science Museums
Sponsor:	National Science Foundation

Background and Study Population: This sheet describes the study so you can decide whether or not you would like to participate.
Purpose: To identify how viewing ecological exhibits affects the types of neighborhoods visitors design.
Study Procedures/ Timeframe: This part of the study will involve a total of four exhibit stations. At three exhibit stations Museum and University researchers will take observations of visitor interactions with exhibit components. At the fourth station Museum and University researchers will conduct one-on-one interviews with visitors in addition to taking observations. Interviews will take approximately 2-5 minutes. Visitors may participate in as many or as few of the interactive stations as they wish.
Study Benefits and Risks: While you and your individual group may not directly benefit from this study, the overall study results should be extremely useful for the City Science exhibit and environmental educators. The final study results will be available as both written articles, as well as on the project web page: www.umass.edu/urbaneco.
It is important to note that we will not share your comments directly with the University of Massachusetts, other government agencies or anyone else. We will report general findings from the range of interviews we conduct, without attributing comments or perspectives to any particular person. If we quote your comments in articles or reports, we will assign an alias to you, unless you directly ask us to use your name in published format. As such, we do not see any known risks to this study, except the time it takes for you to participate.
Furthermore, the following procedures will be used to protect the confidentiality of your study records. The researchers will keep all study records (including any codes to your data) in a secure location (locking file cabinet as an example). Research records will be labeled with a code. A master key that links names and codes will be maintained in a separate and secure location. The master key will be destroyed after six (6) years. All electronic files (e.g., database, spreadsheet, etc.) containing identifiable information will be password protected. Any computer hosting such files will also have password protection to prevent

access by unauthorized users. Only the members of the research staff will have access to the passwords. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations.

Voluntary Withdrawal: Please note that your participation in this study is voluntary. You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you may drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate.

Questions about This Study: We will be happy to answer any question you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the co-principal investigator, Prof. Robert L. Ryan, 413) 545-6633. If you have any questions concerning your rights as a research subject, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) at (413) 545-3428 or humansubjects@ora.umass.edu.

Child:

_____	_____	_____
Participant Signature:	Print Name:	Date:

* If child cannot sign their name parent may leave signature blank and print and date above.

Parent or Guardian:

By signing below I indicate that I have read this form, and will allow my child under 18 to take place in this study. By signing below I also indicate that the general purposes and particulars of the study as well as possible hazards and inconveniences have been explained to my satisfaction. I understand that I can withdraw my child at any time.

_____	_____	_____
Signature of Parent or Guardian	Print Name:	Date:

Appendix M
Letter sent to parents/guardians of study participants

RE: Your child's participation in a city planning research project at the EcoTarium.

Dear EcoTarium Parent or Guardian

During your child's visit to the EcoTarium, he/or she can participate in a research project that studies how viewing ecology exhibits effects how people design their ideal neighborhood. The study will involve 4 different exhibit stations. At each station researchers will be observing how children interact with the activity and at one station, researchers will also be conducting a short 6-question survey. This activity is designed to help city planners make decisions about designing cities in the future. Each activity station takes around 3-5 minutes and all are designed to be fun. It is not a test – there are no right or wrong answers.

Because this activity is part of a University of Massachusetts, Amherst research project, we would like your permission for your child to participate, so that we can include their answers and ideas in our study. All answers are anonymous - we do not include any names of the children in our research. If you would like your child to be included in this study please read through and sign the attached permission slip.

Your child can still participate in the activity without a permission slip, if he or she wants, but we will not include their answers in our research.

After the activity, the group will be free to explore the rest of the EcoTarium.

If you have any questions, you can ask us when you are at the EcoTarium or give us a call or e-mail, we are happy to answer.

Many thanks for your help,

Robert L. Ryan
Professor
University of Massachusetts, Amherst
Tel: (413) 545-6633
rlryan@larp.umass.edu

Betsy Loring
Director of Exhibits
EcoTarium
Tel: (508) 929-2778
bloring@ecotarium.org

If you have any questions concerning your and your child's rights as a research subject, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) at (413) 545-3428 or human subjects@ora.umass.edu.