# Supporting Learners through a Spectrum of Interactivity

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In this exhibit, visitors could pose for a photo with a human-scale model of the robot, WALL-E.

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## Introduction

In developing any exhibition, it is essential to consider the broad range of interests, abilities, knowledge, and experiences of potential visitors. This is especially important when creating exhibitions with high levels of interactivity. Providing an array of activities that range from less to more interactive helps museums better support the needs and preferences of all types of visitors and creates opportunities for deeper engagement within their exhibitions. This article will showcase research and evaluation findings from two studies of *The Science Behind Pixar* (*Pixar*), a traveling exhibition that demonstrates how providing varying levels of interaction helps to engage visitors in gratifying and meaningful ways.

## Exhibition Background and Methods

*The Science Behind Pixar* was developed by the Museum of Science, Boston (MOS) in collaboration with Pixar Animation Studios, the computer animation film studio based in Emeryville, California. The 13,000-square-foot exhibition presents the computer science, math, and science skills that go into creating Pixar's animated films.[1] The exhibition was arranged into eight sections, each focusing on a different phase of Pixar's development process (fig. 1). Visitors entered the exhibition through the "Intro Theater," where they watched a five-minute movie that introduced the main ideas and oriented visitors to the activities within the exhibition. Following the "Intro Theater," the exhibition was organized around eight steps of Pixar's animation process: Modeling, Simulation, Animation, Surfaces, Lighting, Rigging, Sets & Cameras, and Rendering. Each section had five to eight exhibits including:

- a large scale immersive introduction, such as the three-foot high model of the fish Dory from *Finding Dory*, where visitors could play with lighting effects;
- four two-minute videos in which Pixar employees describe a problem they needed to solve, such as how they simulated curly hair in *Brave*;
- a behind-the-scenes story, such as how they created the sparkle for virtual car paint in *Cars*;
- interviews with staff on how they came to do what they do; and
- a variety of physical and digital activities where visitors could try for themselves some of the tasks and skills involved in making a virtual 3D animated film.[2]

To describe the types of interactivity built into the exhibition and how interactivity impacted visitors' engagement, we will be drawing on the following two studies: a National Science Foundation-funded research project conducted as part of the exhibition's development and the summative evaluation of the exhibition.

*Building Computational Thinkers through Informal Exhibit Experiences* (*Building Computational Thinkers*) was a research study that began in 2013 to explore how to effectively support the practice of computational thinking skills and increase visitors' capacities in these skills, given the needs of visitors with novice- to expert-level background knowledge.[3] The construct of computational thinking has been characterized as the "thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent."[4] Research participants included youth in grades six to 12 who were novices with little to no computer programming experience and experts of varying ages with extensive computer programming experience. During this research project, participants provided feedback about the exhibits and their experiences through retrospective think-aloud interviews, as well as pre-, post-, and extended-post surveys.

The summative evaluation of the *Pixar* exhibition studied visitor behavior in the space, identified which exhibit features worked for different visitor groups, assessed the extent to which the exhibition met developers' goals, and informed future exhibition development. One of the exhibition's goals was

1 *The Science Behind Pixar* first opened at MOS in June 2015 and is scheduled to tour nationally and internationally through 2027.

2 A companion website, www.sciencebehindpixar.org, describes the sections and examples of the digital interactives and videos.

3 NSF project number: CNS1339244.

4 Jeannette M. Wing, "Research notebook: Computational thinking – what and why?" *The Link: News from the School of Computer Science* (Spring 2011): 20–23.

fig. 1. This floorplan as it was installed at the Museum of Science, Boston shows how the exhibition was arranged around the eight steps of Pixar's process.


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fig. 2. Visitors collaborated as they took photos of a posed lamp to create their own stop-motion animation movie in "Stop-motion Animation."


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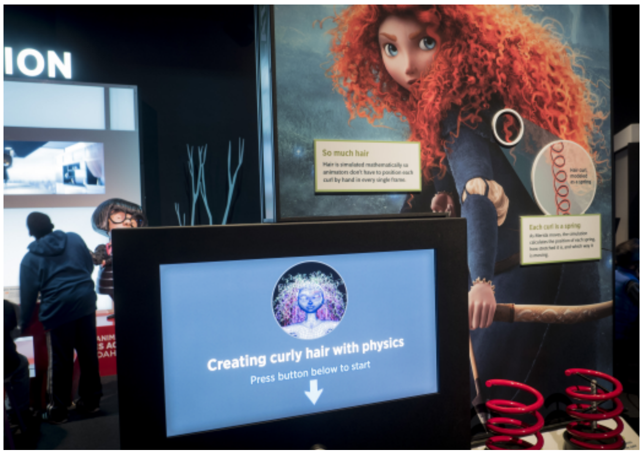


fig. 3. "Pixar's Simulation Challenge" focused on how employees at Pixar Animation Studios addressed the challenge of creating Merida's curly hair in the film *Brave*.

to demonstrate the main message that art, technology, science, and creativity are inseparable in animation. We also hoped, among other things, that visitors would have increased knowledge and understanding of the core STEM content that underlies computer animation. And we wanted to positively increase visitors' attitudes about their ability to learn those concepts.[5] In this study, we solicited feedback from many audience segments, but the findings in this article will detail information learned from visitors with differing abilities and from general public visitors, who were categorized into three audiences:

- groups with children seven and under;
- groups with youth aged eight to 17; and
- adult-only groups.

Science centers often intentionally create exhibitions with varying levels of interactivity. These research and evaluation studies support this intention by using data to demonstrate that varying levels of interactivity are essential within an exhibition experience to heighten the likelihood and opportunities to capture the attention of more visitors and meaningfully engage them.

## Key Findings

### *Varying Interactivity Levels Met the Needs and Preferences of Multi-Generational Audiences*

By including a range of experience options with varying interactivity levels, the exhibition helped to meet the developmental and experiential needs and interests for a variety of visitor groups. Summative evaluation data showed, for example, that groups who visited with children seven and under were most often drawn to the human-scale, character models (imagine a five-foot-tall Buzz Lightyear). Although these exhibits provided low-level interactivity, these groups enjoyed observing and taking photos with models of familiar characters from their favorite movies. These groups were also drawn to interactive activities that provided kinesthetic experiences or tactile models, such as "Build a Robot," where they could pick up or build with pieces to understand the exhibit's physical task and content.

In contrast, groups that included youth aged eight to 17 had longer average dwell times at physical and digital activities than other groups. For example, youth experienced their highest median dwell time of three minutes and eight seconds at "Stop-motion Animation" (fig. 2), a highly interactive, physical activity in which visitors made their own stop-motion animation with a poseable lamp.

Adult-only groups were found to be the most "diligent" of all visitors in *Pixar*, as they participated in all exhibit types regardless of the interactivity level, and had the highest average time spent in the exhibition at one hour and three minutes.[6] At "Pipeline," an exhibit which showed a short movie clip of each of the nine stages of movie production, adult-only groups frequently engaged in discussion and stayed at this exhibit for close to their longest median dwell time at two minutes and three seconds. Adult-only groups also watched exhibition videos more than any other groups, spending almost a third of their time at video-based exhibits (fig. 3).

### *A Spectrum of Interactivity Supported Universal Design*

Different exhibit types and design strategies with diverse sensory cues appealed to visitors (and their group members) with differing abilities and disabilities. While interactivity can enhance a learning experience if it is the right type or right level of interaction, too many highly interactive features can overwhelm these visitors, disrupt their experiences, make critical tasks or features difficult to find, and make it harder to focus attention on the salient factors.[7] From a universal design perspective, over-reliance on one mode of communication is problematic when considering the needs and preferences of visitors with differing abilities. Varying levels of interactivity and

5 Clara Cahill, Leigh Ann Mesiti, Sunewan C. Paneto, Sarah Pfeifle, and Katie Todd, "The Science Behind Pixar Summative Evaluation Report" (Summative report, Boston: Museum of Science, Boston, 2018).

6 Beverly Serrell, "Paying More Attention to Paying Attention," *Informal Science*, last modified July 8, 2016, http://www.informalscience.org/news-views/paying-more-attention-paying-attention. Beverly defines "diligent visitors" as those who engage with more than half of the available exhibit experiences.

7 Sue Allen, "Designs for Learning: Studying Science Museum Exhibits That Do More than Entertain," *Science Education* 88 (2004): S17-S33, https://doi.org/10.1002/sce.20016.

sensory cues in an exhibition support as many people as possible to participate in and learn through their exhibit experiences.

To understand the impact of universal design on Pixar, the summative evaluation captured the experiences and perspectives of visitors with differing abilities. Results showed that these individuals and their groups experienced the exhibition in different ways. For example, Marcia,[8] a 26-year-old with Autism Spectrum Disorder and sensory sensitivities, relied on the consistent and familiar presence of videos, which had a moderate level of interactivity. While exploring each area, Marcia gravitated towards the videos to keep from getting overwhelmed by the exhibition's active environment. Marcia had extensive knowledge about the exhibition's content, and the videos intellectually engaged her without overstimulation.

Alternatively, Mitchell, an eight-year old boy with learning disabilities and sensory processing issues, was attracted to the multisensory aspects of highly interactive exhibits. At "Rotated Shapes" (fig. 4), Mitchell manipulated the tactile model and exhibit controls. When he physically rotated a rectangle and saw a cylindrical battery image emerge on screen, he exclaimed to his mother, "I made a battery!" Mitchell's mom encouraged him to apply what he had learned to predict other shapes, asking, "What do you think this shape is going to be?" as Mitchell started to use other controls. At this exhibit, Mitchell used his whole body to create shapes, seemingly intent and focused.

These two examples illustrate how dissimilar exhibit experiences capture attention differently, facilitating learning across visitors with differing abilities. Some visitors are attracted to less interactive components that include intense, content-focused interactions, while others attend to more fully interactive exhibits that engage their entire bodies.

### *Other Benefits of Including Exhibits with a Range of Interactivity*

As a traveling exhibition with timed tickets, it was important to keep visitors moving through *Pixar*.

8 Pseudonyms have been used to protect study participant identities.

We designed the human-scale models to be less interactive "quick hits" and photo-ops (intro image), and placed them strategically in each installation along prime sight lines near the front of each content area to draw visitors into and through all corners of the exhibition. We placed the minimally-interactive, two-minute videos close to highly interactive exhibits to capture the attention of visitors' queueing nearby. We presented each of the main messages in many ways across the multiple types of interactions so that visitors who preferred one type over another could still access the same big ideas. These design strategies helped visitors successfully navigate the exhibition by mitigating the cognitive load of moving through a busy space and providing opportunities to access content while waiting their turn at the most visited exhibits.

In the summative evaluation, *Pixar* attendees reported that their prime motivation for visiting the museum was to spend time together as a group. Offering a range of interactivity in *Pixar* created diverse opportunities for general public visitors to socially engage with their group members. Some exhibits, such as "Stop-motion Animation," provided a collaborative, full-body experience. This highly interactive exhibit allowed group members to assume different roles to work toward a common goal. Other exhibits had large screens that enabled many visitors to engage together with the projected images. And, where smaller, computer-based interactives could only accommodate one or two visitors, duplicate copies were placed nearby, allowing group members to interact simultaneously and share their work.

### *While Varying Levels of Interactivity May Present Challenges, Other Design Strategies Can Support Visitor Engagement*

In *Pixar*, we aimed to highlight how animators use problem decomposition in their filmmaking work. Problem decomposition, a computational thinking skill,[9] refers to breaking down a problem into discrete steps that, ultimately, can be communicated to and carried out by a computer. We articulated three specific approaches for conveying problem decomposition as part of our *Building Computation Thinkers* research study:

9 Shuchi Grover and Roy Pea, "Computational Thinking in K–12: A Review of the State of the Field," *Educational Researcher* 42 (2013): 38–42.

fig. 4. As visitors rotate a physical shape, they could see it turn into a virtual 3D object on the screen in front of them in "Rotated Shapes."

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…dissimilar exhibit experiences capture attention differently, facilitating learning across visitors with differing abilities.

fig. 5. Examples of three approaches to conveying computational thinking content (left to right): "Pixar's Modeling Challenge," a multimedia narrative (video); "Lighting Effects Basics," a solution exploration; and "Crowd Simulation Workstation," a creative design activity.


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fig. 6. In "Crowd Simulation Workstation," the problem of designing a school of fish is broken down into three parameters (distance between fish, number of groups, and match the direction of other fish) that visitors can modify.


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- “multimedia narratives” used a narrative structure and direct instruction through two-minute videos to present a problem and its solution;
- “solution explorations” allowed visitors to explore and reconstruct an expert’s solution to a complex problem; and
- “creative design activities” offered a more open-ended exploration as visitors created and designed solutions to their own goals (fig. 5).

These exhibit approaches were intended to be broadly applicable across many contexts, including formal education settings. We developed six exhibits inspired from these three specific design approaches (two of each), in addition to implementing these principles throughout the exhibition.

By studying these six exhibits in an early phase of the research study, we identified disparities in how novice and expert participants comprehended and engaged with exhibits that incorporated computational thinking approaches. Although the varying levels of interactivity were intended for all exhibition visitors, some novices had trouble figuring out how to get started, and with their conceptual understanding of the creative design activities.

These challenges were particularly true in “Crowd Simulation Workstation,” where visitors manipulate sliders to change an animation of how fish schooled (fig. 6). To lower the barrier of entry to understanding computational thinking content in this highly interactive, creative design activity, we embedded programming-specific language, such as “variables” or “parameters,” into the activity so that visitors would associate these terms to the activities in which they were engaging. We also subtly pointed to underlying mechanisms of the program by adding numbers that changed when visitors moved the sliders. By connecting their tactile motions to these visual number changes, visitors understood how their actions affected the program they were manipulating. In final design, these embedded design strategies were incorporated into all of the computational thinking approaches to better support novices, regardless of background knowledge, to engage with the exhibits conveying problem decomposition content.

## Conclusion

Spatial and experiential design plays an important role in how multiple visitor audiences engage with exhibitions and what they learn from them. *The Science Behind Pixar* provided rich examples of how a broad spectrum of interactivity supported the diverse needs of multigenerational visitors, novice and expert users, and visitors with differing abilities. Remarkably, while the summative evaluation showed that many exhibits resonated with visitors as being memorable and interesting, no single exhibit emerged as the most iconic. This finding may have been because there was such variety of interactive experiences that appealed to visitors with different needs, desires, and background knowledge. Providing a spectrum of interactivity can be challenging because some experiences might work well for one audience but not work well for another. However, providing a range of experiences that address similar topics and themes can help maximize connections with visitors.

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