Creativity Workshop
Stage I Prototyping
Formative Report

Report Written by Anna Lindgren-Streicher
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Research and Evaluation
Museum of Science
Science Park
Boston, MA 02114
(617) 589-0302
E-mail address researcheval@mos.org

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INTRODUCTION

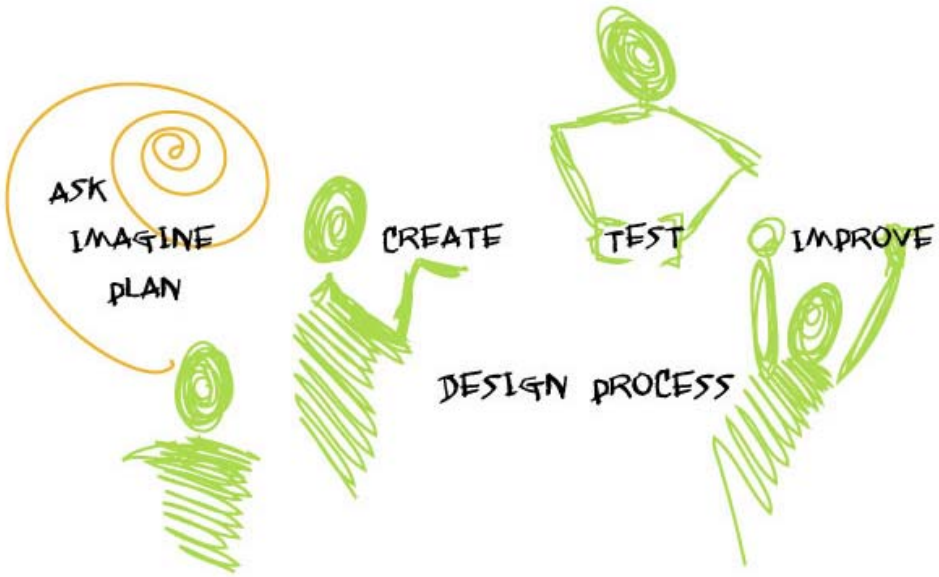
ABOUT THE EXHIBITION

Creativity Workshop (working title) is planned to be an approximately 4,000 square foot permanent exhibit that is part of the Museum of Science's Technology Initiative. The exhibit aims to have visitors participate in interactive activities, allowing them to experience for themselves the engineering design process and creative problem solving techniques. The exhibit will be organized into three main areas:

- "Inventors' Tools," which will introduce visitors to creative thinking tools that can be used to design new technologies and solve technological problems;
- "Engineering Design," which features Engineering Design Labs (EDLs) that give visitors the opportunity to engage in engineering design to solve a given problem; and
- "Art and Technology," which will feature a large multi-media installation that incorporates technological aspects.

Stage I (proof of concept) prototyping, and consequently this report, focused on the "Inventors' Tools" and "Engineering Design" areas of the exhibit. An Inventors' Tool component typically includes a description of the Tool itself, a hands-on activity that illustrates the Tool, and a real-life inventor's story of how the Tool has been used in the real world. An Engineering Design Lab aims to engage visitors in the engineering design process (Figure 1) in order to solve the problem posed at the EDL. Since engineering design is an iterative process, the EDLs are intended to engage visitors in multiple rounds of the design process at any one EDL.

FIGURE 1. Illustration of the engineering design process used in the *Creativity Workshop* exhibit.



The *Creativity Workshop* exhibit is guided by the following educational goals:

- Visitors will learn that technology is the result of the human ability to be creative.
  - Visitors will be inspired by what others have created.
  - Visitors will recognize their own potential to design and/or invent.
- Visitors will learn about and/or experience creative thinking tools.
  - Visitors will learn how these tools can help you solve an existing problem or spark an idea for a product for which there is not yet demand.
- Visitors will create an object or system using the engineering design process.
  - Visitors will understand that there is no perfect design; all design involves tradeoffs based on human preferences.
- Visitors will see that art and technology are related.
  - Visitors will learn that design, whether of a piece of artwork or a new technology, is a creative process.
  - Visitors will learn that art is created using technologies, and will consider whether the resulting creations are also technology.

The following exhibit messages have also guided development:

- Main Message
  - I can have fun playing with, understanding, and creating technologies.
- Supporting Messages
  - I can design technologies using the same processes engineers and inventors use.
  - Designing art and designing technology both require creativity.
  - Everyone, including me, can be creative.
  - There can be many different solutions to the same problem.
  - I can understand how technologies work.

ABOUT THIS REPORT

This report provides a summary of the findings from the testing of Stage I prototypes for the *Creativity Workshop* exhibition. Separate documents created by the exhibit development team describe in more detail the educational goals, messages, and organization strategy of this exhibition, and the process by which those were determined. While evaluation findings, as covered in this report, are an important factor in determining which exhibit components move from Stage I (proof of concept) to Stage II (beta testing), they are not the only factor. This report does not address technical feasibility or other design constraints that are also used to make these decisions.

This report continues with a description of the methods used in this formative evaluation. The Findings section includes a summary of each component that was tested as a Stage I prototype (as written in Component Information Sheets by Alana Parkes, Ed Rodley, and Susan Timberlake), a photograph of the component (courtesy of Emily Roose and Peter Ford), a summary of evaluation findings, and a list of recommended changes for that

particular component. Recommended changes were formulated based on data collected through prototyping, which were then brought to the exhibit team and discussed within the context of the individual component's educational goals and the larger context of the exhibition. The Discussion summarizes some of the larger lessons learned through Stage I evaluation, and highlights areas to focus on in Stage II testing.

METHODS

Stage I of prototyping is used to determine if an early version of a component is meeting its goals – to test for the "proof of concept" for the component. These prototypes are generally less expensive table-top designs, and are tested as individual components rather than as larger exhibitions. By systematically observing and interviewing visitors as they use early exhibit prototypes, information can be collected about the educational, behavioral, or motivational impact of an exhibit, as well as the effectiveness of communication methods chosen for an activity, even if smaller numbers of participants, like 10 visiting groups, are used (Screven, 1999; Taylor, 1991).

While Stage II (beta testing) of prototyping focuses on stand-alone components, this stage of evaluation was conducted with exhibit developers (Alana Parkes, Ed Rodley, and Susan Timberlake) or Design Challenges staff facilitating the activity. Using facilitators in Stage I allows prototypes to be developed more quickly and inexpensively, and if a component is not able to meet its educational goals while being interpreted by a staff person, it is unlikely that it can function as a stand-alone exhibit. Based on Stage I data, as well as educational factors, technical feasibility, and maintainability of each component, the exhibit team has made decisions as to which components will move into Stage II prototyping.

The main methods used for this formative evaluation were visitor interviews and observations. During prototyping periods, the doors to Stearns Hall were opened and visitors were allowed to enter and use any component(s) they wanted for as long as they liked – all observations and interviews were uncued. (See Figure 2 for a photograph of one iteration of the prototyping space.) The evaluator observed visitors as they used the component and interviewed them following their interaction. The interviews focused on visitor reaction to the component, visitor interest in the content, identifying early usability issues, and uncovering if the component was meeting its educational goals. Over the course of Stage I prototyping, the thirteen prototypes discussed in this report were evaluated by 150 visitor groups, which included 426 visitors.

FIGURE 2. The *Creativity Workshop* prototyping space in Stearns Hall (May 2008).

In addition to the observations and interviews conducted, comment cards were used to collect additional information. The comment cards were placed by the exit from the space, along with pencils and a sign encouraging visitors to help us improve the exhibits by leaving their comments. The comment cards asked visitors to report on which of the components they had visited, as well as their favorite thing in the exhibit and what we should change about the exhibit. A total of 96 comment cards were collected over ten days.

FINDINGS

This section of the report includes a summary of the findings for each component and the team's decision as to whether or not the component should move on the Stage II of prototyping. The components are discussed in terms of the two primary categories: Inventors' Tools and Engineering Design Labs.

INVENTORS' TOOLS

Although all of the prototypes tested in Stage I require revision and refinement, several of the Inventors' Tools require only fairly minor changes or additions to the core concept of the activity to successfully transition to Stage II prototyping – Exhaustive Search, Challenging Assumptions, Paying Attention, Making Analogies, and Combining. The final two Inventors' Tools prototypes, Repurposing and Breaking Down a Problem, showed potential in prototyping, but require major changes to meet the stated educational goals.

1. Exhaustive Search

This component illustrates the Inventors' Tool of exhaustive search. Sometimes, when other inventors' tools fail, you can do an exhaustive search, systematically testing a large number of possible solutions. This activity featured a flat table-top "testing board" used to test a large number of blocks that are indistinguishable in appearance. Visitors move the blocks across the testing area to look for a "hit," which is indicated by the block lighting up and vibrating. This component also included a video of High-Throughput Screening, used to discover new drugs, and sections from Thomas Edison's notebook that recorded his extensive search for the right material for a light bulb filament.

1.2 Summary of Exhaustive Search evaluation findings

This activity was tested with 23 visitors in 11 groups ranging in size from two to four people.

Visitor Behaviors & Skills

All (11 of 11) of the groups tested the blocks as intended, with 8 of the 11 groups finding a "hit" and 6 of these 8 groups continuing to search for another "hit" after they found their first one. Although all of the groups used the activity as intended, three parents of young children and three children ages 11-13 wanted clearer directions for the activity. Visitors of all ages, but especially younger children, enjoyed the "payoff" of having the block light up & buzz

with a hit, such as one seven-year-old girl who said, "I liked when it lighted up when you saw the drug." This was also true of the two groups of students with multiple disabilities (physical, cognitive and sensory) that used the prototypes.

Message & Learning

Visitors connected the activity to the specific inventors' stories given or the trial & error that can go into a new invention. Visitors in 4 of 8 groups said that the activity showed the process of finding new medicines or inventing the incandescent light bulb, such as the woman in her 30s who said, "I didn't read the whole thing, but about finding new drugs." Another three groups discussed the more general process of trial & error or the "science and research" that goes into new inventions, such as the woman in her 40s who said the activity was trying to show that, "for all the great inventions, there's a lot of science and research that goes into them." One visitor that identified both of these aspects of the activity was a 12-year-old boy who said the activity showed "how much trial and error it takes to make a discovery, like with medicine."

1.3 Recommended changes to Exhaustive Search for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- To strengthen the message of this activity, draw on visitors' pre-existing understanding of "trial and error" and contrast this with how inventors and engineers use "exhaustive search." Explicitly mention "exhaustive search" in the inventors' story labels, and add a real-world context to strengthen visitors' understanding of this Inventors' Tool.
- To improve the usability of this activity, consider making the "Hints" flip label a part of the instructions and add a graphic that illustrates how to test the blocks.

2. Challenging Assumptions

This component illustrates the Inventors' Tool of challenging assumptions. People often hold assumptions about problems that make them more difficult to solve – identifying those assumptions and questioning if they are necessary can make the answer easier to find. This activity is based on three "lateral thinking" puzzles. Two involved rearranged colored cardboard shapes to form another shape ("two Hs" and "square"). The third involved moving glasses of "milk" (white beads in plastic cups) to form a specific pattern. This activity was facilitated by a staff member who introduced the idea of "challenging assumptions" and then introduced each individual puzzle, as visitors indicated interest. As visitors asked questions or had difficulty

completing the puzzle, the facilitator gave hints, without providing an answer, to help solve the puzzle.

2.2 Summary of Challenging Assumptions evaluation findings

This activity was tested with 24 visitors in nine groups, ranging in size from one to four visitors.

Visitor Behaviors & Skills
Each group attempted between one and three of the three puzzles. The "two Hs" puzzle required the most hints from the facilitator, followed by the "square" puzzle then the "milk" puzzle. In addition, two of the groups that used the "two Hs" puzzle felt as though they found a solution, although it was not the intended solution. Groups' description of the activity showed some confusion as well as enjoyment, such as a ten-year-old girl who said it was, "challenging, but good to think […] in different ways, and of different things," and a nine-year-old girl who said it was, "confusing – just confusing enough. It means what it says, but in a different way."

Message & Learning
All (8 of 8) groups said that they learned to think of or look at things in a different way, such as an 11-year-old boy who said that he learned, "you have to think in a different way. Think outside the box." Several (3 of 8) visiting groups also naturally made connections to the larger theme of the Inventors' Tools area, such as the female in her 40s who said that the activity "demonstrates innovation and thinking outside the box."

2.3 Recommended changes to Challenging Assumptions for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- Decrease visitor frustration and confusion by replacing the "two Hs" puzzle with an easier puzzle and labeling the puzzles as "easy," "medium," and "hard" to allow visitors to choose the activity based on difficulty.
- To make steps towards universal design, where possible, increase the emphasis on non-visual elements of the puzzles should be increased.
- Although visitors connect this exhibit to the concept of how inventors get their ideas, further strengthen this connection as well as the connection to specific inventors' stories.

3. Paying Attention

This component illustrates the Inventors' Tool of Paying Attention. Inventions can be inspired or significantly altered by unexpected discoveries and fortunate accidents, but this can only be taken advantage of if an inventor is on heightened awareness for these accidental discoveries that contain key insights. Two different versions of this activity were prototyped, both of which centered on videos used to research the visual cognition concepts of inattention blindness and change blindness. In the first round of prototyping, the activity focused on whether or not the videos would be effective in a museum setting. In the second round of prototyping, the videos were put in the larger context of an Inventors' Tool.

3.2 Summary of Paying Attention evaluation findings

Over the two iterations of this activity, it was tested with 55 visitors in 17 groups, ranging in size from one to seven visitors.

Visitor Behaviors & Skills

Visiting groups were very engaged in the videos presented in both rounds of prototyping, with all (17 of 17) of the groups watching multiple videos, and most groups (15 of 17) watching at least one video multiple times. Groups typically (in 35 of 44 interactions) watched a video until at least one person in the group spotted the change in the video. During the first round of prototyping, a few of the groups (3 of 11) found some of the tasks difficult, although also "interesting" and "utterly engaging." Issues involving the difficulty of the task did not arise during the second round of prototyping.

Message & Learning

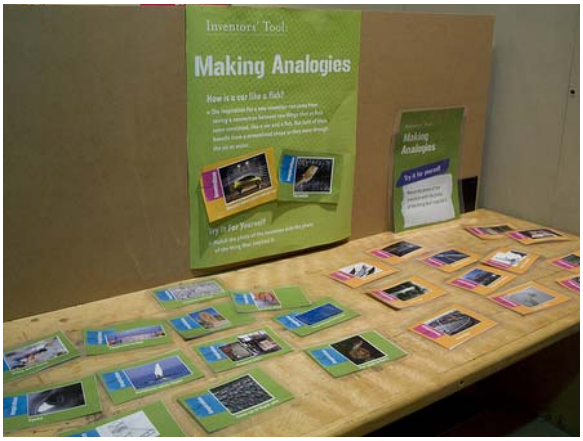
In the first round of prototyping this activity, when the videos were not presented in the context of an Inventors' Tool, few (3 of 11) groups interviewed made a connection between the activity and inventing. However, when presented as an Inventors' Tool in the second round of prototyping, visitors believed that the activity illustrated two different messages – that sometimes inventors get their ideas "by paying attention to details" or "by accident, when you're trying to do something else."

3.3 Recommended changes to Paying Attention for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- Based on which of the two types of activity (inattention blindness or change blindness) they engaged in, visitors are taking away two different messages. These two messages should be reconciled or better connected.
- To further reinforce the connection of this component as an Inventors' Tool, the non-video content, such as instructions and an inventors' story, should be emphasized.
- This activity was engaging enough that it is moving away from the "quick hit" model that the Inventors' Tools are intended to be. Capping the number of videos available for visitors to view should minimize this problem.

4. Making Analogies



This component illustrates the Inventors' Tool of making analogies, in which the inventor gets an idea for a design by noticing a similarity or resemblance to a technology or object in nature that is otherwise not alike. The activity at this component is based on 12 "Invention" and "Inspiration" cards which match up in pairs. The facilitation of the activity varied between two different prototyping sessions. In both sessions, the facilitator gave an introduction to what "making analogies" meant as an Inventors' Tool. As visitors began pairing cards together, they were either cued that one card had a hint on the back and the other had the answer, or given a hint directly from the facilitator. Visitors sometimes shared their thoughts on the analogies with the facilitator, who also asked questions and provided additional hints when visitors had questions or were making an unintended pairing of cards.

4.2 Summary of Making Analogies evaluation findings

This activity was tested with 21 visitors in ten groups, ranging in size between one and four visitors.

Visitor Behaviors & Skills

Most visitors engaged in the activity and matched all of the pairs of cards presented, but several visiting groups walked up to the activity, quickly scanned the introductory text, and walked away without engaging in the matching activity. While several visiting groups (4 of 10) thought the activity was "challenging" and "made you think," they all agreed that the balance between easier and more difficult pairs of cards was good. Children aged 10 and under required more direct facilitation from the staff member or a parent, while children 11 and up were generally able to complete the activity with about the same level of facilitation as adults.

Message & Learning
Visitors made strong connections to the message of this activity, with most visitors (7 of 10 groups) recognizing that ideas for inventions can come from "simple" or "everyday" things, or saying that the activity made them recognize connections they had not thought of before.

4.3 Recommended changes to Making Analogies for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- Getting a hint from the facilitator without receiving the full correct answer was an important part of the interaction at this activity. Systems for delivering hints at an unfacilitiated exhibit should be explored.
- To make the activity more multi-modal and universally designed, and also potentially make it appeal to a broader audience, test adding artifacts, tactile representations, or videos of the featured inventions and inspirations to the cards where possible. This change will hopefully also have the effect of attracting more people to engage with the component, which should be more closely examined in Stage II.

5. Combining

This component illustrates the Inventors' Tool of combining, in which an invention is developed by combining two existing inventions. Visitors were presented with a wide variety of objects, from an MP3 player to a toothbrush, and asked to combine at least two of the objects into a new invention. Prototyping of this component explored two different types of challenges to drive the activity – one type of challenge asked visitors to solve a specific problem (e.g., to develop an invention to help keep bugs off of your plate at a picnic), while the other type of challenge asked visitors to think of as many inventions as they could that involved combining with one specific technology (e.g., a teddy bear).

5.2 Summary of Combining evaluation findings

This activity was tested with 56 visitors in 21 groups, ranging in size from one to three people, over three days.

Visitor Behaviors & Skills
Of the 21 groups observed at the activity, 16 created an invention. Visiting groups liked being able to make their own invention (8 of 16 groups), such as the 11-year-old girl who said, "I like that there are a lot of choices, we get to make our own thing." However, some (5

of 21) groups did not invent anything, and four of these groups said that they did not know what to do or did not understand the activity. Several (5 of 21) visitor groups also thought the presentation of materials for the activity was not well-organized. Visitors seemed eager to share their inventions, whether with the facilitator (9 of 21), another person in their group (10 of 21), or on a piece of paper left at the component (2 of 21).

Message & Learning

Visitors who engaged in this activity connected this activity to inventing (8 of 16), such as a woman in her 60s who said the activity was about, "the idea of inventions, how to start to invent things." Visitors also connected the activity to thinking creatively (4 of 16), and some groups mentioned that the activity made them look at common objects differently (2 of 16). Visitors (7 of 14) also said that the learned about "how to think of something new" or create a new invention.

5.3 Recommended changes to Combining for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- In order to engage more groups in creating an actual invention, the goal of the activity needs to be more clearly introduced to visitors as they approach.
- Better organization of the objects presented for combining will minimize it being viewed as a "table of stuff," which lead to confusion for some visitors.
- To take advantage of visitors' desire to leave behind a record of their invention, a system for visitors to record their invention and see what other visitors have created should be tested.

6. Repurposing

This component illustrates the Inventors' Tool of repurposing, where inventors find new uses for existing technologies. In this component's activity, visitors were presented with a door that banged into a wall as it opened. They were challenged find as many ways as possible to keep the doorknob from banging into the wall.

6.2 Summary of Repurposing evaluation findings

This activity was tested with 21 visitors in eight groups, ranging in size from one to four visitors.

Visitor Behaviors & Skills
Each of the eight groups that used this activity attempted the tennis ball activity and came up with at least two solutions. Groups most commonly found three solutions (4 of 8 groups), and one group found five possible solutions. The overall level of difficulty of the activity was appropriate, and visitors age eight and up were able to successfully participate.

Message & Learning
All of the groups discussed "using things in different ways" or "using a common object in different ways" in their interview. However, visitors tended to focus on the specific activity, or the other inventions presented that used tennis balls, without making the larger connection to how inventors get their ideas.

6.3 Recommended changes to Repurposing for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- To strengthen the connection to the larger idea of how inventors get their ideas, increase the emphasis on the Inventors' stories that are not tennis-ball related.
- To help visitors make broader connections that they can relate to, consider either asking them to use a tennis ball to solve another everyday problem, or use different everyday objects to solve the same door-slamming problem.

7. Breaking Down a Problem

This component describes and illustrates the process of breaking down a complicated thing into simple principles or mechanisms. For the activity, visitors were given photos of three seemingly unrelated objects: a screw gun, a wind turbine, and a pager. They were then asked which of the following features was part of the following objects: an on/off switch, a power source, a mechanical/ electrical power converter, a way

to store and release energy, and a rotating shaft. Prototyping also experimented with presenting visitors with the component parts and asking them to think of an invention, but this approach was not effective in communicating this particular Inventors' Tool and was quickly abandoned.

7.2 Summary of Breaking Down a Problem evaluation findings

This activity was tested with 32 visitors in 12 groups, ranging in size from one to five visitors.

Visitor Behaviors & Skills
Visitors frequently realized (7 of 10 groups), that the three different technologies presented had the same component parts, although six of these seven groups received hints from the facilitator to come to this realization. Facilitation was required in order for visitors to understand what exactly the component parts were, especially the "mechanism to store and release energy" and "a mechanical/electrical power converter."

Message & Learning
Visitors came away from the activity with the understanding that complex objects can be broken down into simpler individual parts (6 of 9 groups), such as a twelve-year-old who said "complex objects can be broken down into simpler individual parts." Visitors (6 of 9) also said they learned about a specific technology, or components within that technology, such as the ten-year-old boy who said he learned that, "the pager, that the rotating shaft makes it vibrate. And the fancy name for a windmill is a wind turbine." Some visitors also said they learned that "different things have the same parts" (4 of 9), and two visiting groups said they learned about how the Wright brothers broke down the airplane into three different parts in order to solve the problem.

7.3. Recommended changes to Breaking Down a Problem for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- Visitors' understanding that different objects have the same individual component parts and can be broken down into simpler parts should be more strongly connected to how inventors get their ideas by developing another activity that focuses on breaking down a *problem* instead of breaking down a *specific technology*.
- Increasing the prominence of the Wright brothers' story and including another Inventors' story might help visitors make this connection. Adding graphic elements that emphasize "breaking down the problem" in the inventors' stories should also be explored.
- If these particular technologies and parts are selected for inclusion in the final exhibit, alternate wordings should be explored for the phrases that confused visitors.

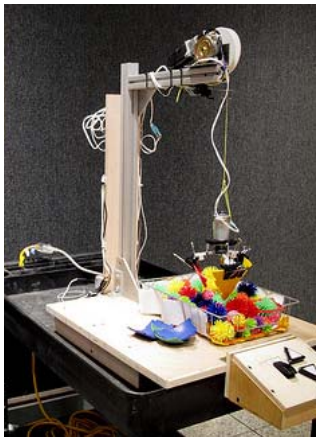
ENGINEERING DESIGN LABS

Overall, the Engineering Design Labs (EDLs) tested in Stage I of prototyping were well-received by visitors. Although timing data were not collected, based on observations in Stage I testing, the EDLs selected to move on to Stage II testing will likely have exceptionally long holding times and promote deep visitor engagement. The EDL's will also likely be popular with visitors-- four of the five EDLs tested in Stage I were the top components listed by visitors on comment cards when they were asked what they liked most about the exhibits in the Creativity Workshop prototyping space.

As Carey Tisdal noted in the summative evaluation of the *Star Wars* exhibition, EDLs are "pushing the envelope in our understanding of what can be accomplished in prolonged deeply engaging exhibits" (Tisdal, 2007). Given this challenge, and the in-depth, multi-step, multi-variable nature of EDLs, the team anticipated that not all five of the EDLs tested in Stage I would continue on to Stage II testing. Identifying problematic components and removing them from consideration for inclusion in the exhibition early in the process will save the team time and money, and allow them to focus only on the potential EDLs that are most promising. With the square footage and proposed layout of the *Creativity Workshop* exhibition, the exhibit development team anticipates that three EDLs will be included in the final exhibition.

As expected, two of the five potential EDLs tested were selected to move on to Stage II prototyping – "The Claw" and "Packaging." In addition, an EDL developed and successfully tested in Stage I prototyping for *Star Wars* but was not included in the final exhibition will also be moved to Stage II prototyping for *Creativity Workshop*. Another potential EDL currently in the early stages of development, "Bit Bot," will be developed in collaboration with Emily Bottis and the Interactive Media department. The "Water Works" EDL is being re-imagined as interactive art piece in the exhibition, the "Programming Blocks" may be integrated into an Inventors' Tool activity, and "Shipping" and will not be included in the exhibition. This report covers only the EDLs tested during Stage I of *Creativity Workshop* prototyping.

1. Claw Engineering Design Lab



This EDL was inspired by the arcade-style claw game, where people maneuver a claw to try to pick up a prize. The activity challenged visitors to design the "fingers" of the claw to pick up either as many or as few objects as possible. The prototyping of this EDL was facilitated by the Design Challenges staff. After much experimenting with pipe cleaners, paper, craft sticks, and other materials, a set of hard plastic pieces were used. These pieces could be snapped together to create additional shapes. The activity setup included two preliminary testing stations where visitors could test their design before giving it the final test.

1.2 Summary of Claw EDL evaluation findings

Forty groups, which included 89 visitors, were observed using this activity, and 20 of these groups were interviewed following their interaction.

Visitor Behaviors & Skills
Overall, groups engaged in between zero and ten full design cycles at this activity, with a median number of two design cycles. Visitors had difficulty troubleshooting their designs, and this was an area where staff frequently provided support (17 of 32 groups). Once staff settled on using the hard plastic pieces in the EDL, much of the visitor confusion and frustration about the actual building or assembling of their claw was decreased. In addition, the number of groups that did not complete at least one full design cycle fell after these materials were introduced.

Message & Learning
In interviews, visitors most frequently said they learned about the shape (7 of 20 groups) or materials (5 of 20) needed to make a good claw, while some visitors also said that they learned "how to make a good claw" without providing specific information (3 of 20).

1.3 Recommended changes to Claw EDL for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- To reduce visitor confusion about the order in which the activity should be completed and frustration over having to transfer their design between the pre-testing and testing stations, the design of the pre-testing and testing stations should be combined into one station for Stage II, with multiple available building & testing stations with full working claws.
- Labels should emphasize the connection between shape and function when introducing the activity and during the redesign phase.
- The building materials should be simple to use, as the hard plastic pieces were, but also allow for a greater degree of flexibility and creativity in use, with a wider variety of shapes available.

2. Packaging Engineering Design Lab

This EDL allows visitors to assemble a shipping container for a simulated delicate object (the "egg"), which must be shipped form one place to another without being subjected to excessive accelerations or temperature changes. This version of the EDL was facilitated by a staff member, and visitors were able to choose between a square or cylinder shaped box, and packing materials that included foam strips, egg crate foam, Velcro straps, and rubber bands. This initial version of the egg was only sensitive to excessive accelerations. The egg was tested by sliding it down a ramp or dropping it off of an approximately 3' high table top. When the egg "broke," lights on the egg flashed and it emitted a beeping sound.

2.2 Summary of Packaging EDL evaluation findings

This activity was tested with 36 visitors in 12 groups, ranging in size from one to seven visitors.

Visitor Behaviors & Skills
Groups engaged in between one and six design cycles, with a median number of two cycles. Eight of the 11 groups who attempted the ramp test completed it successfully, while just three of 10 groups who attempted the drop test completed it successfully, and four of 12 groups did not successfully complete any tests of their design(s). When it came time to improve their designs, visitors were just as likely to discard their design and start from scratch (6 of 12 groups) as make minor changes to their existing design (6 of 12).

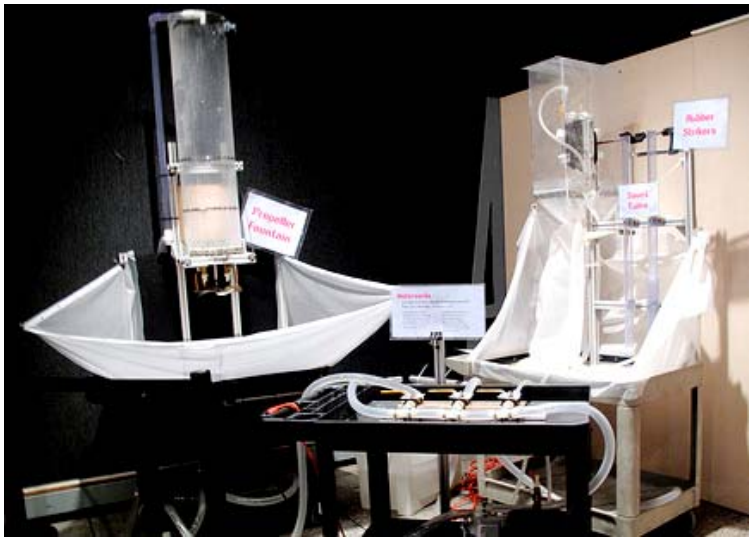
Message & Learning
What visitors stated they learned at this activity varied. Some visitors discussed specific aspects of their design, such as the shape of the container or type of material used (4 of 9). Others said they learned more generally about "how to keep stuff safe in a package," or how difficult it is to package something (4 of 9).

2.3. Recommended changes to Packaging EDL for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- The difficulty level of the activity was too high – the "eggs" should be less sensitive, allowing more visitors to create a successful design.
- Consider the real-world context the packaging is being presented in. One visitor made a connection to "packaging ancient things for the museum," which might be a compelling scenario.
- Phase II prototypes should ensure that visitors will understand the goal of the activity, how to complete the tests, and how success is measured, as these were all areas that were heavily facilitated by staff during this phase.
- Explore ways to get visitors to engage in the more "thoughtful" parts of the design cycle: hypothesizing outcomes before creating & testing, considering when to throw out their design or improve their existing design, and analyzing what went wrong with their design and how to fix it.

3. Water Works Engineering Design Lab



In its final state, the Water Works EDL will be a large kinetic structure with water flowing through tubes, turning paddle wheels, filling tanks, and tumbling over waterfalls. Visitors will be able to interact with the flow of water at 6 to 8 stations where they can close valves, open chutes, and redirect or combine streams, which will be associated with a specific challenge, such as emptying a bucket by adjusting one valve controlling the flow of water into the bucket and a second valve controlling the flow out. In addition to the activity at each station, two or three stations can be adjusted in concert to meet a larger challenge. The Phase I version of this activity included three different valves that controlled water flow to a propeller fountain, a water wheel connected to rubber strikers, and sound tubes that the rubber strikers hit.

3.2 Summary of Water Works EDL evaluation findings

This activity was tested with 28 visitors in 10 groups, which ranged in size from one to four visitors.

Visitor Behaviors & Skills
All groups (10 of 10) adjusted each of the three valves at least once, and at least one valve more than once, and all of the groups observed the Water Works with two and three valves open at once. In some groups, an adult in the group or the facilitator told a child how to open and close the valves. Nearly all visitor groups (9 of 10) made verbal note of the effect opening a valve had at least once, and some (6 of 10) also verbally noted the relationship or tradeoff between the different components of the activity.

Message & Learning
Visiting groups identified the cause and effect aspect of the component's message (6 of 10), and a few visitors explicitly mentioned the tradeoffs associated with having multiple valves open at the same time (2 of 10). No visitors made a connection between this activity and engineering design or the work that engineers do, although some believed it was about the work that water can do (4 of 10) or electricity (3 of 10).

3.3 Recommended changes to Water Works EDL for Stage II

The following recommendations were derived through conversations with team members, based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- Waterworks does not appear to be a strong EDL, so instead focus the component on how engineers must consider cause & effect and tradeoffs in a system. Visitors used this activity as intended, and it was very popular, but visitors failed to make any connection between this activity and invention or engineering design.
- Next iteration of valve controls should be easier to manipulate.
- Place instructions for use close to controls, where visitors' attention naturally focuses.

4. Programming Blocks Engineering Design Lab

In this EDL, visitors assemble a set of blocks, each of which performs a specific function, into a chain that serves as a computer program. Five specific challenges (such as "Create a program that makes a light flash slowly") were presented to visitors, as well as templates for a design if they were having difficulty. There were seven different blocks available, as well as a light, a buzzer, a light sensor, and a touch sensor. The final version of this activity will also include larger "real-world" challenges, such as creating a security system or a light display that follows a certain pattern.

4.2 Summary of Programming Blocks EDL evaluation findings

This activity was tested with 32 visitors in 11 groups, ranging in size from one to four visitors. An additional two groups were interviewed following their interaction, but were not observed.

Visitor Behaviors & Skills
Of the 11 groups observed, eight attempted three different challenges and three attempted one challenge. Only one group did not complete one of their challenges, which was their third. In addition to the five challenges presented, two groups made up their own challenge – to see what they could create using all of the available blocks. All visitor groups needed facilitator help to troubleshoot a program that was not working as intended. This usually involved the facilitator asking the visitors to walk through each step of their program or describing what a particular block did to find and fix the problem. Younger children (around 12 and under) also frequently received parental or facilitator direction to examine all of the available blocks before deciding which to use for their challenge.

Message & Learning
Visitors that had experience with programming, LEGO Mindstorms, snap circuits, or other similar activities seemed to more easily grasp the concept of "building" a program, and the functions of individual blocks. These visitors also (unprompted) made the connection between the activity and computers or circuits during the interview. All of these visitors (3 of the 11 interviewed) were male. No visitors without previous experience in these areas made such a connection.

4.3 Recommended changes to Programming Blocks EDL for Stage II

The following recommendations were derived through conversations with team members and are based on evaluation results, the component's educational goals, and the larger context of the exhibition as a whole.

- This activity required heavy facilitation for most visitors to understand how to use the blocks and troubleshoot the program they created. Because it posed such difficulty to visitors as a facilitated activity, the team should seriously consider not moving it to Stage II, or be prepared for serious revisions to the activity.
- If this activity does move to Stage II, the next iteration of blocks should explore different connection methods between blocks that more easily and intuitively connect, as well as clarify which blocks can connect where. Continue to explore the text (and graphics) used on blocks to communicate the function of each block to visitors, including non-readers (because of personal preference or literacy level).
- When moving to Phase 2, methods of facilitating visitors troubleshooting their own programs through labels, graphics, etc must be carefully considered, as many groups relied heavily on facilitator intervention to walk through the troubleshooting process.

RECOMMENDATIONS

In addition to the component-specific findings, results from Stage I prototyping can also be used to examine the larger lessons the team has learned through the exhibition's evaluation thus far. Looking across the Inventors' Tools components and Engineering Design Labs, several themes emerge. These themes can help to direct the higher-level planning for Stage II prototypes, as well as make the development process more efficient as it continues. With the Inventors' Tools components, most activities need to make a stronger connection between the individual Inventors' Tool and the larger exhibit themes. For EDLs, attention needs to be paid to helping visitors make more analytical decisions and providing support in the key areas that staff facilitators did in Stage I.

1. Make stronger connections between individual Inventors' Tools and larger themes

In examining the Inventors' Tools, six of the seven were successful at imparting the message specific to that Inventors' Tool, but visitors to most of these activities for the most part did not make a connection between the specific Inventors' Tool they interacted with and the larger theme of "creative thinking tools used to develop new technologies." (The "Challenging Assumptions" and "Combining" activities were the two exceptions to this issue.) This issue should be kept in mind as changes to individual components are made.

As testing moves in to Stage II, the exhibits will also be more purposefully arranged according to the area of the exhibition they are associated with. Simply grouping multiple Inventors' Tools together may serve to reinforce the larger theme of the area. Since all prototypes moving in to Stage II have passed the "proof of concept" of Stage I, how the exhibits work together as a themed area can be examined in the coming round of Stage II prototyping.

2. Help visitors to make analytical decisions at EDLs

The EDLs that were successful in Stage I of prototyping also had several common issues that should be considered as they are moved to Stage II. Across both EDLs that will be moving on to Stage II, visitors did not tend to make analytical decisions about how to improve their designs, and were generally just as likely to discard a design that was partially successful as improve it. Encouraging this type of reasoned decision-making in an exhibit context will be difficult, but should be tackled. This in particular is an area in which parent-child scaffolding can play a key role that was not identified in previous engineering design scaffolding work (Kollmann, 2007). Areas where the exhibit should provide visitors with support include:

- "Test" step
    - Discussing the criteria for a successful design
- "Improve" step:
    - Discuss what went wrong with the design
    - Discuss ways to improve the design

3. Build into the exhibit design EDL supports currently provided by staff facilitators

Moving from Stage I to Stage II of prototyping presents additional challenges with EDLs, as exhibits will move from a facilitated to a stand-alone design. With four of the five EDLs tested, facilitators provided key support in introducing the activity, presenting the problem visitors were charged with solving, and drawing their attention to the variety of materials available. They also helped visitors execute the testing and troubleshooting of their designs. These areas should be closely examined in Stage II to ensure that visitors can successfully engage in these parts of the design process independently:

- "Ask/Imagine/Plan" step
    - Identify/select activity goal
    - Discuss which materials/parts to select
- "Test" step
    - Use testing station(s)
    - Discuss the criteria for a successful design
- "Improve" step
    - Discuss what went wrong with the design
    - Discuss ways to improve the design

The Engineering Design Lab and scaffolding work is based on the knowledge developed through the *Star Wars: Where Science Meets Imagination* exhibition and studies of the Design Challenges program. These were used to develop initial theories of what would be necessary for a successful EDL, and what areas would require scaffolding. Now that Stage I prototype testing is complete, the exhibit development team can use the evaluation results to re-examine the criteria used to select EDLs for development and to think critically about the design and scaffolding of Stage II prototypes.

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