CENTER FOR RESEARCH AND EVALUATION

Lifelong Learning Group

Human Plus: Real Lives + Real Engineering

Summative Evaluation

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Executive Summary

Human Plus, an exhibition at New York Hall of Science (NYSCI) in Queens, NY was developed as a collaboration between NYSCI, the Oregon Museum of Science and Industry (OMSI) and the Quality of Life Technology Center (QoLT) at Carnegie Mellon University and the University of Pittsburgh, with funding from the National Science Foundation (#1010507). This report describes two related projects: summative evaluation of (1) a design residency and (2) the exhibition itself.

Design Residency

Key findings

Overall, the design residency resounded strongly with the participants, and the design challenges, ideas from discussions, and specific situations and stories that were heard in the residency influenced the exhibition experience.

An important theme that emerged in the residency and resounded throughout the project was the "hero narrative" which was strongly and passionately contested by the residents with disabilities. Along with arguing against the hero narrative, a theme strongly presented by these residents was the theme of disability being one aspect of an individual, and not something they could see themselves "without." In conjunction with both these, the underlying and continually emerging theme of stories of individuals had a tremendous influence on the narratives used in the final exhibit.

In reflection, three concerns about the process of the residency were then reinforced over the life of the exhibition development. The first was the lack of time in the residency, the second was a desire for additional residency experiences (as had originally been proposed), and the third was a concern regarding the depth of activities in the residency and the lack of specific outcomes. For the participants with disabilities, the work of the residency was ultimately in the final product where they felt they had been heard and that they were present. All participants were pleased with the final product and the strongest approval from the participants with disabilities was around the exhibit focus on individuals and that the exhibit components consistently presented the stories of individuals' first and then moved to technology.

Question 1: Do participants see changes in themselves as a result of their participation?

The residency was seen as an important activity for both the core/design teams and the invited residents. For the core and design teams, the residency became a touchstone for "hearing the voices" of the residents throughout the design and construction of the exhibit. For the invited residents, the opportunity to engage with others around an important component of who they are was profound and lasting. All participants reported consistent, positive changes in their perceptions of themselves in the residency process. They saw the residency as an important activity in their lives, felt it was exciting, and all reported learning from the process.

The core and design team residents felt they learned greatly from the residency, but that the project (the exhibition) was more about the museum than about them as individuals. The strongest changes occurring between the residency and the follow-up measure were principally in exposure to and the humanizing of people with disabilities.

Question 2: Did participation in the residency affect participants' beliefs about museums, exhibitions, and their role in ways that have led to changes?

All participants in the residency saw this effort as an important activity for the museum. For the core team, the residency reinforced their opinions of what a museum can do while the participants with disabilities grew to understand the challenge museums face when attempting to communicate to a general audience, that there is no "neutral" voice, and that messages must be "chosen in a conscious way."

Question 3: Did the residency affect individuals' sense of engagement with—or their roles on—the exhibit?

In the moment, the residency was tremendously meaningful across participant groups. The residents with disabilities felt heard, engaged, and honored. They also noted that the exhibition was not about them, and not the story of one thing. Clearly emerging from the residency was the inherent tension in prioritizing the engineering messages, the stories of those with disabilities, the focus on real needs of individuals driving the technology, and the high-impact, "wow" elements of the exhibit.

For some of the participants, the deep, emotional connections made with each other during the residency continue. For the core team, the importance of this project to the museum was dominant as was the sense of having important things to add to the discussion.

Exhibition Key Findings

The exhibition evaluation was designed to answer six evaluation questions related to the exhibition's organizing framework. This framework posed objectives and intended outcomes utilizing personal stories of individuals with disabilities and the engineers challenged by those stories to enhance awareness, understanding, interest, and perception of engineering as both a profession and a process. Six evaluation questions emerged from these objectives and intended outcomes. Key findings from the exhibition evaluation , listed below, are organized as answers to each of the six evaluation questions.

1. **In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, and innovation?**

Visitors left the exhibition aware of the engineering process as both creative and socially conscious. When visitors used three words to describe engineering, they frequently referenced the "imagine" and the "ask" steps of the engineering process.

2. **How did the exhibition affect how visitors value engineering?**

Messaging concerning awareness of engineering innovation and value was largely successful. When explaining the exhibition's title, "Human Plus," a third of respondents associated it with engineering for the purposes of expanding human potential and specifically human potential for people with disabilities. Other explanations included expanded human potential in general, understanding people with disabilities, or general references to the human body—most of which indirectly, if not explicitly, valued engineering. Adults were more likely than youth to make the explicit association to engineering. Girls' responses were focused strongly on the human aspect of the engineering design process.

The exhibition led visitors to value engineering for its products, historical progress, and social contribution. Interview participants defined engineering largely in terms of valued products created or improved by engineers. In some cases these products were specifically for people with disabilities. Responses also included appreciation for the effects of engineering in terms of historical progress and more general social contribution.

3. **What did visitors learn about engineering, both as a field and a process? How was this learning evidenced several weeks after the exhibition experience?**

Visitors understood engineering as a process, but for some, the steps in the process may have been confused with steps of the scientific method.

Awareness of the "ask" and "imagine" aspects of the engineering process persisted several weeks after the exhibition experience.

4. **How did visitors feel, both immediately after, and weeks after, about their opportunity to contribute, and their actual contribution, to the process of human enhancement engineering, as supported by the exhibition experience?**

The exhibition had a powerful impact on adult visitors' interest in engineering. Overall, adults reported that they entered the exhibition with a fairly neutral interest in engineering, but left with significantly greater interest. Of particular note was their increased sense of enjoyment as they thought of themselves in the profession.

Among youth, interest in a career in engineering differed between girls and boys. A strong majority of boys said they could see themselves becoming engineers, a strong majority of girls said they could not. In general, girls connected their "no" answers to perceptions of their own deficit in aptitude; boys connected their answers to their individual interests, regardless of whether they answered "yes" or "no."

Positive feelings toward engineering emerged equally as frequently among boys and girls. Only among boys with no interest in becoming engineers were there no comments related to positive feelings toward engineering.

Both male and female adults were highly and equally as enthusiastic about sons and daughters choosing to become engineers, suggesting that differences between boys and girls may be coming from sources outside of parenting.

5. **How did visitors' attitudes about and interest in engineering (both as a field, and as an important part of their lives) change as a result of that participation, if at all? Again, *was* this evidenced several weeks after the experience, and if so, how?**

The exhibition improved both adult and youth attitudes towards engineering. Adults showed significantly greater appreciation for engineering as (1) helpful for understanding today's world; (2)necessary for helping to solve problems of everyday life; (3) important for inclusion as a subject of study; and (4) important knowledge for being productive in life.

The improved attitude was even more pronounced among respondents answering in retrospect, several weeks later.

Among youth, the majority reported positive change in perception. Those who reported no change had pre-existing high regard.

6. How did visitors use and interact with this exhibition experience?

Findings related to this question were divided into three areas: (a) how exhibit components contributed to visitor experience; (b) how personal stories helped visitors understand the exhibit messages; and (c) what design considerations helped visitors interpret exhibit messages. Answers to the process questions are arranged accordingly.

Findings about how exhibit components contributed to visitor experience

Visitors engaged well with the exhibition with each of the exhibits contributing differently to their experience. Most of the elements of the experience were used by a plurality of visitors, though the average number of specific exhibit components engaged was three (out of 13) per visitor. Anecdotal observation revealed that crowdedness was a major factor in the number of components and the amount of time spent in the exhibition.

The most frequented exhibits among adults and the most liked among youth were *Every Body Plays; Redesigning You; RAMPS; and More than a Mouse.* Least recalled (i.e. most frequently "not remembered) among adults were *Consider This, Ask, Imagine, Create; Imagine the Possibilities; and Design a Wheelchair.* Among youth respondents, least liked were*, Consider This, Attempts*, and *Finding Your Way*, and *Ask, Imagine, Create*.

Some exhibits were more visually memorable than engaging; others were engaging but easier to miss. Adult respondents tended to remember seeing two exhibits, *Feel the Music* and *Welcome,* more than they experienced them. In other words, these two exhibits were more attractive than engaging. In contrast, *More than a Mouse* and *Re-Designing You* were more experienced than remembered, i.e., easier to miss, but if seen, they were engaging.

Findings about the ways stories helped visitors understand exhibit messages.

Exhibit affected adult enthusiasm for engineering. The average effect on adult respondents' enthusiasm for engineering from just less than "somewhat" (*Attempts*) to halfway between "somewhat" and "a lot" in *More than a Mouse*. Most of this enthusiasm was associated with the "create" and "ask" steps of the engineering process.

Exhibit response ranged in regard to stories most remembered. Stories of how technology enhanced lives of people with disabilities played an important part in visitors' experiences of the exhibits. For three exhibits (*Ask, Imagine, Create; Welcome;* and *Design a Wheelchair*) almost half of respondents who engaged with those exhibits believed the story was either essential or very important to explaining the exhibit to a friend. Exhibits with stories remembered by most respondents were *Welcome*, *Ask Imagine Create*, *Design a Wheelchair*, *Attempts*, *Finding your Way*, and *Imagine the Possibilities*.

Visitors experienced exhibits as balancing personal stories and engineering messages differently. For four exhibits (*Attempts, Re-Designing You, More than a Mouse, and Feel the Music*), the proportion of visitors who reported that the exhibit made them more enthusiastic about engineering was far higher than the proportion of visitors who felt the story was important to understanding the exhibit. In contrast, the proportion of respondents who experienced the stories of the *Welcome* exhibit as important was greater than the proportion of respondents who experienced the exhibit's effect on their enthusiasm for engineering. No exhibits could be classified as having high story importance and low enthusiasm for engineering.

Visitors' own "stories" created during their visit also may have contributed to messages received. Some respondents interpreted "story" to be their own narrative of experiencing an exhibit (e.g., "I felt what it was like to ski with no legs"). Given that the exhibits were intended to be highly interactive and many respondents identified interactivity as an important feature of appeal, these "stories" may also have contributed to the impact of messaging.

Findings about which methods of presentation and which media worked better than others for each group.

The balance between interactivity, personal stories and messaging about engineering affected how visitors interpreted exhibit messages. Although specific design components such as color or music were sometimes mentioned in interview groups' descriptions of why they liked a given component, respondents usually framed their responses in terms of interactivity, themes related to disability, or ideas related to engineering (e.g., a specific type of technology). Most prominent among these categories was interactivity, which appeared especially strongly for a majority of components.

The difference in balance between interactivity, introduction to a personal story, and the experience of engineering appeared to have had an important influence on how well an exhibit component communicated the exhibition's message. Interactivity involving an opportunity to build or modify a product cued interpretation related to engineering process. In contrast, interactivity relating to a user perspective tended to cue interpretation related to disability. Moreover, stories were most effective in connecting to exhibit messages when they were directly linked to design-based interactivity. In some cases, interactivity may have overpowered the message.

Among adults, the exhibitions appeal lay primarily with its sense of fun, and next with its attractiveness. While they rated colors, signage, and videos fairly high, they weighted sense of fun higher. This finding was supported data from the interview participants who overwhelmingly referenced their enthusiasm for the exhibition's interactivity and fun.

Visitor experience was diminished when the space was crowded. Anecdotal observation revealed that crowdedness was a major factor in the number of components experienced and the amount of time spent in the exhibition. The crowdedness aspect of the exhibit was augmented by the tightness of the space, further creating the energy commonly seen in visitors when an area is busy—to move through without engaging.

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Introduction

Human Plus, an exhibition at New York Hall of Science (NYSCI) in Queens, NY was developed as a collaboration between NYSCI, the Oregon Museum of Science and Industry (OMSI) and the Quality of Life Technology Center (QoLT) at Carnegie Mellon University and the University of Pittsburgh, with funding from the National Science Foundation (#1010507). This report describes two related projects: summative evaluation of (1) a design residency and (2) the exhibition itself.

The Design Residency

In the original proposal it was noted that the Human Plus Project would advance the ISE field in an important way: Human Plus would develop a Participatory Design Model to test the effectiveness of engaging underrepresented audiences including people with disabilities in the creation of an exhibition. In Human Plus, these participants would be seen as "end users" because they are both potential audiences for the exhibition and potential users of the technologies being explored in the exhibition. In this model, a cohort of end users would work in close collaboration with NYSCI, OMSI, the Quality of Life Technology Center (QoLT) at Carnegie Mellon University and other members of the exhibition design team.

Because of budget negotiations, a three-stage residency design was eliminated and the length of the remaining single residency was significantly reduced. Even so, the project was committed to the principles of Participatory Design and the core team struggled with ways to use the two-day residency followed by other strategies for continuing the input and voice of those invited to be involved in the residency (hereafter referred to as participants or residents). The condensed residency for Human Plus was held March 19 and 20, 2011 at the New York Hall of Science. The core team, design team, and invited participants were brought together to attempt co-creation of ideas around a proposed exhibition on augmented human ability. One of the concepts was to co-create the exhibition with the users of and the developers of technological advancements for people with physical disabilities. Therefore, there were different types and levels of disability among the invited participants.

The Exhibition

The second part of the evaluation focused on the residency product: the exhibition itself. The thirteen exhibits that comprised the traveling exhibition were each designed to help visitors understand the engineering process which, for this experience, was defined as "ask, imagine, create, test, repeat." In the exhibit, visitors are given a chance to explore videos of individuals telling their own stories, engage in engineering challenges to address specific needs of individuals using the engineering process, and to experience technologically-based activities demonstrating restoration and extension of human abilities.

As a traveling exhibition, Human Plus was evaluated as installed in a temporary exhibit area at the New York Hall of Science. There was no clear entry or exit such that as many people entered from the "rear" of the exhibition as from the front.

The Human Plus exhibition components were each designed to meet, jointly and separately, the project's intended outcomes delineated in the Exhibition's evaluation framework which can be found in Human Plus Summative Evaluation Framework**Error! Reference source not found.**. The framework is designed around four areas of intention: Awareness, Understanding; Interest; and

Attitude. These outcomes were meant to be as relevant to adults as to young people, but they were primarily aimed at adolescent girls.

This summative exhibition evaluation was designed to answer six overarching questions:

1. In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, innovation?
2. In what ways do visitors define engineering in terms of value?
3. In what ways and to what extent do visitors understand engineering as both a field and a process?
4. To what extent did visitors leave the exhibit with an increased interest in engineering?
5. What evidence can be found that visitors leave the exhibit with a positive attitude toward engineering?
6. How did visitors use and interact with this exhibition experience?
    a. How did exhibit components jointly and/or separately contribute to audience experience?
    b. In what ways did the stories help visitors understand exhibit messages?
    c. What design features for presenting exhibits and stories worked better than others?

RESIDENCY EVALUATION

An essential component of the Human Plus exhibition design involved a residency that brought together core exhibition team members with individuals with disabilities who agreed to contribute their perspectives. These residency participants met for two days prior to exhibition design and reconvened after its completion. To document the process and its effect, this evaluation consisted of four studies.

This first study, a process evaluation of that residency, included ethnographic note-taking and reflection against the experience. Participants, or residents, of the experience were not afforded the luxury of reflection time during the intense two days, yet the process itself had an air of reflection and thoughtfulness. For the second study, shortly after the residency, participants completed a reflective questionnaire including post-with retrospective pre measures. Approximately three months following the residency, a third, follow-up, study was undertaken to examine the "stickiness" of the findings from the residency study and included repeat measures from the pre-study. After the opening of the exhibit in the New York Hall of Science, residents were invited to participate in a shared viewing and then to participate in two discussion groups, one with the invited participants only, and one with the participants and members of the core team. The fourth study involved ethnographic account of this gathering.

This report integrates findings across the four components of the evaluation. Likewise, themes across the four study components are explored.

Residency Research Purposes and Questions

This report is to provide a reflection on the residency by those who participated in it. The overarching evaluation question driving this reflection was "How did the residency process affect the participants, the design process, and the exhibit itself?" To address this question, three guiding evaluation questions were asked:

1. Given time for reflection, do participants in the residency see changes in themselves as a result of participation?
2. Did participation in the residency affect participants' beliefs (about museums, about the role of museums, about people with disabilities) in ways that have led to changes?
3. Did the residency affect individuals' sense of engagement with or their roles on the exhibit?

For each question, responses of core team and invited participants were explored and compared.

Residency Evaluation Methods

For the first study, a process evaluation of the residency. the residency purpose drove the evaluation design. According to residency facilitator, Kathy McLean, the two days were to be spent "co-creating this experience." She desired to "start a process where we're all coming together as equals to think/dream ideas that could end up being in an exhibition." To this she asked rhetorical questions to frame the workshop including such questions as "What are important ideas?

Problems? Strengths? Things that really get us excited?" The outcomes of the two days were to "inspire and feed the design of the exhibit."

Thus, given the nature of the residency workshop, the evaluation method for this first study was ethnographic. The evaluator intentionally assumed a role different from his role as a team member on the project. For these two days, the evaluator took detailed notes during full group discussions; moved among the groups as they were doing their work, observed interactions and sought to make sense of the emotional movement of the process.

For the second study, following the residency, a questionnaire to answer evaluation questions 2 and 3 was sent to all participants via a web-based instrument as all the residents use computers routinely whereas some cannot do paper/pencil activities. The instrument was designed to be reflective and open-ended.. There was one scale of expectation and satisfaction constructed as a post with retrospective pre (affect measure question 3) with ten items. Core team members had an additional scale that specifically addressed question 1 with three open-ended questions different from the other residents. The web platform used was Qualtrics.

For the third study, approximately three months following the residency, those involved in the residency experience were invited to participate in an online study about where they were at that point in time. The questions paralleled the key outcome categories and integrated findings from the post-residency report.

Finally, the fourth study involved notes from retrospective reflective discussions of residency participants. After exhibition installation, participants in the residency were invited to NYSCI to first explore the exhibit, and then to engage in discussions (first with the other residents and second the residents with the core team) regarding their perceptions of the experience. Notes from these discussions constituted the data for this fourth study.

Although the first study was process and emergent in nature, there were some guiding areas of interest coming out of the residency which then shaped the follow-up and the post-installation studies. For the residents, the dominant concerns were the ways in which they felt they were included in the experience, whether their voices were authentically heard, and what they gained related to understanding of the exhibit design process. For the design and core team, the concerns were the ways in which their individual and collective thinking was shaped by the residency, the degree to which what they gained from the residency was included in the final experience, and the development of stories that might drive the exhibit experience.

All four studies were conducted under an IRB through E&I, number 11140-03A.

Residency Results

Pre/post comparisons

What We Found

Invited participants (N=8) reported consistent, positive changes in their perceptions of themselves in the process, particularly in the areas of feeling heard and the value of personal contributions. Core team members reported positive changes in the areas of the value of personal contributions, expectations for learning from the experience, and the value of the experience in their lives.

How We Know

Participants responded to a ten-item scale comparing the degree to which they agree with items both before participating and after. Post with retrospective-pre measures have been widely used in the health field since the late 1970s. These approaches have been tested and shown to capture accurate measurement of affect shift (Andrews, Bonta, & Hoge, 1990; Levinson, Gordon, & Skeff, 1990; Skeff, Stratos, & Bergen, 1992; Sprangers & Hoogstraten, 1989) capture change not found in traditional pre and post measures (Hoogstraten, 1982), and play a role in counteracting response-shift confounding (Pohl, 1982). The item rankings were provided to determine the breadth of changes related to the above discussions. These findings are presented here separately to provide a consistent comparison of the two groups; they are discussed and incorporated into the answers to the evaluation questions.

Participants (N=8) reported consistent, positive changes in their perceptions of themselves in the process (Table 1). The lowest pre and the highest gain were both on the item *there is not much I can add to the discussion*. When reverse coded, the pre mean of 4.8 with a large standard deviation of 1.92 had a 1.6 gain score to a mean of 4.4 with a tight standard deviation of 5.5. The highest overall mean score was the exit score for the item *this is an exciting event* with a mean of 6.8 with a gain of 1.0 over the pre-measure. The item with the second lowest exit mean score was *I have important ideas to add*.

The highest mean scores, a very high 6.8 (out of 7) were for three different post items: *this is an important activity in my life*, *this is an exciting event*, and *I did learn from the process*.

Table 1. Invited participant pre/post comparisons.

	Pre-mean	Std Dev	Post-Mean	Std Dev	Difference
I have important ideas to add	5.0	.71	5.4	.55	.4
People listen to me	5.2	1.30	6.4	.89	1.2**
I am an important part of this thought process	5.2	1.30	6.0	.71	.8
There is not much I can add to the discussion	3.2	1.92	1.6	.55	-1.6*
This is an important activity in my life	5.4	1.52	6.8	.45	1.4
This is an important activity for the museum	5.8	1.30	6.6	.55	.8
This is an exciting event	5.8	1.30	6.8	.45	1.0
I am a full participant in this process	5.4	1.52	6.2	.84	.80
People care about what I say in this process	5.4	1.14	6.6	.55	1.2**
I would/did learn from the process	5.8	1.30	6.8	.45	1.0

*significant with p< 1.0; **significant with p< .50[1]

[1] When populations are small, it is generally accepted that p is set at .10 versus the convention of .50 for more standard study populations.

The core team also responded to the same items. For this group (n=9), overall mean scores were slightly lower, especially notable on the post-scores.

The lowest scores were for the item *there is not much I can add to the discussion*. When reverse coded, both pre and post indicators were negative with means of 2.12 and 3.12 respectively. There were also slightly positive scores on the item *people listen to me*, which could relate to the differing roles of individuals on the core team, and the sense of voice toward more than their expertise or work.

Table 2. Core team pre/post comparisons.

	Pre-mean	Std Dev	Post-Mean	Std Dev	Difference
I have important ideas to add	5.37	1.3	6.00	.93	.63**
People listen to me	4.67	1.2	4.63	1.2	.04
I am an important part of this thought process	5.43	1.1	5.75	.87	.32
There is not much I can add to the discussion	3.88	2.0	2.88	2.1	-1.0
This is an important activity in my life	4.62	.74	5.38	.74	.66**
This is an important activity for the museum	4.88	.84	6.25	.71	1.37
This is an exciting event	5.38	.92	5.88	.99	.50
I am an full participant in this process	5.17	1.2	5.88	1.4	.71
People care about what I say in this process	5.17	.75	5.13	1.2	-.05
I would/did learn from the process	5.62	.92	6.88*	.35	1.26**

*significant with p< .10; **significant with p< .50

The largest gain score was on the item *this is an important activity for the museum* though it was not statistically significant. The standard deviations are also low. This might suggest that outliers exist in both pre and post reports: for one or two, their scores were lower and remained lower while for one or two others, both scores were higher and remained higher. The low standard deviation suggests that others clustered around or toward the lower score on the pre and toward the higher on the post. With a small number of participants, one or two outliers would be enough to keep the shift from being statistically significant.

Table 3. Comparison pre/post between groups

	Pre Participant Mean	Pre Core Team	Post Participant Mean	Post Core Team Mean
I have important ideas to add	5.0	5.37	5.4	6.00
People listen to me	5.2	4.67	6.4	4.63
I am an important part of this thought process	5.2	5.43	6.0	5.75
There is not much I can add to the discussion*	3.2/2.8*	3.88/2.12	1.6/4.4	2.88/3.12
This is an important activity in my life	5.4	4.62	6.8	5.38
This is an important activity for the museum	5.8	4.88	6.6	6.25
This is an exciting event	5.8	5.38	6.8	5.88
I am an full participant in this process	5.4	5.17	6.2	5.88
People care about what I say in this process	5.4	5.17	6.6	5.13
I would/did learn from the process	5.8	5.62	6.8	6.88

*First number is actual mean; second number is reverse coded so positive is higher
Both groups report learning from the process and had the highest (or tied at highest) mean.

Question 1: Do participants see changes in themselves as a result of their participation?

What We Found

The residency was seen as an important activity for both the core/design teams and the invited residents. For the core and design teams, the residency became a touchstone for "hearing the voices" of the residents throughout the design and construction of the exhibit. For the invited residents, the opportunity to engage with others around an important component of who they are was profound and lasting. All participants reported consistent, positive changes in their perceptions of themselves in the residency process. They saw the residency as an important activity in their lives, felt it was exciting, and all reported learning from the process.

The core and design team residents felt they learned greatly from the residency, but that the project (the exhibition) was more about the museum than about them as individuals. The strongest changes from the residency to the follow-up measure were principally in exposure to and the humanizing of people with disabilities.

How We Know:

During the residency, there were several moments where dialogue was impassioned and resolutions from the dialogue suggested shifts in individuals. Several of these themes became resonant across the life of the project. The first of these to emerge was that of the "hero" narrative in which there were many passionate comments fighting the narrative such as "I've heard about the 'hero' narrative a lot when I was applying to schools…told I should present my story" and "I get 'you're so brave.' You don't even know who I am. I'm brave for breathing? For living? … I don't want to be seen for just living. I want to be seen for the accomplishments I've made in the community for everyone."

> *...would I go back and change my disability? Don't know that I'd have given up most of it…But that's part of who I am. Disability is an environmental mismatch. Not everybody wants to return to whatever 'normal' is.*
>
> Invited Participant

A second theme was that of disability being one aspect of an individual, and this translated into the disability being a part of the individual and not something they could see themselves "without." This theme led to a finding in some of the design challenges where individuals began to understand adaptive technology as something everyone uses daily to either accomplish things we could not do otherwise (an example from the residency was trying to get something down off a very high shelf without a ladder) or could not do as well (a common reference during the residency was to eyeglasses).

Another emergent theme repeated through the life of the project was that of understanding the limits of technology—and that sometimes, existing technology is more accessible and usable by individuals than new technology. This was revealed in dialogues about the "coolest, hottest new things aren't accessible" and critiques of *solutions* which led to a shared understanding that "technology needs to be at the human level of function or it remains an obstacle" and that it is important to keep the "solution personal versus technological."

The emergent themes which had the most energy in both written and spoken forms, were those around the stories of individuals. More specifically, for the invited residents, it was that the stories are not about technology, but about the needs of individuals to be able to live to their fullest potential.

> *How does a person come to adapt their lives and personality and habits and psyche? People will always look at them a little differently. That's been a difficult exploration I would say. It's not easy. In the meeting, Universal design…not all of it improves things for everybody. It's sliding over the realities of people living their lives with a disability. Yes we have a shared identity—we're all humans, we're well spoken, we can express selves beautifully, we have powerful inner strength. But we're not telling the story of one thing.*
>
> Core Team Member

After the first follow-up, the residency continued to resonate as a meaningful experience for the invited participants who felt the residency and the continuing engagement were valuable. In the first follow-up study, one resident commented "I feel that the process continues to be nothing but inclusive" and another stated "from the perspective of a real person belonging to the target population of the project, I feel I am able to involve myself in the exhibit process as a user, developer, and evaluator."

Over the course of the development, there was not the extended contact originally intended, due in great part to the cut of the second residency as originally proposed but not funded. However, some of the residents were engaged at various points in providing feedback.

Participants reported consistent, positive changes in their perceptions of themselves in the process. The lowest pre and the highest gain were both on the item *there is not much I can add to the discussion* (Table 1 with explanation in Pre/post comparisons section above). The second lowest mean score on the follow-up was: *I have important ideas to add*. These two lower post scores suggested that participants were positive toward, but felt less strongly about their voice being heard as part of the project. However, the strongly positive agreement to the statements *people care* about *what I say*, *people listen to me* and *I am an important part of the thought process* suggested that the lower scores may reflect that participants felt part of the process and included, but perceived limits to what they could bring.

> *We've all seen stories about ourselves told that seem oversimplified and don't resonate. Sometimes, people think we'll make this over-positive. The hero story. That's not what it is that I crave. I crave complex stories. They embody a rich but difficult experience. In the 'More than a Mouse' you could see—the tasks weren't easy. Not 'well done you've solved the problem, move on.' It showed a complex experience. So much more preferable and respectful than if it were just success stories.*
>
> Invited Participant

The highest mean scores, a very high 6.8 (out of 7) were for three different post items: *this is an important activity in my life, this is an exciting event, and I did learn from the process*. These responses suggested that the invited participants had placed residing importance on the residency related to the role the residency played in their lives.

In the first follow-up, the core team participants, on the other hand, principally saw themselves as strongly having learned from the residency but that the project itself was more about the museum than about them. Individuals from the core team did reflect that they felt integrated in the process demonstrated by comments such as "I feel part of the larger group that worked together at the residency. I feel there is a lot of knowledge and experience that we all share" and "I felt my knowledge in my own field was sought after, appreciated, and taken seriously." In another comment, one of the residents expressed the perception that even the core team "were keeping us in mind. It was obvious even if we weren't present physically."

Among the core team, the changes reported between the time of the residency and the follow-up measure were principally in exposure to and humanizing of people with disabilities. Some entered the residency with some concerns: "I felt a certain self-consciousness about working with a group of people with disabilities. I had little prior experience" and "I was challenged to think about my use of language and style of interaction and communication" are examples of comments. The learning outcomes for the core team included thinking about "my use of language and style of interaction and communication," being "more aware of accessibility issues as I'm walking around," and increased comfort with people with disabilities. "I've learned new things about working with people with different abilities, and felt like I gained some insights that I hope I can hang onto and apply in the future." Overall, the core team had a strong sense that the residency had changed their thinking in terms of how to approach the exhibit and also in terms of the types of stories they should share.

However, for the core team, the bigger changes in thinking were related to the longer-term engagement. When talking about what was most salient from the residency, the core team noted things such as "…it shows how impactful that first meeting was. It really was….It was so impactful meeting you guys at the start of the project. What stories to tell…. We talked about [the residency] throughout. The importance of telling those stories…we wanted to make something [a resident] can come to. We wanted to make something [another resident] will like. You were around in our heads—central to our thinking."

The longer-term impact on the design process appeared to have been tied to the shorter term follow-up study findings where several of the comments from the invited participants reflected being heard, with comments such as "I feel that the process continues to be nothing but inclusive" and "I felt my ideas and opinions were heard by many and received attention." In contrast, however, the invited participants' comments suggested a more personal residing impact from the residency: "the residency gave me the opportunity to meet other young people who face similar challenges. That chance is actually pretty rare, and I have kept in touch with many of them;" and "If any part of what was indicated [was] that disability is an extremely complex concept, I would consider that an important contribution." One comment incorporated both individual impact and museum benefit: "From the perspective of a real person belonging to the target population of the project, I feel I am able to involve myself in the exhibit process as a user, developer, and evaluator."

Question 2: Did participation in the residency affect participants' beliefs about museums, exhibitions, and their role in ways that have led to changes?

What We Found

All participants in the residency saw this effort as an important activity for the museum. For the core team, the residency reinforced their opinions of what a museum can do while the participants with disabilities grew to understand the challenge museums face when attempting to communicate to a general audience, that there is no "neutral" voice, and that messages must be "chosen in a conscious way."

How We Know

The residency was designed to engage members of the core and design teams with individuals with physical disabilities around design activities and thoughts about what an experience could have at its core. Overall, the residency was extremely powerful around this work, but there was one design flaw—the final design challenge activity involved groups solving a "fantastical" challenge, and most groups created a superhero type power or similarly extreme solution which fed into the very issues that had been raised as dangerous traps: the hero complex, the use of technology as driving solutions rather than solving problems, and the "high tech/low human" aspect of technology.

In the pre and post measures (Table 2 and Table 3 with explanations in Pre/post comparisons section above), both groups had statistically significant and strong magnitude positive shifts in response to the item this is an important activity for the museum. The core team had a 1.37 point shift from 4.88 pre to 6.25 post mean scores; invited participants had a very strong 6.6/7.0 post mean. Likewise, both groups had positive shifts on this is an exciting event, though it was a .50 gain in agreement for core team, but a 1.0 gain for invited participants to be one of their three highest mean scores of 6.8.

For the core team, the residency reinforced their opinions of the role of museums: "I do think of museums as potential agents of change and I feel this project is a great opportunity for that. In other ways it reinforced my thinking…about the importance of involving audiences in exhibit creation." This impression was, for the invited participants, reinforced by the exhibit experience itself.

There were some critical considerations offered by the core team respondents. In part, the level of engagement determines the individual role of change in the museum as reflected in the comment "I need to be more involved in project design if I am to really make a difference." A few members of the core team shared comments similar to "I think we need to be more rigorous when articulating our goals, and when designing projects to actually achieve those goals," reflecting the role of museums in communicating across exhibits.

The invited participants had a different revelation about museums as a result of the residency. As one noted, "I began to appreciate the extreme challenge of creating museums that must cater to a general audience…there's no way to do an exhibit in a neutral way; by making choices of what to include and how to present it, exhibits always have a slant, or a message, that needs to be chosen in a conscious way."

Question 3: Did the residency affect individuals' sense of engagement with—or their roles on—the exhibit?

What We Found

In the moment, the residency was tremendously meaningful across participant groups. The residents with disabilities felt heard, engaged, and honored. They also noted that the exhibition was not about them, and not the story of one thing. Clearly emerging from the residency was the tension that was necessary among the engineering messages, the stories of those with disabilities, the focus on real needs of individuals driving the technology, and the high-impact, wow elements of the exhibit.

For some of the participants, the deep, emotional connections made with each other during the residency continue. For the core team, the importance of this project to the museum was dominant as did the sense of having important things to add to the discussion.

How We Know

The residency was tremendously meaningful in the moment across the participants. "Gathering with this group of people has been profoundly meaningful to me," according to one participant, and another reported that being present "opened up a door for whole new possibilities, not sure that's the right word. Bringing all the problems we encounter as people with disabilities, in wheelchairs, together and getting to know each other. Nice to know there are people like yourselves out there we can talk to and get together." Another noted it was "interesting that, very rarely, do you have this many people with strong physical disabilities and such strong intellectual activities—we can bounce ideas off each other. Not usual for me to be in [such a group]."" Yes we have a shared identity—we're all humans, we're well spoken, can express selves beautifully, powerful inner strength. But we're not telling the story of one thing. I was very appreciative of how much Peggy and Tara and the OMSI group really stuck to the core idea—these are all people we're talking about. It's not technology."

For the invited participants, the experience of the residency *continued to be nothing but inclusive* in terms of a sense of being engaged. Even though the participants' lowest mean scores related to their not adding to the discussion (slightly positive 4.4 post) and not having important ideas to add (positive 5.4 post), their engagement as part of the thought process (6.0 post mean) and that people listen to them (6.4 post mean) suggest the residency did shift their perceptions of what their roles on the exhibit design process entailed.

A theme that recurs across responses for the invited participants was that of connecting meaningfully with others: "the residency gave me the opportunity to meet other young people who face similar challenges. That chance is actually pretty rare, and I have kept in touch with many of them."

For some, the deep emotional connections made in the residency continue to resound. One participant commented "I think a lot of the stories I shared had to do with a conflict that I faced about the extent to which my disability should be part of my identity. On the one hand, I don't want disability to be the defining feature of who I am. On the other hand, I think it is integral and don't wish to minimize its impact on my identity." Comments from the invited participants supported the perception noted in the data above: "I felt my ideas and opinions were heard by many and received attention." These comments support the strongly positive post mean scores of 6.2 on feeling an important part of the process and 6.0 as being an important part of the thought process.

For the core team, the strongest response related to the exhibit and role was around this being an important activity for the museum, followed by having a sense of having important ideas to add. The core team demonstrated less change over time related to the role and themselves. A couple of respondents noted that their expertise was integrated into the residency: "I feel part of the larger group that worked together at the residency. I feel there is a lot of knowledge and experience that we all share as we develop the exhibit," and "I felt that my knowledge in my own field was sought after, appreciated, and taken seriously." One person noted the difficulty "for people to see the effect they're having" and yet felt optimistic and "a renewed sense of energy about the work I do." For some of the core team, the most powerful outcome from the residency was more as a supportive function: "It definitely increased my excitement about the project."

Reflections on the process

The basic concept of the residency was strongly endorsed by the core team. For example, one commented "the whole notion of bringing diverse people together to do real work is a good one." Another felt that "having each person's viewpoint presented as valid and important" and "getting a diverse group of people to become a cohesive working group" were important outcomes of the process. For another, "the exchange of ideas and experiences was very fruitful." One person offered a note of caution in that "I don't feel I can speak for everyone, however, about how fully all voices were heard."

There were initially three concerns expressed by the core team about the process which were then reinforced over the life of the exhibition development. For several of the core team respondents, time was a central factor. The short time spent together along with the single residency was seen as a concern. Some wanted "more time to work in small groups to develop real exhibit ideas," There were also several comments regarding the need for additional residency experiences: "I wish we were able to convene the group again when we had other things to respond to"; "having more than one residency weekend—as was requested in the original grant—would greatly enhance the quality of information gleaned." "I think a second residency would really enhance and solidify the experience."

> *A follow-up residency with most of the same people would have been tremendously productive and probably given the exhibit designers a lot more to work with, in terms of priorities and scope.*
>
> Core Team Member

There was also a concern regarding the depth of the activities in the residency and the lack of specific outcomes. For example, one person hoped for "more time, and more focused planning and concrete outcomes." Another noted "I was disappointed in the collaborative brainstorming exercises, I do not think the full potential of the group was met. I thought the facilitation could have been better planned and the exercises more diverse." One perspective was that at least one follow-up residency would have allowed the challenges to be addressed, especially in terms of priorities and scope.

> *I hope [visitors] learn things not only about the world, but about themselves. The material will excite and inspire, and visitors will be truly affected in some subtle yet profound way. My wish is to see the exhibit be the spark that sets the world ablaze.*
>
> Invited Participant

For the participants, the work of the residency would, in part, be tested by the final product. From the beginning, participants looked forward to seeing the exhibit "not only because of the personal connection I have to the material, the project, and the people, but because of the importance of the subject." Some "want to see how it was designed and which ideas were incorporated."

The invited participants also shared excitement around what the exhibit might be. One thought "it will be different than anything I've seen before." Another believed it will be a "fun, innovative, interactive HUMAN experience."

Some of the participants on the residency were interested in others' responses to the exhibit. As one stated, "I'm really curious to see how the public reacts to the exhibit." Similarly, another commented "I really want to see how the general population who will come to see the exhibit feel about the project on the spot." Regardless, there was a consistent hope that "this exhibit will really have an impact on how viewers perceive disability" and "help people realize the fact that disability is universal for all people, not local. The exhibit can expand the world of experience of general people." This exhibit could be an opportunity to "allow guests to re-imagine their own abilities."

The responses to the exhibit by the residents indicate that the invited participants felt they had been heard and that they were present in the exhibit. One strong theme was the pleasure of these residents that the exhibit focused on the individuals and they noted the exhibit "always presented the person first, the story first, then falling back on the technology. [In most cases] the user is often forgotten…" In addition, the panel noted the "accessibility of the exhibit for everybody. Options for interaction/access--that's occasionally forgotten." The panel felt their "initial concerns made it into the exhibit…Feel well respected by the people who designed the exhibit."

The core team as well felt strongly that the stories had been heard and had been integrated. There was recognition that they had far more stories of value than they could possibly use. As one of the core team members said, "I hated the process of cutting out things. We started off with a list of 40, 30 components [ideas] for this exhibit that has 12." For the design team, significant changes in personnel in their institution halved the number of those who had been part of the residency who remained on the project. For those individuals, the same comments were echoed: they continually thought of the residency activities revisited the stories and ideas they heard from the invited participants, and it was challenging to be able to select stories. One additional change came from one of the design team members who reflected how the residency helped them humanize the exhibit and focus on less of the high-end, cutting edge (cool stuff) technology. Rather, the focus for the design team became weighted toward stories and adapted technology based on individual needs as inspiration.

All the comments from the core team members demonstrated the strong reflective value of the residency and its impacts on the final product. The discussion during the "reunion" when the exhibit opened was intimate, open, and emotional. The core team members present expressed in depth the impact that sitting in the room with the invited participants had on the exhibit. The invited participants also were able to point to many components of the exhibit and identify how it came from the residency, including some of the design challenges being directly taken from the discussions three years before.

EXHIBITION EVALUATION

Exhibition Evaluation Questions

The overarching visitor-focused question for evaluating the Human Plus exhibition was: *What elements of the exhibition contribute in what ways to the humanization of the engineering design process?* This key question was divided into more specific evaluation questions first about process and second about five impact areas: Awareness of process; Awareness of innovation; Understanding; Innovation; Interest; and Attitude. Questions addressed both immediate and sustained outcomes. Each evaluation question is listed below along with its process or impact area and associated outcome statement:

1. *Awareness of Engineering Experience.* Visitors are aware of engineering as a dynamic experience of discovery, design, imagination, innovation, and meaningful contribution to society.

   In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, innovation?

2. *Awareness of Innovation.* Engineers make a meaningful contribution to society. Intended outcome: visitors define engineering in terms of values.

   In what ways do visitors define engineering in terms of value?

3. *Understanding.* Intended Outcome: Visitors perceive engineering both as a field and a process, and provide evidence of this learning several months after the exhibition. Intended outcome: Visitors describe their understanding of the process by which engineers identify societal problems and propose solutions within constraints.

   In what ways and to what extent do visitors understand engineering as both a field and a process?

4. *Interest.* Visitors increase interest in engineering. Intended outcome: Visitors indicate interest in engineering as a topic for further learning or a career.

   To what extent did visitors leave the exhibit with an increased interest in engineering?

5. *Attitude*. Visitors have a positive, enduring attitude toward human engineering. Intended outcome: Visitors demonstrate a more positive attitude about or image of engineering.

   What evidence can be found that visitors leave the exhibit with a positive attitude toward engineering?

6. *Process.* Stories about individual people help to humanize the profession and the process; stories about individual people help visitors understand exhibit messages.

   Overall question: *How did visitors use and interact with this exhibition experience*?

   d. How did exhibit components jointly and/or separately contribute to audience experience?
   e. In what ways did the stories help visitors understand exhibit messages?
   f. What design features for presenting exhibits and stories worked better than others?

Exhibition Methods

The strategy for answering these evaluation questions involved a mixed method study (in-person structured interviews, in person paper-pencil questionnaires involving both qualitative and quantitative responses, and a follow-up study using a web-based questionnaire). The intention was to gather statistically quantifiable response from the paper-pencil questionnaires and rich response from the interviews. A simple aggregate-group post-test only design with two post-test periods involved (1) an immediate posttest as visitors exited the exhibition area and (2) a delayed posttest eight weeks later. Each of the evaluation questions was operationalized into short open-ended questions or Likert-type response items that could be answered either by paper-pencil–style questionnaire or in structured interviews. The matrix contained in Detail of Methods for Answering Exhibition Evaluation Questions delineates the strategies utilized for answering each evaluation question.

The original plan was to conduct 45 structured interviews with mixed groups of both adults and youth and to gather data from 100 adults; 100 male youth, and 100 female youth. However, limitations associated with youth visitor traffic prompted the evaluation team to shift to seeking richer youth data through structured interviews. This accommodation meant modifying the structured interview to be relevant for both mixed age groups and youth-only groups.

Instrumentation

As noted above, questionnaires and structured interviews were designed to address each of the evaluation questions with both with statistically quantifiable and rich response data. In all, six data collection instruments were designed for use with this study: a short and long version of the adult exit questionnaire; a short and long version of a youth exit questionnaire; a group structured interview; and a delayed post-test online questionnaire. Items included in each of these instruments along with the evaluation questions they address can be found in Detail of Methods for Answering Exhibition Evaluation Questions. Al on-line questionnaire items can also be found in the more extensive adult long-form questionnaire (Paper-pencil Summative Questionnaire).

To assess the exhibit's effect on attitude, the adult questionnaires included Interest in Engineering and perceptions of Engineering scales, both adapted from the Modified Attitudes Towards Science Inventory (Weinburgh & Steele, 2000, 2008). Appropriate items from three original scales (Anxiety toward Science; Self-concept of Science; and Desire to do Science) were adapted to be specific to engineering and folded into the single Interest in Engineering scale used in his survey. Selected items from the Perception of Science scale were adapted to Engineering and combined with two additional questions specifically pertinent to this study: "Engineering is a profession that is easier for men to do than for women to do;" and "Engineering is not a profession for people who like working with relationships between people." To help explore how visitors responded to the exhibition's design features, the exit questionnaire included a five-item perceived visual attractiveness scale based on Van der Heijden's (2003) subscale of the same name.

Data Collection

Survey and interview respondents were gathered from a convenience sample of visitors exiting the exhibition during two weekends (including Fridays) in December 2013. Attendance during those days ranged from sparse to crowded. However, even during the more crowded periods, attendance by the target group of girls between the ages of 10 and 14 accompanied by an adult with the ability to provide parental consent was extremely light. (Most young people of this age attended in school or organization-sponsored groups). Individual adults and adults in groups were approached, provided information about the study, asked if they or the people in their group might have ten minutes to complete a survey or participate in an interview, and reassured that their participation was entirely confidential and voluntary. Invitations to complete paper-pencil surveys or participate in group interviews were interspersed throughout the two weekends. For the questionnaire, the short and long forms were used concurrently. All measures were used concurrently and continuously based on staff capacity and participants' available time. After receiving adult consent, youth were then invited to participate. Long and short versions of the exit questionnaires were also randomly utilized – although the short form was used as a convenience for visitors short on time.

Adult visitors who consented to participation were also invited to respond to an online survey in 6 to 8 weeks ("sometime in February"). They were assured that no data from the current survey would be associated with the follow-up survey and that any information they would provide on-line would be immediately de-identified once received.

By the second data-collection day when fewer than a dozen eligible youth (ten years or older accompanied by a consenting adult) had entered the exhibition, researchers recognized that the goal of collecting 200 questionnaire responses from this group, or even gathering enough data to establish statistical significance in any form would be impossible. As a mid-course correction, an alternative, rich-data structured-interview tool Appendix G was created and eligibility criteria loosened to include youth as young as eight years old. Questionnaire items were translated to quick answer, open-ended interview questions. Researchers sought to conduct 15 to 20 youth only interviews and an equal number with mixed groups of adults and youth or adults only.

Delayed post test data were derived from volunteers recruited from the first two groups. Although these volunteers were recruited from among immediate post-test respondents, delayed post-test data were not paired with immediate posttest results. Volunteers were told that no connection would be established between a respondent's answers to the immediate posttest and answers at the time of the delayed posttest. Seventy-four adults agreed to participate in the delayed survey and provided email addresses for contact purposes. Eleven of those email addresses were returned as undeliverable. Of the remaining 63, after three reminder messages, 11 completed the online questionnaire (17% response).

Respondents

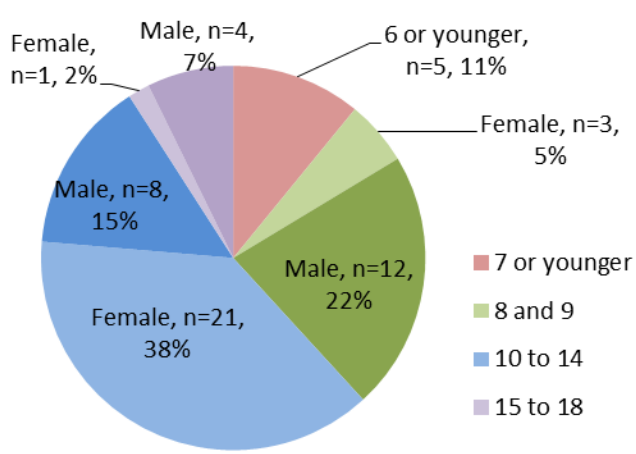
As shown in Table 4, the immediate post test data were derived from paper-pencil questionnaires from 113 individual adult volunteers and structured interviews with a separate set of visitors comprised of 17 volunteer groups of youth only (12 male and 14 female youth) and 17 mixed-age family/friend groups (28 adults; 14 male and 15 female youth).

Table 4. Description of aggregate study groups.

Data collection method	Instrumentation	Subjects
Exit questionnaire	Adult Full questionnaire (n=53) Adult Short questionnaire (n=60)	113 adults
Immediate rich response structured interviews	**Youth Only** Structured interview questionnaire with visual card sort	17 youth interviews involving 12 male and 14 female youth
	Family Group Structured interview questionnaire with visual card sort	17 family groups involving 28 adults; 14 male youth and 15 female youth
Delayed questionnaire	Online survey questionnaire	11 adult volunteers

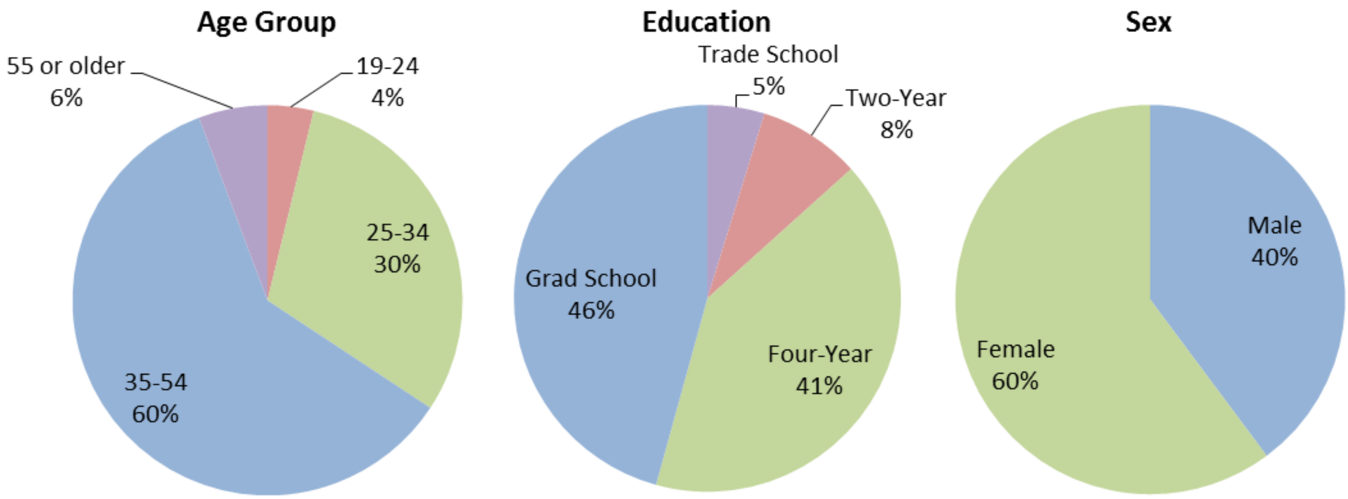
Altogether 55 youth (29 female and 26 male) provided data, all of it rich-response. Distribution by age and sex can be seen in Figure 1. Girls between the ages of ten and 14 constituted the largest group of youth respondents; boys were almost evenly split between the 10 -14 age group and the 8-9. All but one young person engaged in youth-only interviews provided information about parental expectation for their future. All believed their parents expected them to complete four years of college. More than half (9) felt expected to complete graduate school. Among these groups and individuals, two people had a severe disability; three lived in a household with someone with a severe disability and 13 reported having a friend or family member with a severe disability.

Figure 1. Age and sex of youth respondents.



Demographic distributions of the 113 adults completing questionnaire can be found in Figure 2.. More adult respondents were female (60%) than male. The majority of respondents were between the ages of 35 and 54 (60%) with another 30% between 25 and 34. Most (87%) had at least a four-year college education with the remainder having completed either a two-year degree or trade school. Among these respondents only two had a personal severe disability; 8% lived in a household with a person with a severe disability; and 26% had a close friend or family member with a severe disability, a distribution not dissimilar from the respondents to structured interviews.

Figure 2. Demographic distributions of respondents to adult exit questionnaires.



The eleven respondents to the eight-week delayed questionnaire appeared to be similar in demographic spread: 7 (63%) were in the 35-54 age-group; 10 (90%) had at least a four-year college degree; and 7 (63%) were female. Of the eight respondents who provided information about disabilities, there were no respondents with a severe disability, one lived with a household member with a severe disability, and 2 (25%) had a friend or family member with a severe disability.

Approach to Qualitative Data Analysis

Analysis of open-ended items on questionnaires and interviews combined inductive and deductive approaches to coding in order to capture the broadest possible range of responses within a consistent framework for each exhibit component. For example, the engineering design process steps designated *ask, imagine, create, test,* and *repeat* were used as coding categories when the item was keyed to outcomes about process, but other relevant categories were added as supplemental codes where appropriate.

For the purposes of analysis, the term "group" is used inclusively to mean respondents within a given interview who visited the New York Hall of Science together. Therefore, while a single person may be described as a group if interviewing alone, the number of groups does not always reflect the number of individuals answering a given question. On items for which sex and age were identified as key areas of investigation, individual answers have been tracked according to these features; however, given the tendency of individuals within groups to affect one another's answers, some data are considered to be interview group responses, rather than individual responses.

Exhibition Results

As described above, questions and response items were included in the various evaluation instruments to address each of the six evaluation questions. (See Appendix D and Appendix E). This Results section presents the responses to those six items categorized as:; (1) Awareness of Engineering; (2) Awareness of Innovation; (3) Understanding of the engineering process (4) Interest; (5) Attitude; and (6) the process of how the exhibition worked to communicate these ideas. Each subsection, one for each evaluation question, includes a summary of the findings titled "What We Found" each followed by (and hyperlinked to) the methods and specific findings that explain "How We Know."

1. *Awareness of Engineering Experience: In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, and innovation?*

The exhibition's logic model, and consequently this evaluation, included a focus on the exhibition's influence on visitor awareness of engineering as (1) "a dynamic experience of discovery, design, imagination, innovation," and (2) making a "meaningful contribution to society".

What We Found

Visitors left the exhibition aware of the engineering process as both creative and socially conscious. When visitors used three words to describe engineering, they frequently referenced the "imagine" and the "ask" steps of the engineering process.

How We Know

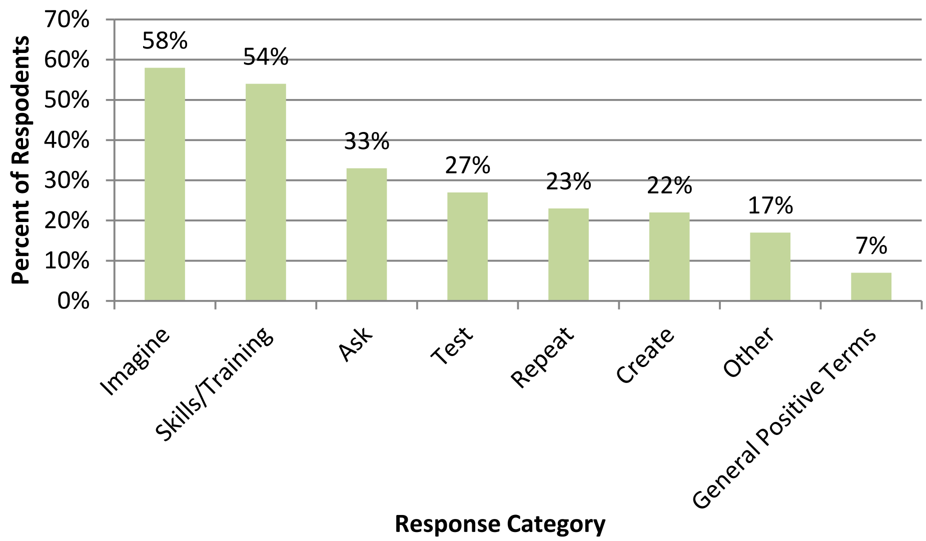
To answer the first question, all survey respondents and interviewees were asked to *provide at least three words to describe the qualities people need to become good engineers*. These words would reveal the extent to which visitors understood engineering in terms of the qualities involved in the "dynamic experience" designers had wanted to convey.

Among the 158 responses to this question (37 interview groups including 29 girls, 26 boys, and 28 adults; and 121 individual adult questionnaire respondents) all five steps of the engineering process were referenced (for frequencies, see Figure 3). Terms associated with the *Imagine* step of the engineering design process (e.g., "able to visualize") were mentioned most frequently. Within this category were responses that alluded to a broad consideration of possibilities, planning, or design. Words such as "strategist," "innovative," and "creative" were coded as *Imagine*.

The second most frequent category of response was not related to any specific step within the five-step engineering process, but to specific skills or the general ideas of being smart or educated (e.g., "have to be really good at math").

About a third of the responses reflected the Ask step of the engineering design process, i.e., they referenced identifying a need or soliciting input from a user. Words used to reference this step included terms such as "thoughtful," "caring," "contributor to societal advancement," "sensitive," and "optimistic ", were more socially conscious than one may have found in a less people-centered engineering exhibition. Ideas related to Create (construction or development of a tangible product), Test (experimentation or trial), and Repeat (reference to cyclical or iterative processes) were each mentioned in about a quarter of responses.

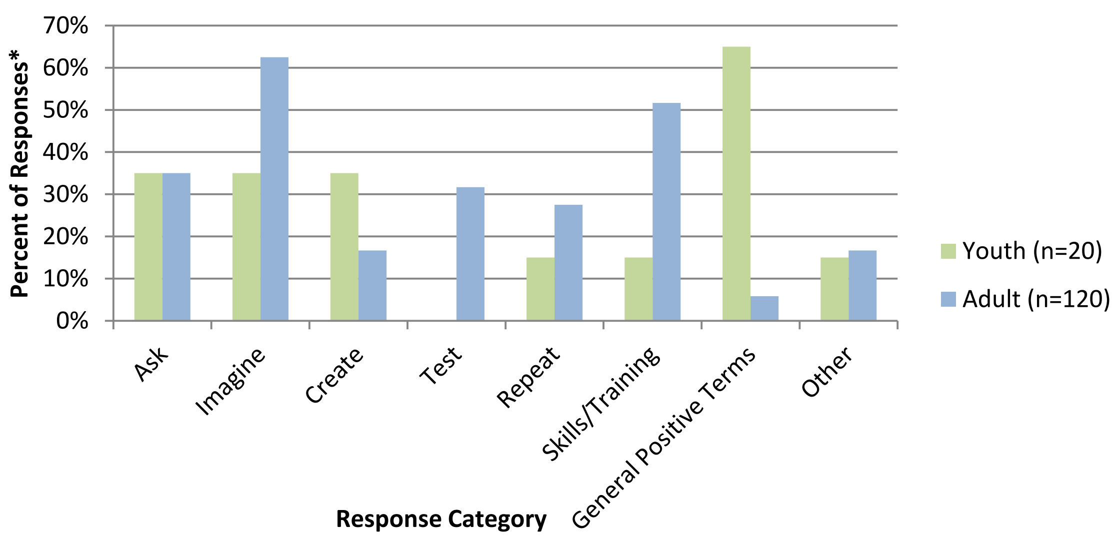
Figure 3. Descriptions of engineers by frequency of response category



Note: Because some responses could be associated with multiple coding categories, the total of percentages exceeds 100%.

Youth interview responses differed somewhat from the adult survey responses (Figure 4). In comparison with their other responses, youth referenced the *Imagine* and *Test* steps less frequently than adults, and the *Create* (build-it) step more often. They were also more likely to describe engineers with more general terms than adults.

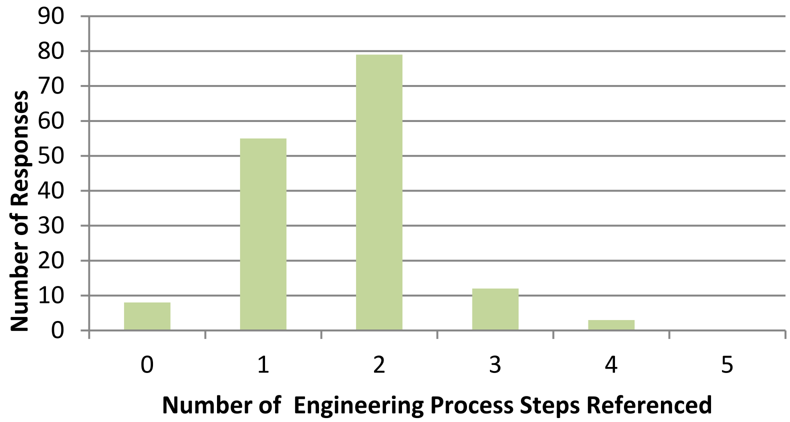
Figure 4. Comparison of adult to youth descriptions of engineers by frequency of response category



Note: Because some responses could be associated with multiple coding categories, the total of percentages exceeds 100%.

Data were also analyzed for the number of process steps represented for each questionnaire respondent or interview group. Results are presented in Figure 5. Of the 157 responses from both formats, only 8 responses involved no reference to the engineering process. Most of the "three words" responses referenced either one or two of the steps.

Figure 5. Numbering of engineering process steps referenced in visitors' "three words" to describe the qualities people need to become good engineers.



Finally, delayed responses to this question were collected from 10 individuals or groups. From among them, all five process steps were referenced with Skills, Ask, and Imagine referenced most frequently.

How respondents' words to describe engineers reflected their awareness of Engineering as a dynamic process.

Most all respondents referenced at least one step of the dynamic engineering process when they described qualities important to becoming a good engineer. On the other hand, only one in ten referenced three or more. Visitors most frequently referenced the *Imagine* step, suggesting that the exhibit was particularly successful in contributing to awareness of engineering's relationship to envisioning something new. Likewise, the relative frequency of responses and the specific terms referencing the *Ask* step suggests that the exhibition also successfully engaged visitors' awareness of the socially conscious entrée into the engineering process.

2. *Awareness of Innovation: In what ways do visitors define engineering in terms of value and innovation?*

Designers were also working to convey the wide range of "meaningful contribution" engineers make to society. Two open-ended questions aimed at uncovering evidence of the successful communication of this idea.

What We Found

Messaging concerning awareness of engineering innovation and value was largely successful. When explaining the exhibition's title, "Human Plus," a third of respondents associated it with engineering for the purposes of expanding human potential and specifically human potential for people with disabilities. Other explanations included expanded human potential in general, understanding people with disabilities, or general references to the human body—most of which indirectly, if not explicitly, valued engineering. Adults were more likely than youth to make the explicit association to engineering. Girls' responses were focused strongly on the human aspect of the engineering design process.

The exhibition led visitors to value engineering for its products, historical progress, and social contribution. Interview participants defined engineering largely in terms of valued products created or improved by engineers. In some cases these products were specifically for people with disabilities. Responses also included appreciation for the effects of engineering in terms of historical progress and more general social contribution.

How We Know

Evidence from the question, " Imagine the world with no engineers and answer the question, 'How would it be different?'"

Participants in group interviews were asked to imagine the world with no engineers and answer the question, "How would it be different?" Altogether, 57 individuals (28 adults and 29 youth) in 37 group interviews responded to this question.

When asked how the world would be different without engineers, respondents within both the mixed and youth-only groups largely answered in terms of products; a majority gave responses related to specific technologies created or improved by engineers (e.g., "There wouldn't be any cars or anything!"). In addition, two respondent groups mentioned technologies related to disability as products that would not exist without engineering. Some participants' answers suggested they were defining engineering in terms of modernity and convenience, as in the comment that without engineers life would be "like the Stone Age." Finally, some gave answers related to their personal associations with engineers (e.g., "Dad would be unemployed") or broader perceptions of what engineers do for society (e.g., "It would be tough").

Evidence from the questions, "The exhibit space you just saw is called 'Human Plus,' Why do you think the exhibit designers gave the exhibit space that name?"

Adult respondents to the long form of the questionnaire, the delayed questionnaire, and participants in mixed age-group and youth interviews responded to this question. It was expected that, if the exhibition had led them to value the contributions of engineers as meaningful, they would associate that meaning to the exhibition's title. Responses generally could be categorized into one of four areas (with frequencies illustrated in Figure 6.):

1. References to engineering or technology (coded as "Engineering"), e.g., "it helps humans with tools."
2. Expanded human potential, capabilities, or quality of life (coded as "Improvement"), e.g., "goes beyond the limits of a normal human body".
3. References to understanding people with disabilities and/or special needs (coded as ("Disability"), e.g., "most of the inventions are additional things people have where they don't have certain parts")
4. General references to the human body (coded as "Body"), e.g. "It's about what's in your body and how it interacts."

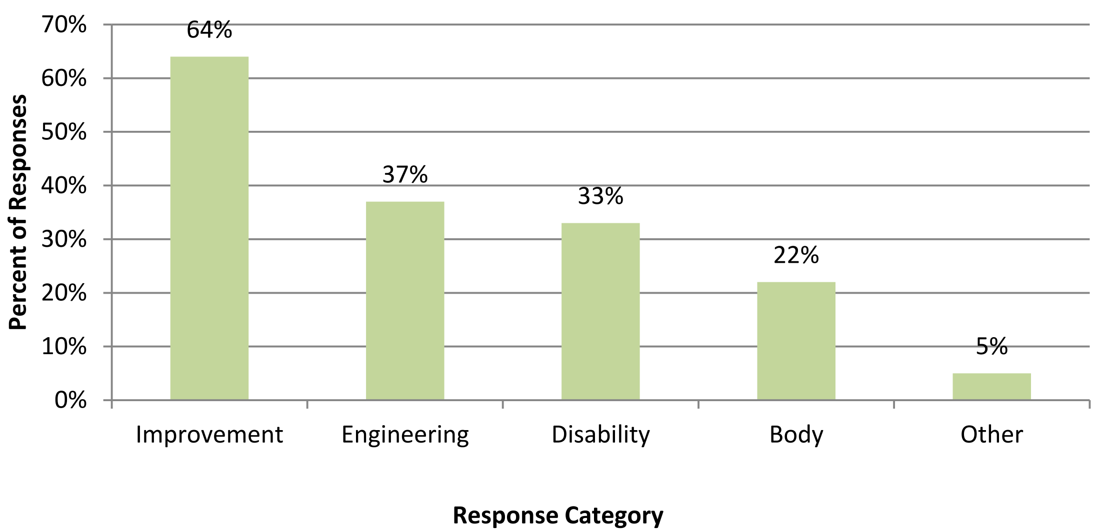
Among the 99 responses to this question, a majority of respondents cited the concept of expanding human potential and capabilities, especially as it related to people's physical abilities. Comments referencing engineering and disability also appeared as prominent categories of response. About one in five respondents mentioned the human body more generally without reference to disability.

Many responses could be coded into more than one of the categories, thus creating five additional categories:

5. Engineering for expanding human capability and potential (Engineering and Improvement); e.g., "It's about how humans try to make better things for other people."
6. Engineering for expanding human capability and potential for people with disabilities (Engineering, Improvement, and Disability); e.g., "They're all sharing different ways that machines can help people do things you think you can't do. Like skiing with no legs and feeling and seeing things while blind."
7. Expanded human potential and capability for people with disabilities (Improvement and Disability); e.g., "It's about people who have disabilities and ways they can still have fun or overcome their disabilities."
8. Engineered products for people with disabilities (Engineering and Disability); e.g., " It's about how different things are for people with disabilities."
9. How people with disabilities use their bodies (Disability and Body); e.g., "interact with body parts, see how the handicapped handle things"

Four comments fell outside these categories and were coded either as "Space" because they referenced the exhibition space or as "Other" because they had little to do with any of the other categories. Specific items constituting each category can be found in Appendix I.

Figure 6. Associations with exhibit title by frequency of response category (102 responses).



Note: Because some responses included multiple coding categories, the total of percentages above exceeds 100%.

Frequency of responses divided into the 8 categories can be found in Table 5. Almost half of respondents associated the name "Human Plus" to understanding the human body and expanding human potential and capabilities. A third associated the name with engineering for the purposes of expanding human potential and specifically human potential for people with disabilities.

Table 5. Exhibit themes by age group and youth sex.

Message Theme	Count of all response statements	%	Adult	%	Youth	%	Girls	%
Expanded human potential and capabilities (Improvement)	26	25%	22	33%	4	11%	3	15%
About the Human Body (Body Only)	20	20%	9	13%	11	31%	8	42%
Engineering for Expanding Human Capability and Potential (Engineering & Improvement)	18	18%	14	21%	4	11%	0	0%
Engineering for Expanding Capability and Potential for People with Disabilities (Engineering, Improvement, Disability)	15	15%	11	16%	4	12%	3	16%
Understanding People with Disabilities (Disability only)	8	8%	6	9%	2	6%	2	11%
Expanded human potential for people with disabilities (Improvement and Disability)	3	3%	2	3%	1	3%	1	5%
Engineered Products for People with Disabilities (Engineering and Disability)	3	3%	1	1%	2	6%	1	5%
Engineering Only	3	3%	1	1%	2	6%	0	0%
Associations with the Exhibit Space	2	2%	0	0%	2	6%	0	0%
Other	2	2%	0	0%	2	6%	1	5%
How people with Disabilities Use their Bodies (Disability and Body)	2	2%	1	1%	1	3%	0	0%
Total	**102**		**67**	**66%**	**35**	**33%**	**19**	**58%**

Further analysis revealed some interesting differences between adult and youth responses (35 from youth and 10 from adults in 37 interviews; 57 from adult exit questionnaire respondents; Table 5). Youth provided approximately one third of the responses, but were more likely than adults to associate the "Human Plus" title more generally with the human body (Table 5). On the other hand, adults were more likely to associate the title with expanded human potential and capabilities and also with engineering for expanded potential and capabilities.

Discussion of the ways visitors defined engineering in terms of value.

Respondents understood the value of engineers and engineering primarily through the products of engineering. This finding is similar to many other studies of engineering (Nelson, 2004; Rogers, 1983) and science (Abd-El-Khalick & Lederman, 2000; Lederman, 1992; McComas, Clough, & Almazroa, 2002; Wolpert, 1994) where the process is secondary to the tangible thing or the factoid. This exhibit was attempting to integrate easily understood process steps for engineering design, and this finding might suggest that even if people are able to identify the steps, the cultural norm for value is in the product or tangible result of having worked through the engineering process.

On the other hand, many visitors responding to the exhibition as a whole demonstrated an understanding of the connection between engineering and adaptive technology for people with disabilities. Over half the respondents mentioned engineering for human capability or potential for people with disabilities. Interestingly, over half the youth responding focused on the human body and less on the stories surrounding the engineering for specific needs. Girls' responses were focused strongly on the human-aspect of the engineering design process.

In terms of value, the high frequency of responses related to *improvement* is an important indicator for visitors' understanding engineering as providing "meaningful contribution" to society (as stated in the exhibit outcome associated with this evaluation question). Likewise, the relative frequency of the *Ask* step appearing reflected in the three-words to define engineering suggests that visitors made some connections between engineering and meaningful contribution, especially when contribution was defined as designing technology for a specific user or need.

3. *Understanding: In what ways and to what extent do visitors understand engineering as both a field and a process?*

The second focus of this evaluation was on visitors' understanding of engineering not only as a field, but also as a process. The logic model defined two intended outcomes related to this focus area: (1) Visitors perceive engineering both as a field and a process, and provide evidence of this learning several months after the exhibition; and (2) Visitors describe their understanding of the process by which engineers identify societal problems and propose solutions within constraints.

What we found

Visitors understood engineering as a process, but for some, the steps in the process may have been confused with steps of the scientific method.

Awareness of the "ask" and "imagine" aspects of the engineering process persisted several weeks after the exhibition experience.

How we Know

To answer this evaluation question, a structured interview question intended for group interviews was designed to provide evidence about the extent to which these outcomes were achieved. The question was repeated in the follow-up questionnaire.

> *You just went through an exhibit area that was about how engineers solve problems. Think of a problem you need to solve (for example, fixing a broken appliance or changing a bad habit). If you think like an engineer, what steps will you take? followed by prompts: "First step;" "Next step;" "Then;" "Then;" "Then;" "Anything else?")*
>
> *The Human Plus exhibition helped visitors understand the steps engineers take to solve problems. Thinking back to your visit to the exhibition, which of these steps do you recall?*

Participants in 18 group interviews responded to this question.

Evidence that the exhibition communicated about engineering as a process.

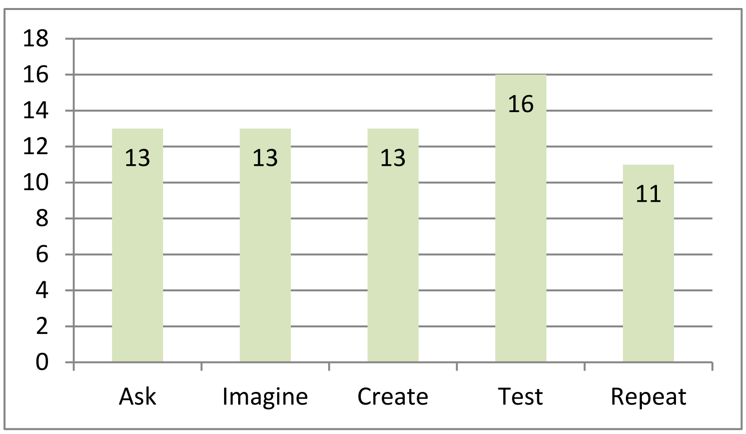
When asked to describe how they might solve a problem like an engineer, most respondents in adult and mixed-age interviews listed a series of actions that reflected three or more (most frequently, four) of the steps in the engineering design process (see Table 6).

Table 6. Number of engineering design process items referenced in problem solving by interview groups (number of groups=18).

Number of steps referenced	Number of respondent groups	Delayed Respondents
0	0	5
1	1	0
2	1	1
3	5	0
4	7	0
5	4	5

Among the steps themselves (detailed in Figure 7), Test was alluded to most frequently, with references made by 16 out of 18 groups. Among eight-week delay respondents, five listed varying versions of all five steps presented in the exhibition. One had "no idea" and the remainder chose not to answer the question.

Figure 7. Frequency of references to each step of the engineering process.



The strong presence of the design steps in visitors' responses suggests that interviewees did understand the exhibit's framing of engineering as a process. On the other hand there was some indication that the type of process may have been less clear, and in some cases, confused with the scientific method. Four respondent groups made reference to the scientific process as it is formally taught in most American schools. For example, parents attempted to prompt their children by saying things like "State the problem," a statement commonly referenced as the first step in the scientific method. This parental prompt may partially account for the high incidence of the *test* step, because the notion of trial and error has clear overlap with the processes of scientific experimentation. In short, the difference between a scientific problem (answering a question) and an engineering problem (meeting a need) in some cases seemed to make a difference between whether or not respondents were referred to the *imagine* step or *create* step. When framing the problem as needing an *answer* rather than a *solution*, interviewees were less likely to give responses that reflected engineering steps.

Evidence that understanding persisted weeks after the exhibition experience

In the data collected from the 6-week delayed questionnaire, responses to this question were sparse. The absence of data was perhaps as important as its presence. If respondents had recognized the various steps immediately after the exhibition experience, many may have forgotten the specifics by eight weeks later. On the other hand, however sparse the responses, the completeness within them suggests something positive. Either the exhibition resonated with existing knowledge in a way that could be remembered or, if these respondents had little pre-existing knowledge, they learned quite a bit from the exhibition.

Even though the delayed response data suggested that visitors may not have been clear about the engineering process per se, as has been discussed, they were aware of the importance of the qualities and concepts some of those steps involve as evidenced by the frequency of the "ask" and "imagine" words they used to describe engineering (See Awareness results).

4. Interest: To what extent did visitors leave the exhibit with an increased interest in engineering?

Exhibition designers sought to enhance *visitors' interest in engineering as a topic for further learning or a career*. Two approaches were used to answer the related evaluation question. First, eleven questions constituting an Interest In Engineering subscale were included in the short form of the adult exit questionnaires and in the delayed questionnaire. These items were adapted from three subscales (Anxiety toward Science; Self-Concept of Science, and Desire to Do Science) of the Modified Attitudes toward Science Inventory (Weinburgh & Steele, 2008). Second, youth in the youth-only interviews were asked the question, "Could you see yourself becoming an engineer: why? Why not?" To understand possible differences between girls' and boys' responses, adults were asked to respond to a statement about enthusiasm for having a son or a daughter choosing to become an engineer.

What We Found

The exhibition had a powerful impact on adult visitors' interest in engineering. Overall, adults reported that they entered the exhibition with a fairly neutral interest in engineering, but left with significantly greater interest. Of particular note was their increased sense of enjoyment as they thought of themselves in the profession.

Among youth, interest in a career in engineering differed between girls and boys. A strong majority of boys said they could see themselves becoming engineers, a strong majority of girls said they could not. In general, girls connected their "no" answers to perceptions of their own deficit in aptitude; boys connected their answers to their individual interests, regardless of whether they answered "yes" or "no."

Positive feelings toward engineering emerged equally as frequently among boys and girls. Only among boys with no interest in becoming engineers were there no comments related to positive feelings toward engineering.

Both male and female adults were highly and equally as enthusiastic about sons and daughters choosing to become engineers, suggesting that differences between boys and girls may be coming from sources outside of parenting.

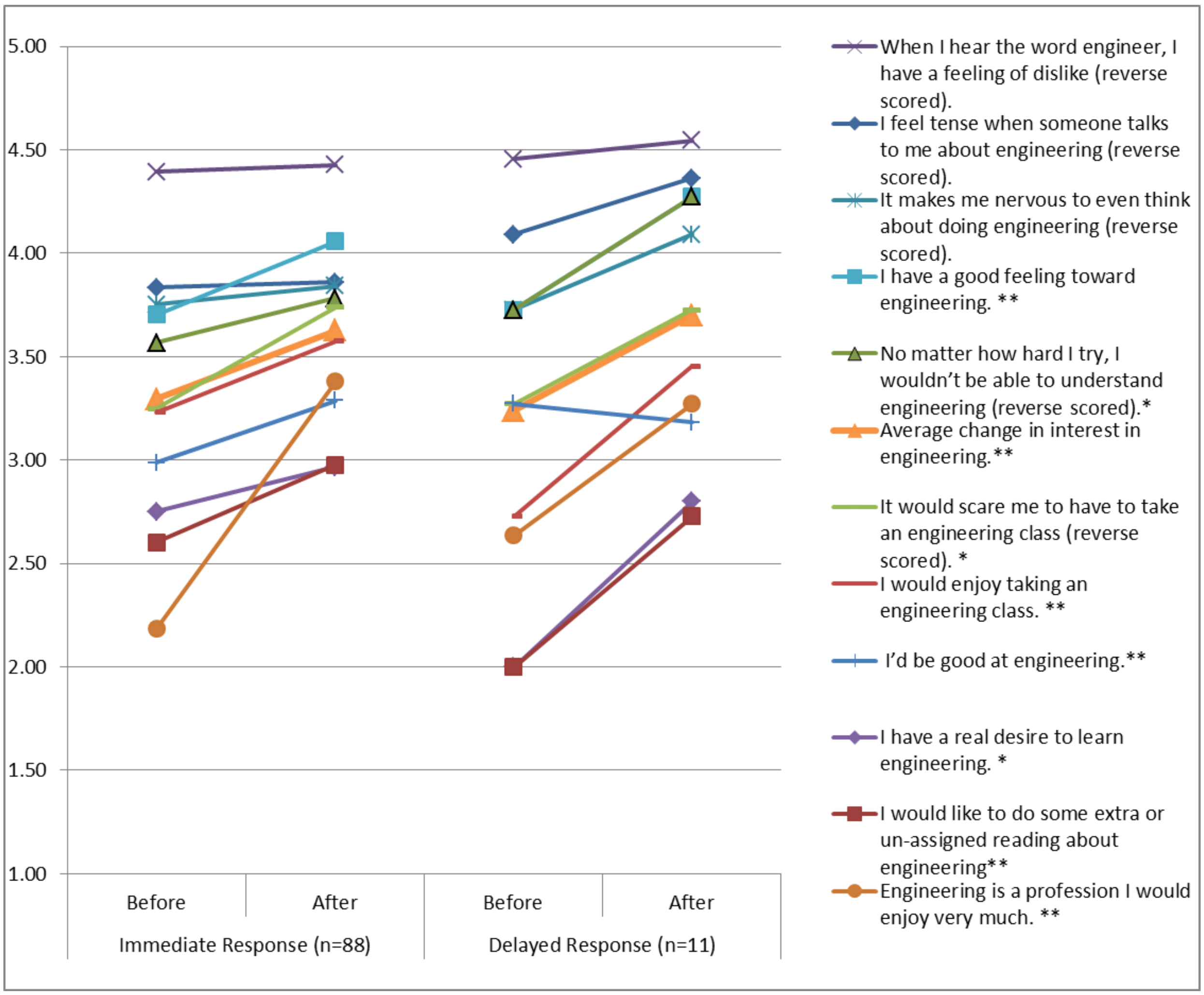
How We Know

Answers to this evaluation question were gathered from adult responses to the an Interest in Engineering scale; and youth responses to the question "could you see yourself becoming an engineer?"

Evidence from the Interest in Engineering subscale.

The Interest in Engineering subscale consisted of eleven statements to which respondents rated their level of agreement on a five point scale from 1= strongly agree to 5 = strongly disagree. The statements (listed in Figure 8) encapsulated a range of factors that would indicate an underlying interest in Engineering. These factors included both statements about both aversion and attraction to engineering.

Figure 8. Interest in engineering: Immediate and eight-week-delay respondents' retrospective report of change from before to after exhibition experience



* significant at <.05; ** significant at less than .01

Results from the 90 adults who responded to this survey subscale demonstrated an overall statistically significant increase in interest (3.4 to 3.5, paired *t* =5.0, p<.001, range 1=strongly disagree; 5=strongly agree). Unchanged were the high levels of pre-exhibition disagreement with negative statements about aversion to engineering (illustrated in Figure 8 as reverse scored). In other words, on the average, respondents entered and exited the exhibit without aversion to the word "engineering," aversion to talking about engineering, or aversion to thinking about doing engineering.

They reported that before seeing the exhibition, they had moderate agreement with aversive statements referencing never being "able to understand engineering" or fear of "taking a course in engineering." In both cases, responses to these negative statements demonstrated significantly less ($p<.05$)agreement after experiencing the exhibition.

On the average, prior to the exhibition, respondents had low to moderate agreement with statements positively associated to interest in engineering. They also reported significantly increased ($p<.001$) agreement with those statements after the exhibit. Of particular note was the average increase in agreement with the statement "Engineering is a profession I would enjoy very much." Respondents moved from clear disagreement into the range between neutral and agreement. Respondents to the delayed questionnaire showed a similar response pattern (right-hand column of Figure 8).

On the average, groups of male and female adults responded with no significant difference in the amount of change they experienced (t=.50, df = 85, p=.62). However, across all but one ("feeling of dislike") statement, after seeing the exhibition, compared to men, women agreed significantly less with the positive statements and more with the negative (women average interest = 3.4; men = 3.9, equal variances not assumed; t= 3.48, df=101, p=.001).

Eight weeks after seeing the exhibition, as a group, the eleven responding visitors recalled significantly greater change in their Interest in Engineering than the group that reported immediately (t=2.3, df=99, p=.02). Analyzed by item, only one statement showed significant difference in change from before to after: I have a real desire to learn engineering." For that statement the report of agreement from before to after went from being relatively the same (.21) immediately after the exhibition to half a point higher (.51) eight weeks later (see right-hand column of Figure 8. Interest in engineering: Immediate and eight-week-delay respondents' retrospective report of change from before to after exhibition experience. (Note that the apparent differences in the graphic representation were insignificant due to the low number of respondents.)

Evidence from the Interview Question: Could you see yourself becoming an engineer? Why or why not?

When asked about engineering in relation to their own future careers, youth interviewees at the individual level gave responses that appear to have some relationship to gender. Whereas a strong majority of boys said they could see themselves becoming engineers, a strong majority of girls said they could not (see circled results in Table 7**Error! Reference source not found.**). When prompted to explain their answers (detailed in Table 8), girls to connect their "no" answers to perceptions of their own deficit in aptitude (e.g. "No, I'm not good at technical stuff"). Boys tended to connect their answers to their individual interests, regardless of whether they answered "yes" or "no." Meanwhile, every group except for boys who answered "no" included an instance of positive feelings about engineering.

On a scale of ranging from 1= extremely unenthusiastic to 5= extremely enthusiastic, after experiencing the exhibition, male and female adults were highly and equally enthusiastic (4.5) about the possibility of either a son or daughter choosing engineering as a profession.

Table 7. Frequency of youth answers by sex ("Could you see yourself becoming an engineer?")

	Yes	No	Maybe
Girls	2	9	3
Boys	7	3	2

Table 8. Future with engineering: frequency of youth justifications by sex and answer type.

	Aptitude	Interest	Positive Feelings
Girls Yes	1	1	1
Girls No	6	3	1
Girls Maybe	0	1	1
Boys Yes	2	5	1
Boys No	0	3	0
Boys Maybe	0	1	1

Note: Coding categories were not mutually exclusive, so the sum of categorized responses will exceed the number of actual responses

Discussion of the effect of the exhibition on visitors' increased interest in engineering.

There was strong evidence that the exhibition had a powerful impact on visitors' interest in engineering. Overall, adults reported that they entered the exhibition with a fairly neutral interest in engineering, but left with significantly greater interest. Of particular note was their increased sense of enjoyment as they thought of themselves in the profession.

Among youth, interest in a career in engineering differed between girls and boys. The repeated assertion of low aptitude among girls who said they could not see themselves becoming engineers—especially in contrast to boys' focus on interest—suggests that youth interviewees entered the exhibit with some external, potentially gendered messages about STEM fields. This possibility is supported by the finding among female adults, for whom agreement with statements that would support an interest in a career in engineering was significantly lower than among male adults. On the other hand, the presence of youth respondents' positive comments about engineering in all but one category, along with reported change in perceptions of engineering, support the finding that the exhibit communicated both new information and value about engineers' roles in and contributions to society in general. Again, this finding is also reflected in responses from adults, who reported they had experienced significantly positive changes in the perceptions of engineering. There was evidence that these differences did not stem from parents, who were highly and equally as enthusiastic about sons and daughters choosing to become engineers.

5. Attitude: What evidence can be found that visitors leave the exhibit with a positive, enduring attitude toward engineering?

Exhibition designers also wanted visitors' *to leave the exhibition with a positive, enduring attitude toward engineering.* Three approaches were used to answer this question. First, seven questions constituting a Perception of Engineering subscale were included in the exit questionnaires. Second, youth in youth-only interviews were asked the question, "Could you see yourself becoming an engineer: why? Why not?" Finally, data from the delayed questionnaires would provide indicators of this positive attitude "enduring."

What We Found

The exhibition improved both adult and youth attitudes towards engineering. Adults showed significantly greater appreciation for engineering as (1) helpful for understanding today's world; (2)necessary for helping to solve problems of everyday life; (3) important for inclusion as a subject of study; and (4) important knowledge for being productive in life.

The improved attitude was even more pronounced among respondents answering in retrospect, several weeks later.

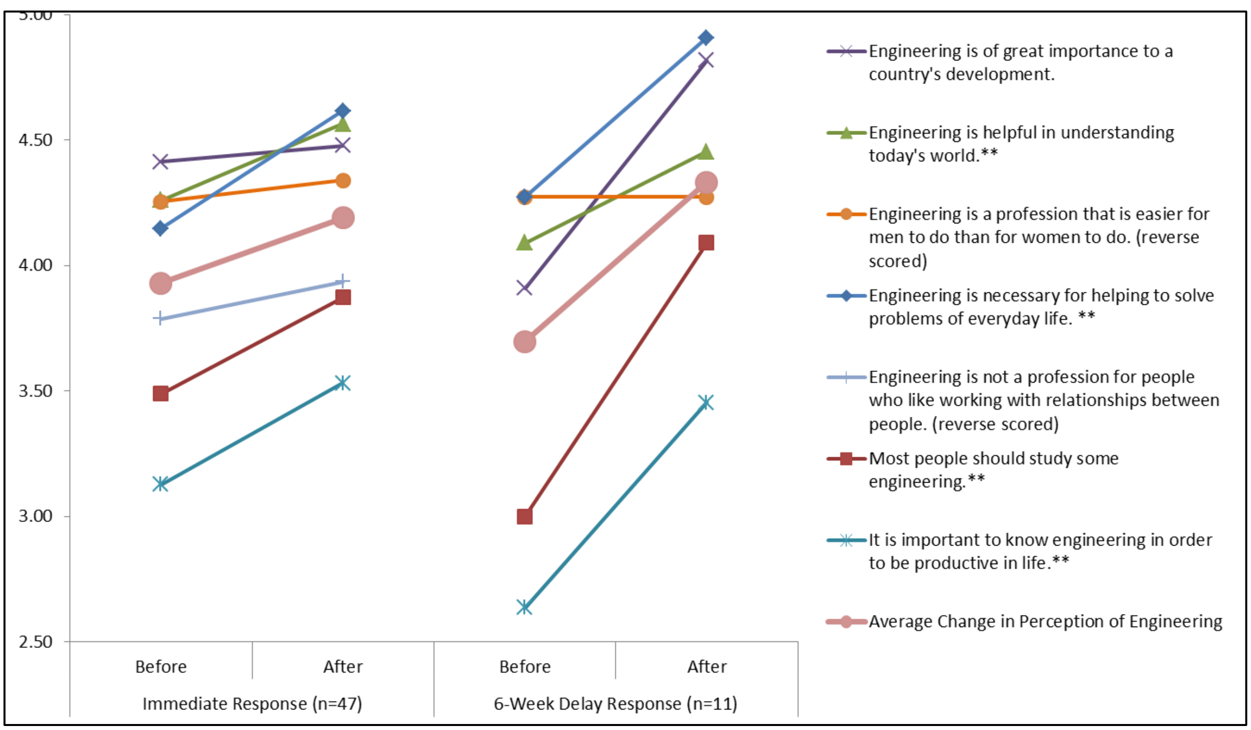
Among youth, the majority reported positive change in perception. Those who reported no change had pre-existing high regard.

How We Know

Evidence from the Perception of Engineering Subscale

The perception of engineering subscale consisted of seven statements to which respondents rated their level of agreement on the same five point scale as the Interest in Engineering subscale (see section 4 above). Five of the seven statements (listed in Figure 9) were adapted from the Perception of Science subscale of the Modified Attitudes toward Science Inventory (Weinburgh & Steele, 2008). The two additional statements, specifically designed for this exhibition addressed the perception that engineering is easier for men than women; and that engineering would be unlikely to capture the attention of people (especially girls) who tend to be interested in human relationships. This subscale was included in the exit questionnaire long form and in the delayed questionnaire.

Figure 9. Perception of engineering: exit and eight-week-delay respondents' retrospective report of change from before to after exhibition experience



** Exit response significant change from before to after ($p < .01$); significance for six-week delay not reported due to small sample size.

Using this subscale, 47 adult respondents reported significantly improving their perceptions in four of the seven areas addressed by the scale (marked with "**" in Figure 9). Among the unchanged items were "Engineering is of great importance to a country's development" which began and ended with highly positive agreement. Also unchanged were two reverse-scored items specifically designed for the evaluation of this exhibition: "Engineering is a profession that is easier for men to do than for women to do" had a fairly high level of agreement and "Engineering is not a profession for people who like working with relationships between people" which generated neutral amount of agreement.

Across most all of the items, respondents to the eight-week-delayed questionnaire reported themselves entering the exhibit with lower agreement that they had reported immediately.

Eight weeks after seeing the exhibition, as a group, the eleven responding visitors recalled significantly greater change in their Perception of Engineering than the group that reported initially. This difference was located specifically with three statements (see right-hand column of Figure 9). Change in agreement with "Most people should study some engineering" went from a less than half a point (.38) to greater than a full point (1.1); change in agreement with "Engineering is of great importance to a country's development" went from almost no change (.06) to almost one full point (.90); and change in agreement with the statement, "It is important to know engineering in order to be productive in life rose less, but significantly, from .40 to .82. Reports of their agreement with the Perception of Engineering statements before seeing the exhibition did not differ. Nor did their average agreement differ after the exhibition. However within that average, there was one significant difference between the two groups. Visitors responding eight weeks later agreed more strongly with the statement "Engineering is necessary for helping to solve problems of everyday life,"(equal variances not assumed, $p<.01$; $t=2.4$, $df=41.62$, $p=.02$).

Evidence from the Youth Interview question: This exhibition was about engineering. Do you think this experience changed what you think about engineering and people who are engineers?

When asked about changes in perception of engineering after seeing the exhibition, nine of 12 boys and ten of 13 girls reported that change had occurred (Table 9). Those who reported no change already had positive perceptions. Both girls and boys who reported change privileged some specific product or process related to engineering (see Table 10Table 10. Reason(s) for reported change among youth by sex and response (n=25). In particular, a theme that emerged in these answers was the idea that engineering involves creative thinking and design, not just building objects. Some youth who reported change also connected engineering themes to disability themes by referring to the needs of particular users. Interestingly, the girls who reported no change in their perceptions both referred to information that they already knew about engineers, whereas the boys who reported no change referred to personal experience with engineering (e.g., "My dad is an engineer.").

Table 9. Perception of Engineering: frequency of reported change among youth by sex (n=25).

	Yes	No	Maybe or "Kind of"
Girls	10	2	1
Boys	9	3	0

Table 10. Reason(s) for reported change among youth by sex and response (n=25)

	Engineering	Skills/Qualities	Personal	Disability
Girls Yes	8*	4	0	2*
Girls No	2*	0	0	1
Girls Maybe	0	1	0	1
Boys Yes	7*	0	1	3*
Boys No	0	1	3*	0
Boys Maybe	0	0	0	0

Discussion of the evidence that visitors left the exhibit with a positive, enduring attitude toward engineering:

As with interest in engineering, visitors engaged in the summative evaluation had strong gain scores related to their attitudes towards engineering immediately following their experience in the exhibition. Respondents reported moderate agreement with the statement about engineering being easier for men than. women prior to the exhibit and even a bit higher (though not significantly so after the exhibit. It is important to note that some respondents may have agreed with the item not because they thought that thinking like an engineer is easier for men than women but that women have a more difficult time succeeding in the profession because of the generally poorer acceptance of women by the profession.

Although some responses to this item did not reflect change in perception about engineers, neither those answers nor those that did reflect change yielded evidence of negative perceptions of engineering. Among the respondents who reported change in their perceptions, value was sometimes defined in terms of the ways that engineering can help meet needs. Importantly, a strong majority of these respondents also commented that they learned something new about the roles and processes associated with engineering (e.g., "It's more than just building").

Of lingering concern is the disparity in sex and interest/attitude toward engineering. The girls in the target range responded to the exhibition as intended in that they identified with the individuals and the narrative stories. Even so, there appears to be the external gender-role pressure to see engineering as a male career.

6. Process: How did visitors use and interact with the exhibition experience?

Visitor response to the various methods of inquiry in this evaluation provided data used to understand three aspects of how visitors used and interacted with the exhibition experience:

- How exhibit components contributed to visitor experience;
- Ways stories helped visitors understand exhibit messages; and
- Methods of presentation and story media that worked better than others for each group.

What We Found

Findings about how exhibit components contributed to visitor experience

Visitors engaged well with the exhibition with each of the exhibits contributing differently to their experience. Most of the elements of the experience were used by a plurality of visitors, though the average number of specific exhibit components engaged was three (out of 13) per visitor. Anecdotal observation revealed that crowdedness was a major factor in the number of components and the amount of time spent in the exhibition.

The most frequented exhibits among adults and the most liked among youth were *Every Body Plays; Redesigning You; RAMPS; and More than a Mouse.* Least recalled (i.e. most frequently "not remembered) among adults were *Consider This, Ask, Imagine, Create; Imagine the Possibilities; and Design a Wheelchair.* Among youth respondents, least liked were*, Consider This, Attempts*, and *Finding Your Way*, and *Ask, Imagine, Create*.

Some exhibits were more visually memorable than engaging; others were engaging but easier to miss. Adult respondents tended to remember seeing two exhibits, *Feel the Music* and *Welcome,* more than they experienced them. In other words, these two exhibits were more attractive than engaging. In contrast, *More than a Mouse* and *Re-Designing You* were more experienced than remembered, i.e., easier to miss, but if seen, they were engaging.

Findings about the ways stories helped visitors understand exhibit messages.

Exhibit affected adult enthusiasm for engineering. The average effect on adult respondents' enthusiasm for engineering from just less than "somewhat" (*Attempts*) to halfway between "somewhat" and "a lot" in *More than a Mouse*. Most of this enthusiasm was associated with the "create" and "ask" steps of the engineering process.

Exhibit response ranged in regard to stories most remembered. Stories of how technology enhanced lives of people with disabilities played an important part in visitors' experiences of the exhibits. For three exhibits (*Ask, Imagine, Create; Welcome;* and *Design a Wheelchair*) almost half of respondents who engaged with those exhibits believed the story was either essential or very important to explaining the exhibit to a friend. Exhibits with stories remembered by most respondents were *Welcome*, *Ask Imagine Create*, *Design a Wheelchair*, *Attempts*, *Finding your Way*, and *Imagine the Possibilities*.

Visitors experienced exhibits as balancing personal stories and engineering messages differently. For four exhibits (*Attempts, Re-Designing You, More than a Mouse, and Feel the Music*), the proportion of visitors who reported that the exhibit made them more enthusiastic about engineering was far higher than the proportion of visitors who felt the story was important to understanding the exhibit. In contrast, the proportion of respondents who experienced the stories of the *Welcome* exhibit as important was greater than the proportion of respondents who experienced the exhibit's effect on their enthusiasm for engineering. No exhibits could be classified as having high story importance and low enthusiasm for engineering.

Visitors' own "stories" created during their visit also may have contributed to messages received. Some respondents interpreted "story" to be their own narrative of experiencing an exhibit (e.g., "I felt what it was like to ski with no legs"). Given that the exhibits were intended to be highly interactive and many respondents identified interactivity as an important feature of appeal, these "stories" may also have contributed to the impact of messaging.

Findings about which methods of presentation and which media worked better than others for each group.

The balance between interactivity, personal stories and messaging about engineering affected how visitors interpreted exhibit messages. Although specific design components such as color or music were sometimes mentioned in interview groups' descriptions of why they liked a given component, respondents usually framed their responses in terms of interactivity, themes related to disability, or ideas related to engineering (e.g., a specific type of technology). Most prominent among these categories was interactivity, which appeared especially strongly for a majority of components.

The difference in balance between interactivity, introduction to a personal story, and the experience of engineering appeared to have had an important influence on how well an exhibit component communicated the exhibition's message. Interactivity involving an opportunity to build or modify a product cued interpretation related to engineering process. In contrast, interactivity relating to a user perspective tended to cue interpretation related to disability. Moreover, stories were most effective in connecting to exhibit messages when they were directly linked to design-based interactivity. In some cases, interactivity may have overpowered the message.

Among adults, the exhibitions appeal lay primarily with its sense of fun, and next with its attractiveness. While they rated colors, signage, and videos fairly high, they weighted sense of fun higher. This finding was supported data from the interview participants who overwhelmingly referenced their enthusiasm for the exhibition's interactivity and fun.

Visitor experience was diminished when the space was crowded. Anecdotal observation revealed that crowdedness was a major factor in the number of components experienced and the amount of time spent in the exhibition. The crowdedness aspect of the exhibit was augmented by the tightness of the space, further creating the energy commonly seen in visitors when an area is busy—to move through without engaging.

A summary of per-exhibit findings

For the reader interested in an exhibit by exhibit analysis, a summary of the findings described above are shown in Table 11.

Table 11. Summary of findings of how individual exhibits contributed to visitor experience.

		Every Body Plays	Re-Designing You	RAMPS	More Than A Mouse	Design A Wheelchair	Feel The Music	Ask, Imagine, Create	Caring For A Pet	Imagine The Possibilities	Finding Your Way	Attempts	Consider This	Welcome
Engagement among adults	Most	x	x	x	x									
	Least					x		x		x			x	
Recall among adults	Most	x	x	x										x
	Least					x		x		x			x	
Favorite among youth		x	x	x	x									
Frequency of design feature attractiveness*	Interactivity	xm**	x	xm	xm									
	Disability	xm		x					m		m		m	m
	Engineering		x		x	xm						m		
Relatiosnhip of recall to engagement	more attractive than engaging						x							x
	Easier to miss, but engaging if seen		x		x									
Effect on enthusiasm for engineering	Most				x			x						x
	Least			x						x		x		
Relationship of story to engineering	more story less engineering													x
	more engineering, less story		x		x		x					x		
	story just slightly more than engineering	x		x		x		x	x	x	x		x	
Most informative about engineering*		x			x									
Most informative about disability*		x			x						x			
Associated to "create" step of engineering process				x	x	x		x			x		x	
Associated to "ask" step of engineering process		x	x									x		
Most informative about disability*		x			x						x			

* based on qualitative feedback from small sample
** "m" refers to findings from mixed age-group interviews

How We Know

Exhibition designers wanted the stories about individual people to *help to humanize the engineering profession and the process.* They also wanted these stories *to help visitors understand the exhibit messages.* These two intentions led to three evaluation questions, each addressed by questionnaire items or interview questions.

a) How did exhibit components jointly and/or separately contribute to audience experience?
b) In what ways did the stories help visitors understand exhibit messages?
c) What design features for presenting exhibits and stories worked better than others?

Both exit questionnaire and rich-response strategies were employed to understand how visitors interacted with the exhibits and the effect of the exhibits and exhibit stories had on enhancing exhibit messages. Exit questionnaires included a photo of each exhibit captioned with a short phrase that would trigger memory (e.g., the *Consider This* exhibit photo was followed by the phrase, "reconsider your assumptions interactive video"). For each picture (one per exhibit), respondents could select "I do not remember it," "I did not do much with it," or "I did it, read it, or played with it." If they answered that they had engaged with the exhibit, they continued on to three more questions: (1) In this exhibit did you read a video or read a story about a person? (yes/no response); (2) If so, how important would this story be in explaining this activity to a friend? (scale ranging from 1="not important" to 4="essential"; and (3) How much did this exhibit affect your enthusiasm about engineering? (scale ranging from 1= "Not at all" to 3= "A lot").

For the mixed-age group interviews, this same series of questions was presented using photos on 5 x 8 cards with verbal explanations. Following each photo, interview participants responded to open ended questions, "Do you remember a story that went with this part of the exhibit?" and "What was that story about?" Participants of youth-only interviews engaged in a variation of this question. Instead of addressing each of the exhibit components, they were asked to select from the stack of cards, which four they liked the most. For each choice, they told the interviewer why they liked it and what the exhibit told them about engineering.

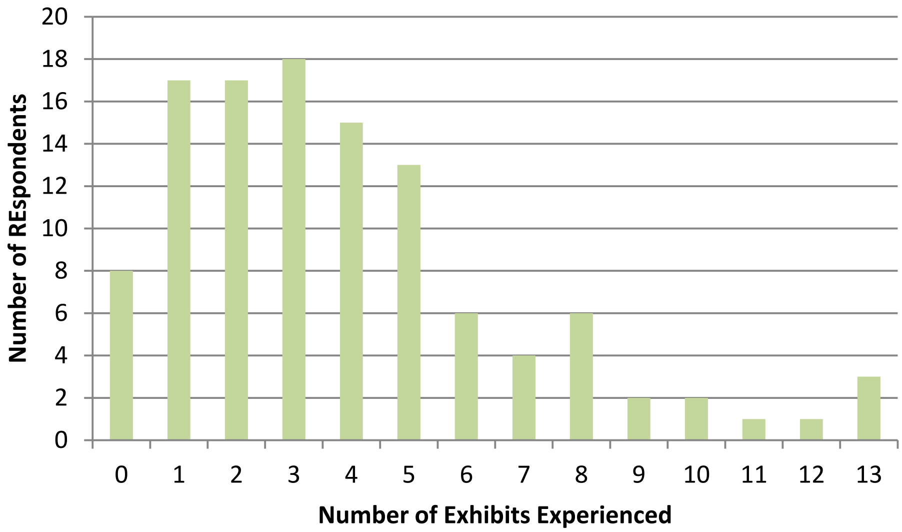
Evidence of how exhibit components jointly and/or separately contribute to audience experience.

To understand how exhibit components contributed to visitor experience, data from questions about individual exhibits were analyzed for (1) total number of exhibits experienced and (2) comparative level of engagement at each exhibit.

Number of Exhibits Experienced

Overall, the average adult respondent engaged with three exhibits (the mode and median of the distribution); because of the skew, the average number of interactions was four. Figure 10 illustrates the distribution of respondents by the number of exhibits they experienced. Evaluators collecting data recalled that the exhibit use was extremely high when the exhibit was sparsely attended and lower as the volume of visitors in the exhibition area rose. Nineteen respondents reported engaging with seven or more exhibits, thus constituting a Percent of Diligent Visitor rate of 18% (the proportion of visitors who engaged with at least half, in this case seven or more, of the exhibits; see Serrell, 2010). A Percent of Diligent Visitor rate of 50% or more marks a "thoroughly used exhibition" but this level of use is exceedingly rare.

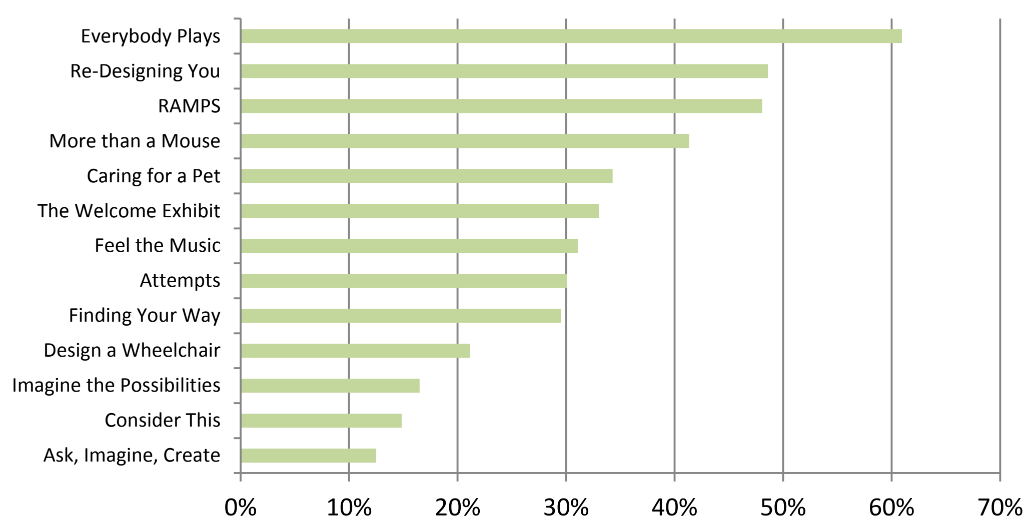
Figure 10. Distribution of respondents by number of exhibits experienced (n=109).



Exhibits with which visitors engaged most

The Human Plus exhibition area included 13 exhibits. For each, 109 respondents to the adult questionnaire selected if they (1) remembered the exhibit ("I do not remember it"); (2) "I did not do much with it"; or (3) "I did it, read it, or played with it." For analysis purposes, the "did it, read it, or played with it" responses were considered signs of "engagement." Engagement was then considered by individual exhibit. Across exhibits, engagement ranged from a high of 61% in the *Every Body Plays* exhibit to a low of 13% in *Ask, Imagine, Create* (Figure 11). The mixed age-group interviews reinforced a similar engagement. The *Every Body Plays* and *RAMPS* exhibits were most engaging and the *Ask, Imagine, Create* and *Consider This* exhibits, the least.

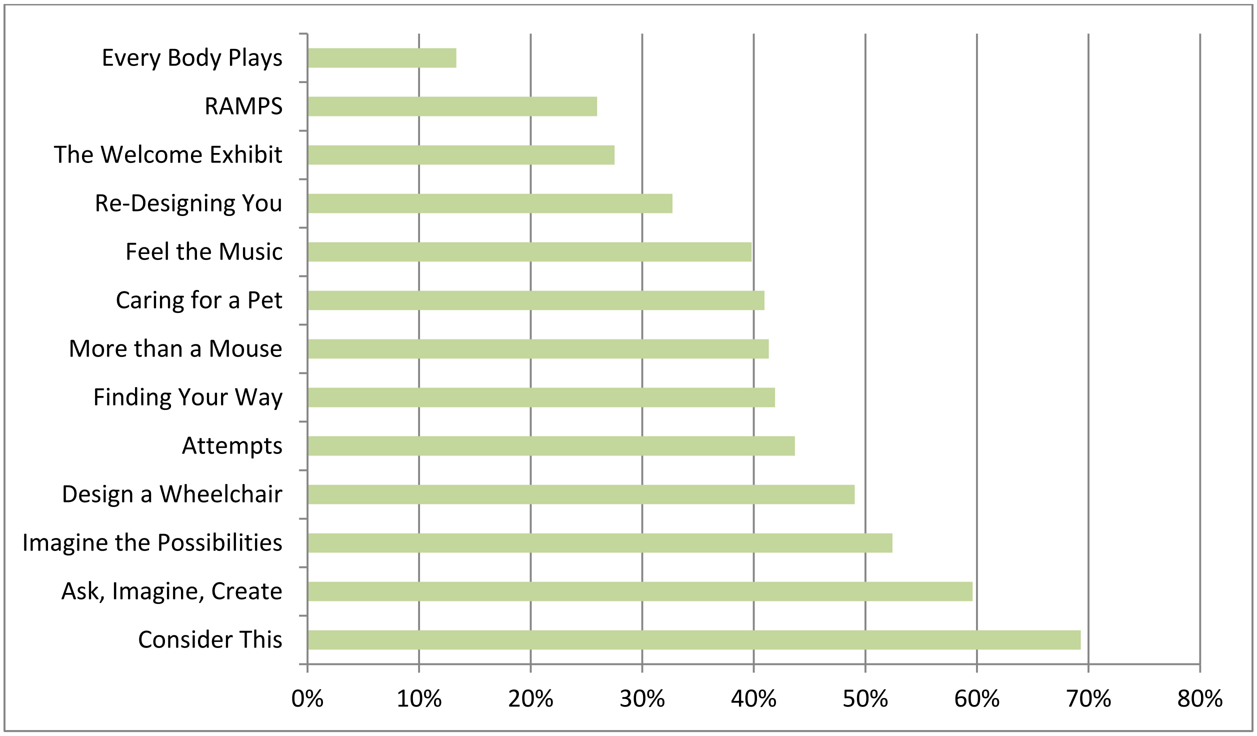
Figure 11. Percentages of total adult questionnaire respondents engaged with exhibits.



Visitors' recall of exhibits

Another approach to understanding how exhibits affected visitor experience was through the exhibits they were unable to remember. Figure 12 illustrates the rank order of exhibits not remembered. Across exhibits, lack of recall ranged from a low of 13% unable to recall the *Every Body Plays* exhibit to a high of 69% unable to recall the *Consider This* exhibit. The group interviews reinforced a similar engagement. The *Every Body Plays* and *RAMPS* exhibits were most engaging and the *Ask, Imagine, Create* and *Consider This* exhibits, the least.

Figure 12. Percent of total adult questionnaire respondents (n=109) who did not remember exhibits.



Favorite exhibits among youth

With youth interview groups the evaluators used a card sort technique, and unlike the adult questionnaire and mixed group card sort, the questions associated with specific exhibits were framed in terms of appeal, rather than recall. Evaluators asked respondents to select from the set of exhibition photographs the three or four exhibit components they liked best.

Youth most frequently selected as "Liked" *Every Body Plays, Re-Designing You, RAMPS,* and *More Than a Mouse*. These favorites were the same exhibits most frequently engaged by adults. Among youth, all components except *Welcome* were selected at least once, and because time limitations required listing *favorite* liked components, rather than *all* liked components, lower frequencies should not be interpreted as deficits, but rather as relative counts in light of the exhibit as a whole. The frequency of each component's selection is listed in Table 12.

Table 12. Frequencies of exhibits selected by youth as "favorite."

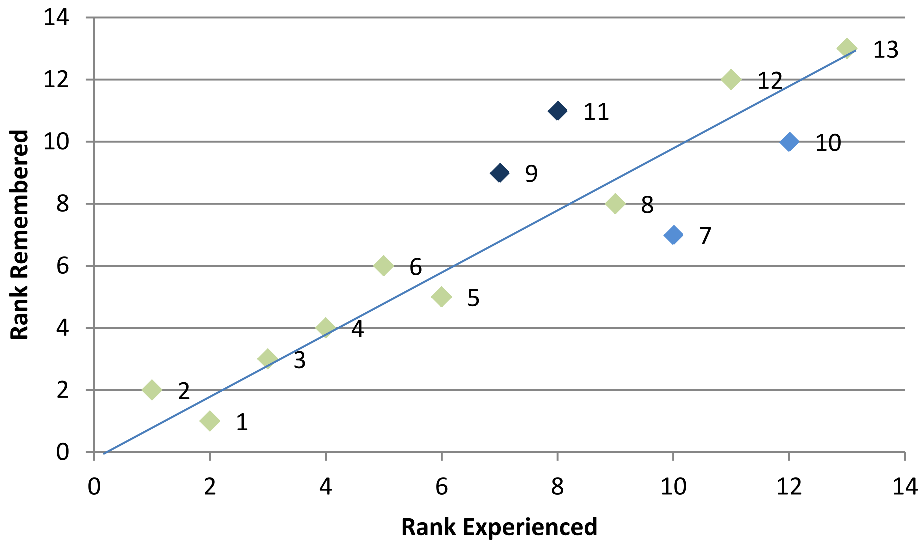
Component	Not selected	Selected
Every Body Plays	4	**16**
Re-Designing You	7	**13**
Ramps	8	**12**
More Than A Mouse	10	10
Design A Wheelchair	15	6
Feel The Music	16	4
Ask, Imagine, Create	17	3
Caring For A Pet	17	3
Imagine The Possibilities	17	3
Finding Your Way	18	2
Attempts	18	2
Consider This	19	1
Welcome	20	0

Note: Most frequent responses appear in bold.

Exhibits that optimized visual recall and engagement.

Visitors' amount of recall of exhibits directly and highly related to their level of engagement with those exhibits (Pearson *r* >.90). **Error! Reference source not found.** Figure 13 illustrates the relationship between visitors' ranking of each. Because of such high correlation, of interest were exhibits that prevented these rank orders from being exactly the same. *Imagine the Possibilities*, *Design a Wheelchair*, and *Every Body Plays* ranked the same for recall as for experience and lie on the diagonal line in Figure 13. Most of the other exhibits lay near that line. Those that lie further from the line warrant some consideration. Specifically, *Feel the Music* (point #9 in Figure 13) was ranked higher for recall (9th) than it was for experience (7th); the *Welcome* exhibit was 11th for recall and 8th for experience. In other words, visitors tended to remember these exhibits (dark blue in Figure 13) more than they experienced them; they were more visually memorable than perceived as engaging. In contrast, *More than a Mouse* (pt. # 7) ranked 10th highest for experience but only 7th for recall; *Re-Designing You* ranked 12th highest for experience but tenth for recall. These exhibits below the diagonal line (light blue in Figure 13) were more experienced than remembered. These exhibits were easier to miss than to pass up; if seen, they were engaging.

Figure 13. Relative rankings of visitor recall and engagement with exhibits.



Key to exhibit labels in Figure 10			
1	Consider This	8	Caring for a Pet
2	Ask, Imagine, Create	9	Feel the Music
3	Imagine the Possibilities	10	Re-Designing You
4	Design a Wheelchair	11	The Welcome Exhibit
5	Attempts	12	RAMPS
6	Finding Your Way	13	Every Body Plays
7	More than a Mouse		

Evidence of how stories helped visitors understand exhibit messages.

The exhibition was designed to build enthusiasm for engineering as a profession and process by engaging visitors with stories of people with disabilities whose life experiences had been enhanced by engineering innovations. The evaluation design therefore included an assessment of (1) the extent to which individual exhibits affected respondents' enthusiasm about engineering; and (2) the importance of the stories to engaging with specific exhibits.

What the exhibits told visitors about engineering

Among adults who recalled the exhibit, exhibits' effect on enthusiasm for engineering ranged from 1.86 (*Attempts*) to 2.46 (*More than a Mouse*) on a scale of 1 to 3 with 1 being "Not at all" and 3, "A lot." Youth and mixed-group interviews helped reveal the nature of this effect. For exhibits selected for discussion interviewees were asked, "What did this tell you about engineering? Their responses were coded both within the framework of individual steps of the engineering design process and within the categories of interactivity, disability, and engineering in general (i.e. responses that referred to engineers or technology but not necessarily a specific phase of design). The majority of exhibit components were connected most strongly to the CREATE step of the design process (see Table 13); these components were *RAMPS; Ask, Imagine Create; Finding Your Way; More Than a Mouse; Consider This; and Design a Wheelchair*. Meanwhile, *Every Body Plays, Re-Designing You,* and *Attempts* were most prominently associated with the ASK step of the design process, and *Imagine the Possibilities* was most strongly associated with the Imagine step. Two of the components (notably, both with lower total selection frequencies) showed equal representation across steps: *Caring for a Pet* saw responses spanning Ask and Create and *Feel the Music* was associated with Ask, Imagine, and Create."

Table 13. Frequencies of categories emerging from the interview question, "What did this [exhibit] tell you about engineering?"

Component	ASK	IMAGINE	CREATE	TEST	REPEAT	Interactivity	Disability	Engineering (General)
Every Body Plays	**4**	0	2	0	0	4	3	3
Re-Designing You	**4**	1	1	2	0	2	1	1
Ramps	2	2	**3**	0	0	2	4	1
Ask, Imagine, Create	0	0	**2**	0	0	0	0	0
Caring For A Pet	**2**	1	**2**	0	0	0	0	0
Finding Your Way	0	0	**1**	0	0	1	2	0
More Than A Mouse	0	0	**1**	0	0	3	1	4
Consider This	0	0	**1**	0	0	0	0	0
Design A Wheelchair	1	1	**2**	1	0	0	0	0
Feel The Music	**1**	**1**	**1**	0	0	1	0	1
Attempts	**1**	0	0	0	0	0	1	0
Imagine The Possibilities	1	**3**	0	0	0	0	0	0

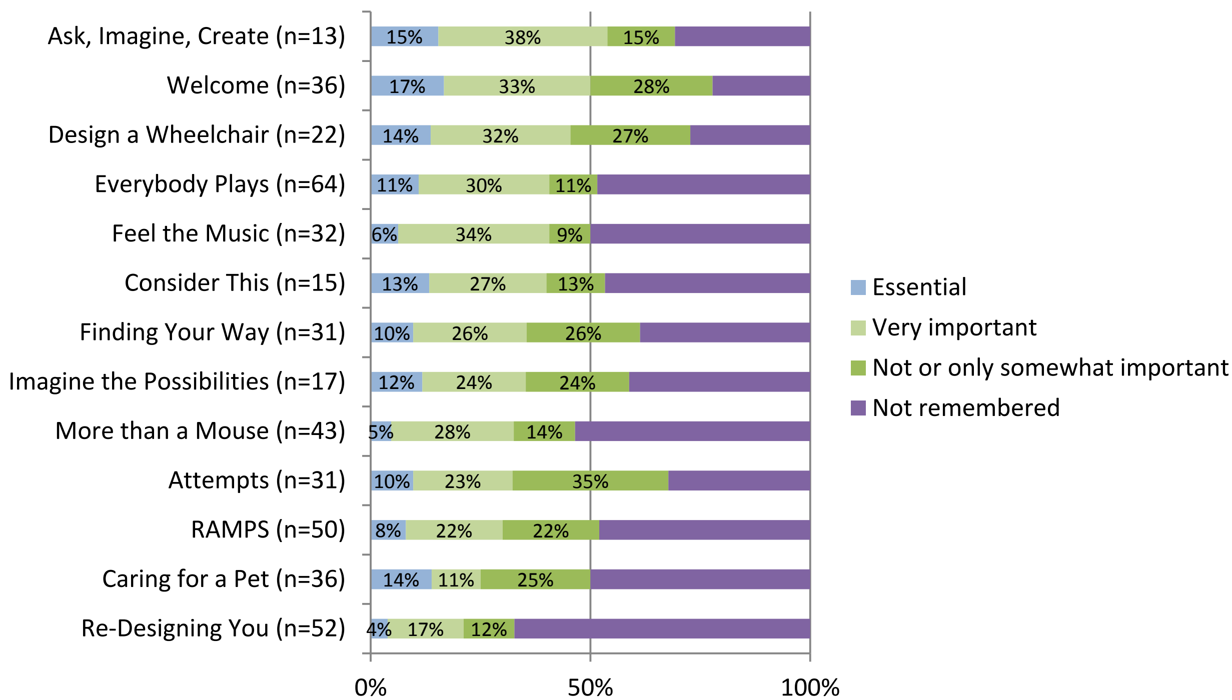
Note: Most frequent categories appear in bold.

Associating a written or video story with specific exhibits.

For each exhibit with which respondents said they had engaged, they also reported whether in conjunction with that exhibit they remembered reading or watching a story about a person. If so, they then recorded how important that story would be to telling a friend about the exhibit.

As illustrated in Figure 14, stories played an important part in visitors' experiences of the exhibits. For three exhibits (*Ask, Imagine, Create; Welcome;* and *Design a Wheelchair*) almost half of respondents who engaged with those exhibits believed the story was either essential or very important to explaining the exhibit to a friend. Exhibits with stories remembered by most respondents were *Welcome*, *Ask Imagine Create*, *Design a Wheelchair*, *Attempts*, *Finding your Way*, and *Imagine the Possibilities*.

Figure 14. Adult questionnaire respondents' report of stories remembered and their importance to explaining the exhibit.

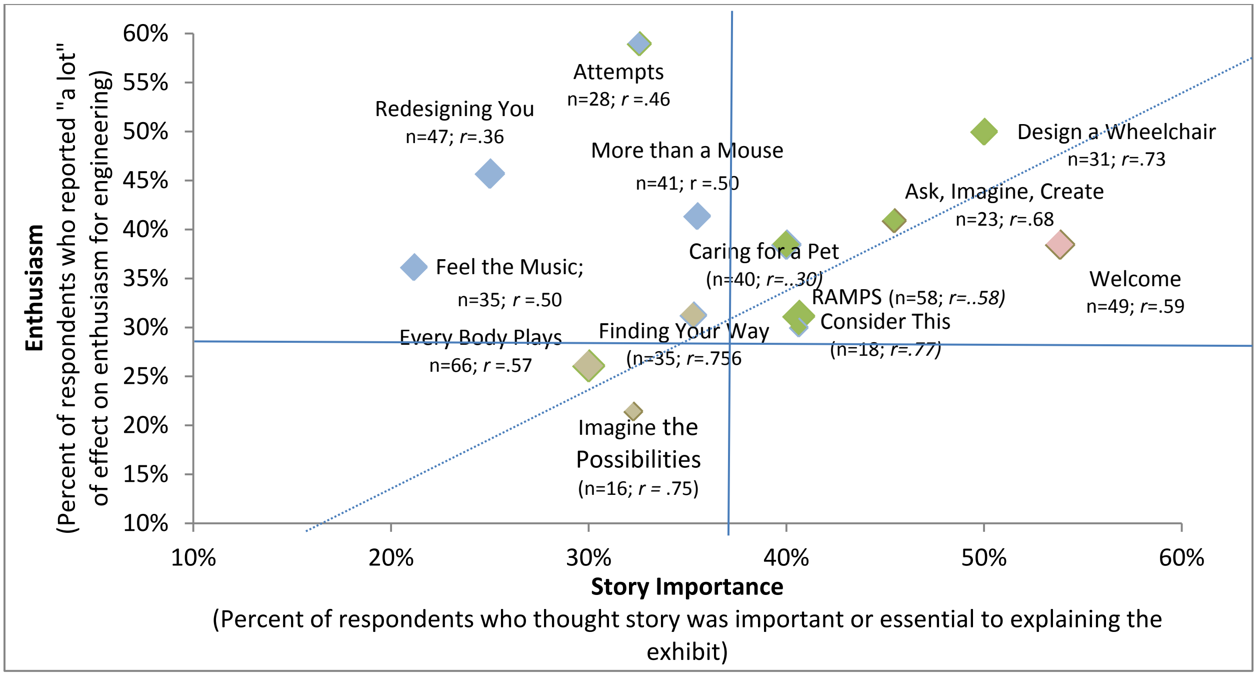


* n = the number of respondents who engaged with the exhibit.

Note: Exhibit titles are arranged in order of the percent of respondents who believed stories to be either essential or very important.

Another way of examining the experiences is to chart the exhibit's effect on enthusiasm against the salience of the story associated with the exhibit experience. Figure 15 shows the percent of visitors who expressed high amounts of each. For most of the exhibits (eight of thirteen), plotted along the diagonal line in Figure 15, the proportion of visitors valuing the story was just greater than the proportion who felt the exhibit strongly affected their enthusiasm for engineering. For four exhibits (*Attempts, Re-Designing You, More than a Mouse, and Feel the Music*; in the upper left quadrant of Figure 15), the proportion of visitors enthusiastic about engineering was far higher than those who found importance in the story. In contrast, more people experienced the stories of the *Welcome* exhibit as important than those who experienced enthusiasm for engineering.

Figure 15. Story Importance by Effect on Enthusiasm



Note: Marker size reflects n (number of respondents who engaged with the exhibit); *r* = Pearson correlation between story importance and enthusiasm.

The four exhibits about which engineering enthusiasm was so much greater than story importance were among the most interactive. It is possible that for these exhibits, the interactivity distracted visitors from, "story" aspect behind the engineering. On the other hand, these exhibits less associated with stories did not appear to detract from the exhibits' effect on respondents' enthusiasm for engineering. Exhibits generating high enthusiasm involved exhibits at both ends of the story-importance range. It is also noteworthy that no exhibits could be classified as having high story importance and low enthusiasm for engineering.

Visitor's own stories as they experienced the exhibit.

An interpretive issue that emerged during data collection was that respondents did not seem to share a stable understanding of "story" in relation to the exhibit. Although many of the interviewees did describe the efforts of individuals with disabilities and/or engineers related in the exhibit, others simply focused on their own experiences with exhibit components. However, even responses that did not directly relate to the stories recounted in the exhibit yielded useful information about how visitors interpreted *Human Plus*. Given that the exhibit is intended to be highly interactive and many respondents identified interactivity as an important feature of appeal, narratives associated with visitor experience suggest that the role users adopt for interacting with a given component is a critical consideration not only for appeal, but also for anticipating the impact of messaging.

Evidence of how methods of presentation and stories and varying media worked for each group.

A third set of analyses concerned the effect of exhibit presentation on exhibition messaging. These analyses included (1) the effect of the balance of focus between interactivity, disability, or engineering and (2) the design features and their appeal.

The effect of the balance of focus on interactivity, disability, or engineering

In the youth interviews, in reference to each of the four exhibits chosen as the ones they "liked the most," youth participants answered the question, "Why did you like this?" were coded for references to stable categories associated with specific design features; interactivity; stories of people with disabilities built into the exhibits, and steps in the engineering design process. Counts of their responses, coded into any of the four categories can be found in Table 14 in which exhibits are arranged from those with most "like" comments to least.

Table 14. Frequencies of themes in youth responses to "Why did you like this [one of four favorites] exhibit?"

Component	Specific design feature	Interactivity	Disability	Engineering
Re-Designing You	2	12	1	3
Every Body Plays	1	**7**	**7**	1
RAMPS	2	**8**	4	2
Design A Wheelchair	0	**5**	2	3
More Than A Mouse	1	4	1	4
Imagine The Possibilities	0	2	2	2
Caring For A Pet	0	**3**	0	2
Feel The Music	2	**3**	0	0
Ask, Imagine, Create	1	0	**2**	0
Finding Your Way	0	0	**2**	0
Attempts	0	0	1	0
Consider This	0	0	0	0

Note: Most frequent responses per exhibit appear in bold; most frequent response per feature appears underlined in red.

In Table 14, each exhibit can be reviewed for its most appealing feature (marked in bold) and also for how exhibits conveyed exhibition messages of disability and engineering. The most effective exhibit for each feature is marked in red and underlined. Some exhibits, such as *Design a Wheelchair* or *RAMPS* were attractive because of their disability and engineering messages as well as their interactivity. In contrast, *Re-Designing You* was attractive primarily because of its interactivity.

Among these youth, interactivity was the most consistently appealing aspect of the exhibits. However, the frequency with which youth cited themes related to disability or specific people with disabilities in their answers suggested that stories were also an important facet of youth appeal. The difference in balance between interactivity, story, and the experience of engineering appeared to have had an important influence on how well an exhibit component communicated the exhibition's message. In some cases interactivity served to communicate engineering messages; in others, messages about people with disabilities; and in others, both. In still others, interactivity may have overpowered the message.

In the mixed-age group interviews, participants were asked more generally about story and to share what they could recall. Their responses therefore included both the stories of people with disabilities as well as their own stories of their experiences in the exhibit. These responses were coded for references to the interactive aspect of the experience, references to engineers and engineering, and references to people with disabilities or a disability in general. These codes were not mutually exclusive. Only interviewees who reported remembering a story for a given component were asked this item, so the number of respondents per component varies; it is therefore most useful to consider each component in terms of which category was most prominent among responses for that component, rather than the highest categorical frequencies across the exhibit. The components for which the interactivity was most prominent in interviewees' stories were *Re-Designing You, RAMPS,* and *More Than a Mouse*. Concepts of disability were most prominent in stories about *Welcome, Every Body Plays, Caring for a Pet, Finding Your Way,* and *Consider This*. Engineering messages were most prominent in the stories associated with *Design a Wheelchair* and *Attempts.* Finally, one of the two respondents who described a story for *Feel the Music* focused on interactivity, while the other foregrounded disability, and the respondent who remembered a story about *Imagine the Possibilities* gave equal priority to all three categories.

Interactivity in this exhibition engaged visitors with technology for people with disabilities, however interactivity took on distinctly differing forms. Some exhibits emphasized using the technology while others emphasized designing it; still others involved both the process of designing a given technology and seeing it in action. Moreover, some exhibit interactivity required the visitor to adopt the role of a person with a disability, while other exhibit interactivity placed the visitor in the role of the engineer. These different roles and relationships to technology seemed to elicit differing perceptions of the exhibition's main messages.

For example, in *Every Body Plays*, interactivity was driven by the visitor assuming the role of a person for whom technology was produced. The interactivity presented a challenge that lay in the visitor's use of the technology, rather than designing it. When asked about this exhibit, interview participants talked about the story associated with the technology's end-user or, in some cases, the experience of trying out her mono-ski.

The *RAMPS* exhibit offered a different experience. Interactivity of *RAMPS* generated less relationship to story (which the visitor only saw by looking on the reverse side of the interactive panel) and instead drew on the visitor's own experience of what it might be like to have a disability: interviewees tended to connect their answers more to sitting in a component shaped like a wheelchair than they did to the associated story.

More Than a Mouse and Re-Designing You functioned similarly. Although both exhibits presented stories about the development of the technology for a person or people in need, its interactivity was focused on using the technology. The responses associated with each of these exhibits (*RAMPS*, *More Than a Mouse, and Re-Designing You*) mostly concerned the product of the engineering and the experience of using it, rather than the story or the design process behind it.

In contrast, the interactivity of *Design a Wheelchair* presented a user's needs as the starting point for a design challenge, and the story explained what to do and why to do it. With this exhibit, interviewees tended to frame their experiences in terms of both stories associated with disability *and* the engineering design steps they used to address the need.

These findings suggest that the type of interactivity that presented an opportunity to build or modify a product cued interpretation related to engineering process, whereas interactivity relating to a user perspective tended to cue interpretation related to disability. Moreover, stories were most effective in connecting to exhibit messages when they were directly linked to design-focused interactivity.

The Perceived Visual Attractiveness subscale of the exit questionnaire also provided relevant data. For richer understanding of the responses, mixed age-group structured interviews included the question, "What did you think of the design aspects of this Human Plus exhibition (i.e., the signage, the colors, the layout)?" followed by the prompts, "What appealed to you most? What parts did not appeal to you?" Youth interviews included the direction, along with potential probing prompts, "Now think about how the exhibit and its appeal or attractiveness to you. Did you like how it looked? Was it fun? Were there good colors, videos, and signs? In other words, did you like how it looked to you? Why or why not?"

Data about design features and their appeal

Respondents to the adult exit questionnaire rated their agreement (range: 1=Wholly Disagree to 5 =Wholly agree) with five statements about the exhibition's overall attractiveness, sense of fun; colors, videos, and signage. Across these five attributes, the exhibition's appeal was high with average ratings between 4.1 and 4.5 (Figure 16). Respondents agreed with the statement about the exhibit space as "fun," significantly more than the other attributes. All responses were highly correlated, ranging from .60 (Attractive with Color) to .801 (Videos with Signage; see Table 15). Of most interest was that the highest correlation to Attractive was Sense of Fun (r = .724).

Figure 16. Adult questionnaire responses to items about exhibition appeal.

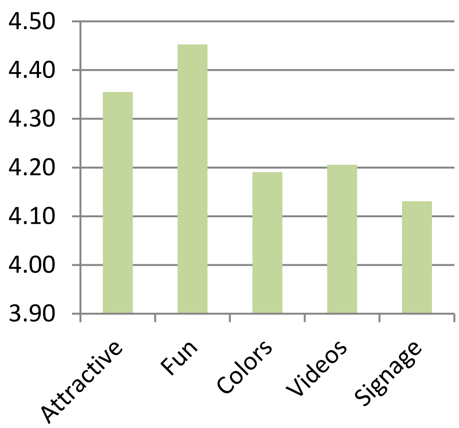


Table 15. Correlations between items related to exhibition appeal

	Attractive	Fun	Colors	Videos
Fun	.724			
Colors	.600	.662		
Videos	.628	.687	.770	
Signage	.639	.632	.774	.801

Among mixed-age interview groups, there was near consensus that interactivity was the most appealing aspect of the exhibition design, and two groups specifically commented that they found it easy to understand what to do at each component. While some groups also spoke positively about the "flow" of the exhibit space and the ability to navigate it freely, a few commented that the space seemed cluttered or commented on other exhibits in NYSCI's Central Pavilion. In particular, the responses that included reference to areas other than *Human Plus* tended to mention areas that were immediately adjacent to the exhibit which suggests that thresholds may have been unclear to some visitors. Some groups also commented that they enjoyed the information presented in the exhibit, and although two groups asked for more detailed information, one interviewee identified the stories associated with the information as a high point. Among respondent groups who mentioned specific features of exhibit components, a few spoke very positively about the inclusion of music, and one respondent commented that the audio labels were useful in helping her grandmother navigate the exhibit. While a few groups suggested making the colors in the exhibit brighter or lighter, several others described the colors of the exhibit as "pretty" or "attractive."

Finally, while a few respondent groups described the exhibit design as "not interesting" or "not attractive," a similar proportion answered "everything" when asked what they found appealing.

Interview respondents overwhelmingly referenced the interactivity of the exhibition as most appealing. This finding supports the questionnaire response correlation between attractiveness and fun. Although all the design elements were generally appealing, none overshadowed the visitor's enthusiasm for the interactivity and fun.

Visitor context

Anecdotally, when the exhibition was not crowded, the observed stay time seemed much greater, and recall of elements and the narratives attached to the various exhibits was very high. The evaluators noted that the busier the museum/exhibition, both the recall and the engagement with elements was reduced. Even more, the narratives from the exhibit seemed to be much lower. As this was an informally observed phenomenon, it was not captured in the data, but the patterns were compelling in terms of the group interviews and the quantitative data on engagement.

Thus, narratives supporting the exhibit components seemed most successful when people spent the most time in the exhibition. Further, the recall of the narratives was rich. In this particular space, when busier, the crowdedness aspect of the exhibit was augmented by the tightness of the space, further creating the energy commonly seen in visitors when an area is busy (Maeng, Tanner, & Soman, 2013; Rafaeli & Sutton, 1990; Smith & Haythorn, 1972). In these conditions visitors were more likely to move through without engaging.

Conclusions as Related to each Intended Outcome

Residency Evaluation Conclusions

Three questions drove the process, formative, and summative evaluations for the residency component of this project. These questions were overarching, asking:

1. Given time for reflection, do participants in the residency see changes in themselves as a result of participation?
2. Did participation in the residency affect participants' beliefs (about museums, about the role of museums, about people with disabilities) in ways that have led to changes?
3. Did the residency affect individuals' sense of engagement with or their roles on the exhibit?

This final compilation across the four measures (the process evaluation, the immediate post-measure, the post-workshop follow-up, and analysis of the discussion groups following the exhibit opening) reveals that at all four points, the answers to these questions were qualified affirmative responses.

Summary of Answers to Residency Evaluation Questions

1. Given time for reflection, do participants in the residency see changes in themselves as a result of participation?

Yes. The participants in the residency entered the experience with an expectation that they would learn new things, be exposed to some new ideas, and maybe challenge some of their assumptions. During the residency, there were obvious points of shift, such as the intense discussions around "hero" stories and the need to be recognized for achievements, not for daily living, clearly created a shift in both relationships of the residents and also in the core team's insights and understanding. The design activities around solving basic problems, brought into the residency by one of the invited participants and integrated into the process by the facilitator, provided the invited residents a chance to see the intense process and thought required to create learning experiences for museum visitors.

These types of changes resided beyond the residency and into the follow-up. Post opening, these insights into the lives of the other were central to the dialogue but were not shared as "changes in self" possibly because the changes were subtle at the time and then were reinforced over the ensuing three years.

Members of the core team most clearly articulated changes in themselves. These changes ranged from greater awareness of language, to challenging long-held assumptions—some culturally based. Some changes have resulted in individuals reporting doing their work differently and in how they think about disabilities and accessibility.

Some of the ancillary impacts of changes are related to unanticipated outcomes from the residency. The app ACCESS Together (www.accesstogether.org) was a brainstorm idea at the residency that became a reality due to the follow-up work of a designer and an invited resident at the workshop. The app is also mentioned in the exhibit (and was noted by the invited residents as needing a QR code to make it more immediately accessible so people would not forget it). Another unintended outcome was the deep connections that emerged between the invited participants. In the discussions, they talked about how difficult it was to find a community "of people like me" and the value in finding "role models" within the group. At the reunion, it was obvious that there were ongoing connections among the invited participants as the casual discussions prior to the formal interview were full of recent catch-up dialogues and revealed ongoing conversations through references to having spoken recently and prior knowledge to recent events in others' lives.

2. Did participation in the residency affect participants' beliefs (about museums, about the role of museums, about people with disabilities) in ways that have led to changes?

Yes, to a moderate degree. Overall, the residency strengthened core and design team members' beliefs in ways that led to incremental changes in practice. It is these changes in practice more than in their beliefs that appear to be salient. Comments reflected internalization of awareness at a deep level about accessibility and design considerations by the core and design team. Additionally, comments from the core team and design team members suggests these understandings are extended well beyond the design realm as comments pointed to a raised awareness of access issues. There was less strong a change in the invited participants' beliefs and practice, though their appreciation for the process of development and design of exhibits appeared to help create a deeper appreciation for the limitations of exhibits and experiences. The invited participants did have a strong view of the power an exhibit can have on visitors.

3. Did the residency affect individuals' sense of engagement with—or their roles on—the exhibit?

Yes, to some degree. Although the residency did not at all affect individuals' roles on the exhibit, in great part due to the removal of the additional residencies, the residency had a tremendous impact on the sense of engagement with the exhibit in the invited participants. For the core team, the residency had impact, not on the sense of engagement for themselves, but on their thinking about the invited participants throughout the design process.

In summary, it would appear the residency was tremendously powerful in shaping the exhibit experience, influencing both this exhibit and likely future exhibits by the core and design teams, and affecting the people involved. The impacts had less to do with dramatic changes in the individuals and the process of exhibit development, but were strongly related to subtle, internal and deeply meaningful shifts in perception, humanizing an exhibit and telling honest stories, and putting technology in the role of addressing needs of specific people, and not being about the "cool, new."

Exhibition Evaluation Conclusions

The exhibition evaluation was designed to answer six evaluation questions related to the exhibition's organizing framework. This framework posed objectives and intended outcomes utilizing personal stories of individuals with disabilities and the engineers challenged by those stories to enhance awareness, understanding, interest, and perception of engineering as both a profession and a process. Six evaluation questions emerged from these objectives and intended outcomes. Key findings from the exhibition evaluation , listed below, are organized as answers to each of the six evaluation questions.

1. In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, and innovation?

Visitors left the exhibition aware of the engineering process as both creative and socially conscious. When visitors used three words to describe engineering, they frequently referenced the "imagine" and the "ask" steps of the engineering process.

2. How did the exhibition affect how visitors value engineering?

Messaging concerning awareness of engineering innovation and value was largely successful. When explaining the exhibition's title, "Human Plus," a third of respondents associated it with engineering for the purposes of expanding human potential and specifically human potential for people with disabilities. Other explanations included expanded human potential in general, understanding people with disabilities, or general references to the human body—most of which indirectly, if not explicitly, valued engineering. Adults were more likely than youth to make the explicit association to engineering. Girls' responses were focused strongly on the human aspect of the engineering design process.

The exhibition led visitors to value engineering for its products, historical progress, and social contribution. Interview participants defined engineering largely in terms of valued products created or improved by engineers. In some cases these products were specifically for people with disabilities. Responses also included appreciation for the effects of engineering in terms of historical progress and more general social contribution.

3. What did visitors learn about engineering, both as a field and a process? How was this learning evidenced several weeks after the exhibition experience?

Visitors understood engineering as a process, but for some, the steps in the process may have been confused with steps of the scientific method.

Awareness of the "ask" and "imagine" aspects of the engineering process persisted several weeks after the exhibition experience.

4. **How did visitors feel, both immediately after, and weeks after, about their opportunity to contribute, and their actual contribution, to the process of human enhancement engineering, as supported by the exhibition experience?**

The exhibition had a powerful impact on adult visitors' interest in engineering. Overall, adults reported that they entered the exhibition with a fairly neutral interest in engineering, but left with significantly greater interest. Of particular note was their increased sense of enjoyment as they thought of themselves in the profession.

Among youth, interest in a career in engineering differed between girls and boys. A strong majority of boys said they could see themselves becoming engineers, a strong majority of girls said they could not. In general, girls connected their "no" answers to perceptions of their own deficit in aptitude; boys connected their answers to their individual interests, regardless of whether they answered "yes" or "no."

Positive feelings toward engineering emerged equally as frequently among boys and girls. Only among boys with no interest in becoming engineers were there no comments related to positive feelings toward engineering.

Both male and female adults were highly and equally as enthusiastic about sons and daughters choosing to become engineers, suggesting that differences between boys and girls may be coming from sources outside of parenting.

5. **How did visitors' attitudes about and interest in engineering (both as a field, and as an important part of their lives) change as a result of that participation, if at all? Again, *was* this evidenced several weeks after the experience, and if so, how?**

The exhibition improved both adult and youth attitudes towards engineering. Adults showed significantly greater appreciation for engineering as (1) helpful for understanding today's world; (2)necessary for helping to solve problems of everyday life; (3) important for inclusion as a subject of study; and (4) important knowledge for being productive in life.

The improved attitude was even more pronounced among respondents answering in retrospect, several weeks later.

Among youth, the majority reported positive change in perception. Those who reported no change had pre-existing high regard.

6. **How did visitors use and interact with this exhibition experience?**

Findings related to this question were divided into three areas: (a) how exhibit components contributed to visitor experience; (b) how personal stories helped visitors understand the exhibit messages; and (c) what design considerations helped visitors interpret exhibit messages. Answers to the process questions are arranged accordingly.

Findings about how exhibit components contributed to visitor experience

Visitors engaged well with the exhibition with each of the exhibits contributing differently to their experience. Most of the elements of the experience were used by a plurality of visitors, though the average number of specific exhibit components engaged was three (out of 13) per visitor. Anecdotal observation revealed that crowdedness was a major factor in the number of components and the amount of time spent in the exhibition.

The most frequented exhibits among adults and the most liked among youth were *Every Body Plays; Redesigning You; RAMPS; and More than a Mouse.* Least recalled (i.e. most frequently "not remembered) among adults were *Consider This, Ask, Imagine, Create; Imagine the Possibilities; and Design a Wheelchair.* Among youth respondents, least liked were*, Consider This, Attempts*, and *Finding Your Way*, and *Ask, Imagine, Create*.

Some exhibits were more visually memorable than engaging; others were engaging but easier to miss. Adult respondents tended to remember seeing two exhibits, *Feel the Music* and *Welcome,* more than they experienced them. In other words, these two exhibits were more attractive than engaging. In contrast, *More than a Mouse* and *Re-Designing You* were more experienced than remembered, i.e., easier to miss, but if seen, they were engaging.

Findings about the ways stories helped visitors understand exhibit messages.

Exhibit affected adult enthusiasm for engineering. The average effect on adult respondents' enthusiasm for engineering from just less than "somewhat" (*Attempts*) to halfway between "somewhat" and "a lot" in *More than a Mouse*. Most of this enthusiasm was associated with the "create" and "ask" steps of the engineering process.

Exhibit response ranged in regard to stories most remembered. Stories of how technology enhanced lives of people with disabilities played an important part in visitors' experiences of the exhibits. For three exhibits (*Ask, Imagine, Create; Welcome;* and *Design a Wheelchair*) almost half of respondents who engaged with those exhibits believed the story was either essential or very important to explaining the exhibit to a friend. Exhibits with stories remembered by most respondents were *Welcome*, *Ask Imagine Create*, *Design a Wheelchair*, *Attempts*, *Finding your Way*, and *Imagine the Possibilities*.

Visitors experienced exhibits as balancing personal stories and engineering messages differently. For four exhibits (*Attempts, Re-Designing You, More than a Mouse, and Feel the Music*), the proportion of visitors who reported that the exhibit made them more enthusiastic about engineering was far higher than the proportion of visitors who felt the story was important to understanding the exhibit. In contrast, the proportion of respondents who experienced the stories of the *Welcome* exhibit as important was greater than the proportion of respondents who experienced the exhibit's effect on their enthusiasm for engineering. No exhibits could be classified as having high story importance and low enthusiasm for engineering.

Visitors' own "stories" created during their visit also may have contributed to messages received. Some respondents interpreted "story" to be their own narrative of experiencing an exhibit (e.g., "I felt what it was like to ski with no legs"). Given that the exhibits were intended to be highly interactive and many respondents identified interactivity as an important feature of appeal, these "stories" may also have contributed to the impact of messaging.

Findings about which methods of presentation and which media worked better than others for each group.

The balance between interactivity, personal stories and messaging about engineering affected how visitors interpreted exhibit messages. Although specific design components such as color or music were sometimes mentioned in interview groups' descriptions of why they liked a given component, respondents usually framed their responses in terms of interactivity, themes related to disability, or ideas related to engineering (e.g., a specific type of technology). Most prominent among these categories was interactivity, which appeared especially strongly for a majority of components.

The difference in balance between interactivity, introduction to a personal story, and the experience of engineering appeared to have had an important influence on how well an exhibit component communicated the exhibition's message. Interactivity involving an opportunity to build or modify a product cued interpretation related to engineering process. In contrast, interactivity relating to a user perspective tended to cue interpretation related to disability. Moreover, stories were most effective in connecting to exhibit messages when they were directly linked to design-based interactivity. In some cases, interactivity may have overpowered the message.

Among adults, the exhibitions appeal lay primarily with its sense of fun, and next with its attractiveness. While they rated colors, signage, and videos fairly high, they weighted sense of fun higher. This finding was supported data from the interview participants who overwhelmingly referenced their enthusiasm for the exhibition's interactivity and fun.

Visitor experience was diminished when the space was crowded. Anecdotal observation revealed that crowdedness was a major factor in the number of components experienced and the amount of time spent in the exhibition. The crowdedness aspect of the exhibit was augmented by the tightness of the space, further creating the energy commonly seen in visitors when an area is busy—to move through without engaging.

Emergent Findings: Ties between the Exhibition and Residency Evaluations

An emergent finding from the exhibition data is its relationship to evaluation data (Heimlich, 2014) from the exhibition residency, a period of participatory planning involving both the exhibition's core team of designers and organizers, along with community stakeholders who could speak to a range of personal experiences with disabilities. While the evaluation of the *Human Plus* residency was largely intended to measure changes in participants' attitudes (i.e. "more positive and stable attitudes toward the design process" and "positive and sustained attitudes toward the experience and, toward engineering and human enhancement"), both formative and summative data suggest that the residency and the relationships forged during it may have had some unanticipated behavioral outcomes, as well. For example, a key finding about the residency was that "For the Core Team, the residency had impact not on sense of engagement for themselves, but that the thinking about the invited participants was continued throughout the design process." Among the community stakeholders who participated in the residency, a formative stage finding was that "there was a consistent hope that 'this exhibit will really have an impact on how viewers perceive disability' and 'help people realize the fact that disability is universal for all people, not local" and that the exhibit could be an opportunity to "allow guests to re-imagine their own abilities." When the same stakeholders toured the completed exhibit during the summative stage, they were pleased to find "that the exhibit focused on the individuals and they noted the exhibit 'always presented the person first, the story first, then falling back on the technology.'" Taken together, these findings suggest that the experience of the residency had some influence on designers' thinking about how to present a people-first, inclusive representation of the relationship between disability and technology

Meanwhile, within data from the exhibit itself, human experiences and disability were recurring themes, even in the context of engineering-focused audience outcomes. Moreover, some visitors reported their own interactivity experience as the narrative they associated with a given component. This was particularly true of components that framed interactivity as consumption or use of technology. Although visitors sometimes struggled to map stories about disability directly to the exhibit's engineering design messages, there is evidence that some visitors included themselves in a broader conversation about assistive technology and human experiences. Alongside the residency finding that "the focus for the design team became weighted toward stories and adapted technology based on individual needs as inspiration," these exhibit data suggest that some visitors indeed had experiences that were consistent with community stakeholders' wishes—likely due in part to the participatory process of exhibit development. In short, visitors' experience of *Human Plus* appears to be at least somewhat connected to outcome achievement among core team members in the residency phase. As a whole, the project represents a positive example of sharing community values and input with end users.

Works Cited

Hoogstraten, J. (1982). The retropsective pretesgt in an educational training context. *The Journal of Experimental Education, 50*(4), 200-204.

Levinson, W., Gordon, G., & Skeff, K. (1990). Retrospective versus actual pre-course self-assessments. *Evaluation & the Health Professions, 13*(4), 445-452.

Pohl, N. F. (1982). Using retrospective pre-ratings to counteract response-shift confounding. *The Journal of Experimental Education, 50*(4), 211-214

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Andrews, D. A., Bonta, J., & Hoge, R. D. (1990). Classification for Effective Rehabilitation - Rediscovering Psychology. *Criminal Justice and Behavior*, *17*(1), 19–52. Retrieved from <Go to ISI>://A1990CR51300004

Hoogstraten, J. (1982). The retrospective pretest in an educational training context. *Journal of Experimental Education*, *50*(4), 200–204.

Lederman, N. G. (1992). (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359.

Levinson, W., Gordon, G., & Skeff, K. (1990). Retrospective Versus Actual Pre-Course Self-Assessments. *Evaluation & the Health Professions*, *13*(4), 445–452. doi:10.1177/016327879001300406

Maeng, A., Tanner, R. J., & Soman, D. (2013). Conservative When Crowded: Social Crowding and Consumer Choice. *Journal of Marketing Research*, *50*(6), 739–752.

McComas, W. F., Clough, M. P., & Almazroa, H. . T. nature of science in science education. S. N. (2002). "The role and character of the nature of science in science education." *The Nature of Science in Science Education Science & Technology Education Library*, *5*, 3–39.

Nelson, R. R. (2004). The market economy, and the scientific commons. *Research Policy*, *33*(3), 455–471.

Pohl, N. F. (1982). Using retrospective pre-ratings to counteract response-shift confounding. *Journal of Experimental Education*, *50*(4), 211–214.

Rafaeli, A., & Sutton, R. I. (1990). Busy stores and demanding customers: how do they affect the display of positive emotion? *Academy of Management Journal*, *33*(3), 623–637.

Rogers, G. F. C. (1983). *The nature of engineering: a philosophy of technology*. Macmillan Press.

Serrell, B. (2010). Paying More Attention to Paying Attention : Informal Science. *Informalscience.org*. Retrieved March 17, 2014, from http://www.informalscience.org/perspectives/blog/paying-more-attention-to-paying-attention

Skeff, K. M., Stratos, G. A., & Bergen, M. R. (1992). Evaluation of a Medical Faculty Development Program: A Comparison of Traditional Pre/Post and Retrospective Pre/Post Self-Assessment Ratings. *Evaluation & the Health Professions*, *15*(3), 350–366. doi:10.1177/016327879201500307

Smith, S., & Haythorn, W. W. (1972). Effects of compatibility, crowding, group size, and leadership seniority on stress, anxiety, hostility, and annoyance in isolated groups. *Journal of Personality and Social Psychology*, *22(1), 67.*(1), 67–79.

Sprangers, M., & Hoogstraten, J. (1989). Pretesting effects in retrospective pretest^posttest designs.

Van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in The Netherlands. *Information & Management*, *40*(6), 541–549. doi:10.1016/S0378-7206(02)00079-4

Weinburgh, M. H., & Steele, D. (2000). The Modified Attitudes Toward Science Inventory: Developing an instrument to be used with fifth grade urban students. *Journal of Women and Minorities in Science and Engineering*, *6*(1). Retrieved from http://www.dl.begellhouse.com/journals/00551c876cc2f027,124ed7f300310376,6dd710212a11302d.html

Weinburgh, M. H., & Steele, D. (2008). Modified Attitudes towards Science Inventory (mATSI) | Assessment Tools in Informal Science (ATIS). *Assessment Tools in Informal Science (ATIS)*. Retrieved February 27, 2014, from http://www.pearweb.org/atis/tools/7

Wolpert, L. (1994). *The unnatural nature of science*. Harvard University Press.

Appendices

Appendix A. Residency Initial Study Instruments

Thank you so much for your time and honest reflections. Think back a few months to the weekend of March 19th at the New York Hall of Science. We were all gathered to participate in a residency to think about the design for the traveling exhibit "Human Plus." During that time, you shared a lot of yourself and your insights. We'd like to capture what you've thought about the experience since that time.

This web survey is designed to let you reflect and share your insights since the experience. We look forward to your responses!

Thinking back to the stories and experiences you shared, in what ways do you feel you are a "part" of the exhibit process?

What were the challenges you had to address in participating in the residency? These could be physical challenges as well as mental or emotional challenges in the process.

For the following, think about how you thought before the residency, and how you think now. If you strongly disagree with a statement (e.g. Before the residency, I strongly disagreed that I thought I would be on the cover of People Magazine) you'd circle a 1 (one.) If you strongly agree with a statement (e.g. Since the residency, I strongly agree that I like oranges) you'd circle a 7 (seven). If you're somewhere in the middle, you'd circle 3, 4, or 5.

Before								Now						
Strongly Disagree						Strongly Agree		Strongly Disagree						Strongly Agree
1	2	3	4	5	6	7	**I have important ideas to add**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**People listen to me**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I am an important part of this thought process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**There is not much I can add to the discussion**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an important activity in my life**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an important activity for the museum**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an exciting event**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I am an equal participant in this process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**People care about what I say in this process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is a fun process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I would/did learn from the process**	1	2	3	4	5	6	7

Looking back, what has changed about *you* since this residency, if anything?

What were the benefits this process created for you?

Did this experience change your thinking about museums? How? Why? (why not?)

*Do you want to see the exhibit when it is completed? Why?

*What do you expect the exhibit to be?

*What, if anything, do you see your role to be as the exhibit process continues?

ADDITIONAL ITEMS FOR CORE TEAM ONLY (with deletion of * questions above):

How much do you agree with each statement?	**Strongly Disagree**						**Strongly Agree**
The residency approach was different from my usual approach to design	1	2	3	4	5	6	7
The residency provided useful information	1	2	3	4	5	6	7
The residency changed my thinking about what the exhibit could be	1	2	3	4	5	6	7
The residency did not change my thinking about design of exhibits	1	2	3	4	5	6	7
The residency succeeded in providing differing perspectives	1	2	3	4	5	6	7
The residency succeeded in providing differing voices	1	2	3	4	5	6	7
The residency concept is a good one	1	2	3	4	5	6	7
The potential of the residency was fully met	1	2	3	4	5	6	7
There was enough time for the residency	1	2	3	4	5	6	7
We exhausted the potential of the residency in the two days	1	2	3	4	5	6	7
All participants were given "voice" in the residency	1	2	3	4	5	6	7
All participants had a sense of "ownership" in the outcomes	1	2	3	4	5	6	7

Using a similar agreement scale as was used above, tell us how you feel about the residency itself.

What worked about the residency?

What might have enhanced the residency?

Did the residency change your thinking about designing exhibits? Why/how or why not?

Appendix B. Residency Follow-up Study Instruments

Thank you so much for your time and honest reflections. Think back a few months to the weekend of March 19th at the New York Hall of Science. We were all gathered to participate in a residency to think about the design for the traveling exhibit "Human +." During that time, you shared a lot of yourself and your insights. We'd like to capture what you've thought about the experience since that time.

This web survey is designed to let you reflect and share your insights since the experience. We look forward to your responses!

Thinking back to the stories and experiences you shared, in what ways do you feel you are a "part" of the exhibit process?

What were the challenges you had to address in participating in the residency? These could be physical challenges as well as mental or emotional challenges in the process.

For the following, think about how you thought before the residency, and how you think now. If you strongly disagree with a statement (e.g. Before the residency, I strongly disagreed that I thought I would be on the cover of People Magazine) you'd circle a 1 (one.) If you strongly agree with a statement (e.g. Since the residency, I strongly agree that I like oranges) you'd circle a 7 (seven). If you're somewhere in the middle, you'd circle 3, 4, or 5.

Before								Now						
Strongly Disagree						Strongly Agree		Strongly Disagre e						Strongly Agree
1	2	3	4	5	6	7	**I have important ideas to add**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**People listen to me**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I am an important part of this thought process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**There is not much I can add to the discussion**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an important activity in my life**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an important activity for the museum**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is an exciting event**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I am an equal participant in this process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**People care about what I say in this process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**This is a fun process**	1	2	3	4	5	6	7
1	2	3	4	5	6	7	**I would/did learn from the process**	1	2	3	4	5	6	7

Looking back, what has changed about *you* since this residency, if anything?

What were the benefits this process created for you?

Did this experience change your thinking about museums? How? Why? (why not?)

Do you want to see the exhibit when it is completed? Why?

What do you expect the exhibit to be?

What, if anything, do you see your role to be as the exhibit process continues?

ADDITIONAL ITEMS FOR CORE TEAM ONLY (with deletion of * questions above):

How much do you agree with each statement?	**Strongly Disagree**						**Strongly Agree**
The residency approach was different from my usual approach to design	1	2	3	4	5	6	7
The residency provided useful information	1	2	3	4	5	6	7
The residency changed my thinking about what the exhibit could be	1	2	3	4	5	6	7
The residency did not change my thinking about design of exhibits	1	2	3	4	5	6	7
The residency succeeded in providing differing perspectives	1	2	3	4	5	6	7
The residency succeeded in providing differing voices	1	2	3	4	5	6	7
The residency concept is a good one	1	2	3	4	5	6	7
The potential of the residency was fully met	1	2	3	4	5	6	7
There was enough time for the residency	1	2	3	4	5	6	7
We exhausted the potential of the residency in the two days	1	2	3	4	5	6	7
All participants were given "voice" in the residency	1	2	3	4	5	6	7
All participants had a sense of "ownership" in the outcomes	1	2	3	4	5	6	7

Using a similar agreement scale as was used above, tell us how you feel about the residency itself.

What worked about the residency?

What might have enhanced the residency?

Did the residency change your thinking about designing exhibits? Why/how or why not?

Appendix C. Post Opening Residency Data Discussion Groups

Residents with DISABILITIES

Thank you so much for agreeing to talk with me today. We are going to have a discussion among *you* for about an hour, and then we're going to invite the design and core team of the project in to engage in a structured discussion. All of this is being done to help us better understand the outcomes of the process of creating Human +. You are free to respond or not respond to any question, and you have the right to withdraw at any time. All comments will be used in the aggregate and individual quotations will be de-identified before being used. I am going to take notes by computer. Does anyone have any concerns about the evaluation study or your role in it?

Thanks. Let's begin by hearing your reactions to the exhibit. What did you think? We'll do this in three pieces: your overall reaction; things that delighted or surprised you or things that you think turned out really well; and then things you would like to have turned out differently somehow.

What was your overall reaction?

What delighted/surprised you or turned out really well?

What would you like to have turned out differently?

Think back to the intense few days we spent together at the beginning of the project. What ideas that emerged from that work did you see in evidence in the exhibit?

In what ways, if any, do you think those early dialogues helped shape the exhibit?

Was it worth your time and energy to engage in this project? How/why?

SHARED DIALOGUE COMPONENT

Welcome! Let's do a quick "reintroduction" of ourselves so everyone remembers who's who in the room.

Thanks. Before we start, I need to remind everyone that this dialogue is part of the evaluation for the project and is being done to help us better understand the outcomes of the process of creating Human +. You are free to respond or not respond to any question, and you have the right to withdraw at any time. All comments will be used in the aggregate and individual quotations will be de-identified before being used. I am going to take notes by computer. Does anyone have any concerns about the evaluation study or your role in it?

I'd like you to all think for 3 minutes about what you're going to say. What is the ONE thing the designers/core team/the panel should know about the exhibit and your experience in getting to this point today.

(After 3 minutes) We're going to start with the panel talking to the designers/core team members. At this point, this is not a dialogue, but a chance to listen intensely. When all have finished, we'll then switch to the designers/core team members sharing. Make notes of things that you might want to respond to as you listen, but do not get caught in trying to respond in the moment.

Listening across all the comments you heard, from both groups, what are you hearing as commonalities? Anything?

What about differences?

Were there any ideas or expressions that you wanted to respond specifically to? Share the comment, *why* you want to respond to it, and then what your response is.

Finally, I'd like each of you to share something you learned about yourself through this project…. If you can't think of anything, that's ok.

Thank you all so very much. I think it's time for a celebration! Eric, Peggy, Tara….tell us what's happening next!

Appendix D. Human Plus Summative Evaluation Framework

Impact	Category	Audience Objectives	Example of Evidence
Visitors are aware of engineering as a dynamic experience of discovery, design, imagination, innovation, and meaningful contribution to society	Awareness	Visitors define engineering in terms of process and value	**In exit interviews, 75% of visitors describe engineering in terms of discovery, design, imagination, innovation, and contributory value** **In follow-up telephone or e-mail interviews, 50% of visitors clearly describe engineering in terms of discovery, design, imagination, innovation, and contributory value** **Student scores on NAE items and pre/post measures show increases among the majority of students**
Visitors perceive engineering both as a field and a process, and provide evidence of this learning several months after the exhibition	Understanding	Visitors describe their understanding of the process by which engineers identify societal problems and propose solutions within constraints	**In exit interviews, 75% of visitors provide a clear example that reveals and understanding of the process of engineering.** **In follow-up telephone or e-mail interviews, 50% of visitors clearly recall the process of engineering and provide an example**
Visitors increase interest in engineering	Interest	Visitors indicate interest in engineering as a topic for further learning or a career	**80% of visitors express interest in learning more**
Visitors have a positive, enduring attitude toward human engineering	Attitude	Visitors demonstrate a more positive attitude about or image of engineering	**Pre/post measures demonstrate a 10 point gain on a scale of 100 toward engineering** **Telephone follow-up interviews reveal stability over time in attitudes toward and images of engineering**

Appendix E. Detail of Methods for Answering Exhibition Evaluation Questions

Category	Evaluation Question	Item	Paper-Pencil Questionnaire long and short forms (adult)	Youth Interview	Group Interview	Delayed On-Line Questionnaire
Awareness	1. In what ways did the exhibition contribute to visitors' awareness of engineering as a dynamic experience of discovery, design, imagination, innovation?	Q2. Please give at least three words that describe the qualities people need to become a good engineers.	x	x	x	x
	2. In what ways do visitors define engineering in terms of value?	Q3. Imagine our world with no engineers. How would it be different?			x	
		Q1. "The exhibit you just saw is called Human Plus. Why do you think the exhibit designers gave this exhibit that name?."	long form only	x	x	
Under-standing	3. In what ways and to what extent do visitors understand engineering as both a field and a process?	4. You just went through an exhibit that was about how engineers solve problems. Think of a problem you need to solve. If you think like an engineer, what steps will you take?		x	x	x
Interest	4. How did visitors' attitudes about and interest in engineering change as a result of that participation? Did this change persist several weeks after the experience?	**Interest** in engineering.	x			x
		Could you see yourself as an engineer? Why or why not?		x		
Attitude	5. To what extent did visitors leave the exhibit with an increased interest in engineering?	**Perception** of engineering scale.	Long form only	x	x	x
		This exhibition was about engineering. Do you think this experience changed what you think about engineering and people who are engineers?		x		

Category	Evaluation Question	Item	Paper-Pencil Questionnaire long and short forms (adult)	Youth Interview	Group Interview	Delayed On-Line Questionnaire
Process	6. In what ways did the exhibition stories help to humanize the engineering profession and process?	For each exhibit: Do you remember seeing this part of the exhibit today? In this exhibit, did you watch a video or red a story about a person? (Interview question: Do you remember a story that went with this exhibit?)	x		x	
	In what ways did the stories help visitors understand exhibit messages?	(If so, how important would this story be in explaining this activity to a friend? (Interview: What was that story about?)	x		x	
		How much did this exhibit affect your enthusiasm about engineering?	x	x		
	What design features of the exhibition hold the most appeal 10-14 y.o. girls? Differently than others?	What did you think of the design aspects of this Human Plus exhibition? (i.e., the signage, the colors, the layout.) What appealed to you most? What parts did not appeal to you?			x	
		Now think about how the exhibit and its appeal or attractiveness to you. Did you like how it looked? Was it fun? Were there good colors, videos, and signs? In other words, did you like how it looked to you? Why or why not?		x		
		Perceived Visual Attractiveness subscale	x			
	How did exhibit components jointly and/or separately contribute to audience impact?	Analysis of all Process items				

Appendix F. Paper-pencil Summative Questionnaire

Thank you for giving us a few minutes of time to give the Hall of Science some feedback. The Hall of Science and its research partner, The Lifelong Learning Group, are very interested in knowing what *you* think of the Human Plus exhibition.

The exhibit you just saw is called Human Plus. Why do you think the exhibit designers gave this exhibit that name?

Please give at least three words to describe the kind of person who you think can become a good engineer.

The following statements are about engineering. Please read each statement carefully. Use the following scale to show how much you agree or disagree with each statement.

If you STRONGLY DISAGREE	1	2	3	4	5
If you DISAGREE	1	2	3	4	5
If you are UNDECIDED	1	2	3	4	5
If you AGREE	1	2	3	4	5
If you STRONGLY AGREE	1	2	3	4	5

It is important that you respond to *every statement*:

- Circle only one number per statement about how you felt **BEFORE** seeing this exhibit space
- Circle one number per statement about how you feel **AFTER** visiting the exhibit space.

Before I experienced this exhibit space I would have said:		**After** experiencing this exhibit space, I think:
1 2 3 4 5	a. Engineering is necessary for helping to solve the problems of everyday life.	1 2 3 4 5
1 2 3 4 5	b. Most people should study some engineering.	1 2 3 4 5
1 2 3 4 5	c. Engineering is helpful in understanding today's world.	1 2 3 4 5
1 2 3 4 5	d. Engineering is of great importance to a country's development.	1 2 3 4 5
1 2 3 4 5	e. It is important to know engineering in order to be productive in life	1 2 3 4 5
1 2 3 4 5	f. Engineering is a profession that is easier for men to do than for women to do.	1 2 3 4 5
1 2 3 4 5	g. Engineering is not a profession for people who like working with relationships between people.	1 2 3 4 5
1 2 3 4 5	h. When I hear the word "engineer," I have a feeling of dislike.	1 2 3 4 5

The next statements are about your interest in engineering. Please read each statement carefully. Use the same scale as before to show how much you agree or disagree with each statement.

It is important that your respond to *every statement*:

- Circle only one number per statement about how you felt BEFORE seeing this exhibition
- Circle one number per statement about how you feel AFTER visiting the exhibition.

Before I experienced this exhibition I would have said:		**After** experiencing this exhibition, I think:
1 2 3 4 5	i. When I hear the word engineer, I have a feeling of dislike.	1 2 3 4 5
1 2 3 4 5	j. No matter how hard I try, I wouldn't be able to understand engineering.	1 2 3 4 5
1 2 3 4 5	k. Engineering is a profession I would enjoy very much.	1 2 3 4 5
1 2 3 4 5	l. I feel tense when someone talks to me about engineering	1 2 3 4 5
1 2 3 4 5	m. I'd be good at engineering.	1 2 3 4 5
1 2 3 4 5	n. I would like to do some extra or un-assigned reading about engineering.	1 2 3 4 5
1 2 3 4 5	o. It makes me nervous to even think about doing engineering.	1 2 3 4 5
1 2 3 4 5	p. I would enjoy taking an engineering class.	1 2 3 4 5
1 2 3 4 5	q. It would scare me to have to take an engineering class.	1 2 3 4 5
1 2 3 4 5	r. I have a real desire to learn engineering.	1 2 3 4 5
1 2 3 4 5	s. I have a good feeling toward engineering.	1 2 3 4 5

Think of yourself as the parent of either a real or imagined daughter. How enthusiastic would you be to learn that she has chosen to become an engineer?

1	2	3	4	5
Extremely unenthusiastic	Unenthusiastic	Neither enthusiastic nor unenthusiastic	Enthusiastic	Extremely Enthusiastic

Think of yourself as the parent of either a real or imagined son. How enthusiastic would you be to learn that he has chosen to become an engineer?

1	2	3	4	5
Extremely unenthusiastic	Unenthusiastic	Neither enthusiastic nor unenthusiastic	Enthusiastic	Extremely Enthusiastic

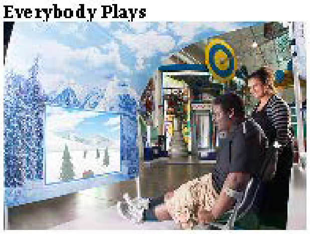
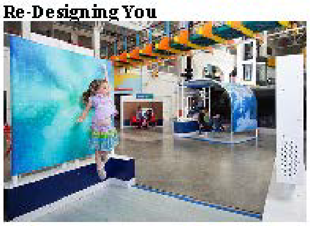
Please respond to these statements about attractiveness. Where would you put yourself on a scale between wholly disagreeing and wholly agreeing? Select any value from one to five.

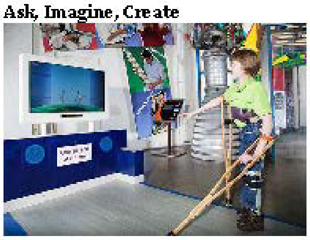
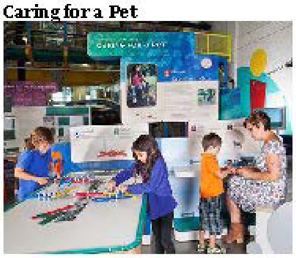
	Wholly disagree				Wholly agree
Overall, I find that this exhibition looks attractive.	1	2	3	4	5
Overall this exhibition is fun.	1	2	3	4	5
The colors used in this exhibition are attractive	1	2	3	4	5
The videos in this exhibition are attractive	1	2	3	4	5
The signage in this exhibition is attractive.	1	2	3	4	5

Here are pictures from the Human Plus exhibit. For each:

- In Column A check one of the three choices:
  - I do not remember seeing the activity today;
  - I saw it but did not do it;
  - I did the activity.
- If you did the activity, please respond to the questions in Columns B and C.
- In column B answer:
  - If you remember a story of a person related to the activity
  - If so, tell us how important that story is to explaining the activity to a friend.
- In column C, please tell us if the activity affected your enthusiasm about engineering a lot, a bit, or not at all.

	Column A	Column B	Column C
Welcome 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all

	Column A	Column B	Column C
Everybody Plays 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
Re-Designing You 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
RAMPS 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all

	Column A	Column B	Column C
Ask, Imagine, Create 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
Caring for a Pet 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
Finding Your Way 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all

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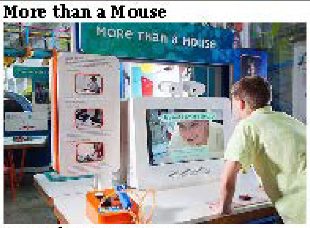
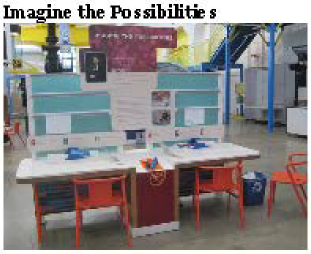
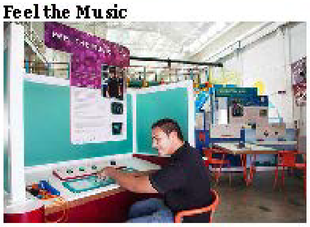
More than a Mouse  Using the Camera Mouse	☐ I do not remember it ☐ I did not do much with it. ☐ I did it, read it, or played with it.	In this exhibit, did you watch a video or read a story about a person? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	How much did this exhibit affect your enthusiasm about engineering? (select one) ☐ Not at all ☐ A bit ☐ A lot
Consider This  Reconsider your assumptions interactive video	☐ I do not remember it ☐ I did not do much with it. ☐ I did it, read it, or played with it.	In this exhibit, did you watch a video or read a story about a person? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	How much did this exhibit affect your enthusiasm about engineering? (select one) ☐ Not at all ☐ A bit ☐ A lot
Attempts  Dancing with crutches	☐ I do not remember it ☐ I did not do much with it. ☐ I did it, read it, or played with it.	In this exhibit, did you watch a video or read a story about a person? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	How much did this exhibit affect your enthusiasm about engineering? (select one) ☐ Not at all ☐ A bit ☐ A lot

	Column A	Column B	Column C
Imagine the Possibilities 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
Feel the Music 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all
Design a Wheelchair 	☐ Did not see this activity ☐ Saw, but did not do this activity ☐ I did this activity (if yes, continue to Columns B&C)	Do you remember a story of a person related to this activity? ☐ Yes ☐ No If so, how important would this story be in explaining this activity to a friend? ☐ Not Important ☐ Somewhat Important ☐ Very Important ☐ Essential	This activity affected my enthusiasm about engineering. (select one) ☐ A lot ☐ A bit ☐ Not at all

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Please help us understand a little bit more about who you are.

Do you have a severe, permanent disability?	☐ Yes	☐ No
Does anyone in your household have a severe, permanent disability?	☐ Yes	☐ No
Do you have a close friend or relative with a severe permanent disability?	☐ Yes	☐ No

Are you: ☐ Male ☐ Female ☐ Transgender

How old are you? ☐ 19-24 ☐ 25-34 ☐ 35-54 ☐ 55 or older

What level of education have you completed?

☐ Elementary school ☐ 2-year college
☐ Middle school ☐ 4-year college
☐ Trade/vocational school ☐ Professional or Graduate school

Thank you!

Appendix G. Group and Individual Youth Structured Summative Interviews

HUMAN PLUS
Real Lives + Real Engineering

Thank you for giving a few minutes of your time to give the Hall of Science some feedback. The Hall of Science and its research partner, The Lifelong Learning Group, are very interested in knowing what *you* think of the Human Plus exhibit space.

The exhibit space you just saw is called "Human Plus." Why do you think the exhibit designers gave this exhibit space that name?

What words or phrases describe the qualities you think someone needs to become a good engineer.

1.
2.
3.

Ask only if group. Imagine our world with no engineers. How would it be different?

GROUP ONLY

Ask if youth only. This exhibition was about engineering. Do you think this experience changed what you think about engineering and people who are engineers?

Tell me why you think that.

YOUTH ONLY	

Ask if youth only. Could you see yourself as an engineer? Why or why not?

YOUTH ONLY	

Ask if youth only. Now think about how the exhibit and its appeal or attractiveness to you. Did you like how it looked? Was it fun? Were there good colors, videos, and signs? In other words, did you like how it looked to you? Why or why not?

YOUTH ONLY	

Ask if youth only. I'm going to show you some pictures of all the pieces of the exhibit. I want you to choose the ones you liked the most.

YOUTH ONLY

Ask if youth only. I'm going to show you some pictures of all the pieces of the exhibit. I want you to choose the ones you liked the most.

Great. Now, let's look at each one. (SHOW THE FIRST). I'd like you to tell me first, why did you like this, and then secondly, what did this tell you about engineering?

SECOND: Why did you like this one? What did this tell you about engineering?

THIRD: Why did you like this one? What did this tell you about engineering?

FOURTH: Why did you like this one? What did this tell you about engineering?

Finally, I'd like to ask just a little bit about you.

Do you have a severe, permanent disability?		Y	N
Does anyone in your household have a severe, permanent disability?		Y	N
Do you have a close friend or relative with a severe permanent disability?		Y	N
Do you consider yourself to be a boy or a girl?	M	T	F

How old are you?	6-9		10-12		13-15	16-18
What grade are you in at school?	1	2	3	4	5	6
	7	8	9	10	11	12

What level of education do you think your parents or guardians expect you to complete?

- ☐ Elementary school
- ☐ Middle school
- ☐ High School
- ☐ 2-year college
- ☐ 4-year college
- ☐ Professional or Graduate school

THANK AND CLOSE

Ask if GROUP only:

You just went through an exhibit area that was about how engineers solve problems. Think of a problem you need to solve (for example, fixing a broken appliance or changing a bad habit). If you think like an engineer, what steps will you take?

GROUP ONLY

First step: ____________________

Next step: ____________________

Then: ____________________

Then: ____________________

Then: ____________________

Then: ____________________

Anything else? ____________________

Here are pictures from the Human Plus exhibit. For each:

- In the green column, check one of the three choices:
- If you remember the activity, please respond to the questions in the blue column.
- Tell us:
  - If you remember a story of a person related to the activity
  - If so, tell what that story was about

GROUP ONLY	**A**	**WELCOME**	☐ Don't remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	B	**Everybody Plays**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	C	**Re-De signing You**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	D	**RAMPS**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
GROUP ONLY	**E**	**Ask, Imagine, Create**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	F	**Caring for a Pet**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?

	G	**Finding Your Way**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	H	**More than a Mouse**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	I	**Attempts**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	J	**Imagine the Possibilities**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	K	**Feel the Music**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	L	**Design a Wheelchair**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?
	M	**Consider This**	☐ I do not remember it ☐ I saw it but did not do much with it. ☐ I did it, read it, or played with it.	Do you remember a story that went with this exhibit? ☐Yes ☐No What was that story about?

What did you think of the design aspects of this Human Plus Exhibition? (i.e. the signage, the colors, the layout). What appealed to you most? What parts did not appeal to you?

GROUOP ONLY	

Please help us understand a little bit more about who you are.

GROUOP ONLY			
	Does anyone in your group today have a severe, permanent disability?	☐Yes	☐ No
	Does anyone in your household have a severe, permanent disability?	☐Yes	☐ No
	Do any of you have a close friend or relative with a severe permanent disability?	☐Yes	☐ No

Tell Us about the people in your group:

GROUOP ONLY	How many	Male Adult	Female Adult	Male Youth	Female Youth	Other

What is the highest level of education in this group?

GROUOP ONLY

- ☐ Elementary school
- ☐ Middle school
- ☐ Trade/vocational school
- ☐ 2-year college
- ☐ 4-year college
- ☐ Professional or Graduate school

Thank you!

Appendix H. Coding Scheme for Awareness of the Engineering Process

CODE	Description	Examples
Ask	Responses that include identifying a need or soliciting input from a user	motivated, thoughtful, caring, perceptive, contributor to societal advancement, curious, inquisitive, observant, altruistic, someone who understands challenges, sensitive, optimistic
Imagine	Responses that include broad consideration of possibilities, planning, or design	strategist, innovative, creative, have a lot of ideas, mastermind
Create	Responses that refer to construction or development of a tangible product	strong, building, handy, tinkering, detail-oriented, precise
Test	Responses that describe experimentation or a trial process	analytical, logic, problem-solving, systematic
Repeat	Responses that describe design or engineering as cyclical or iterative	patient, perseverance, determined, grit, focused, disciplined
Skills and Training	Responses that include specific skills or types of knowledge related to engineering	smart, educated, mathematical, scientific
General Positive Terms	General positive descriptors that were too broad to readily fit other categories	cool

Appendix I. Comments within Coding Scheme for Why Exhibit was Named "Human Plus."

	Expanded human potential and capabilities (Improvement)
I1	M: we're adding something to humans
I2	f7 Plus the future and how people will live
I3	we can!
I4	Beyond human
I6	M: goes beyond the limits of a normal human body; F: being able to do activities beyond basic needs
I35	f13: It has a lot to do with what humans need.
I15	f6: a lot of the things were for humans; M: expanding abilities/what you have
I33	m9: because it allows you to advance human ability
Q29	more powerful than "raw" human being
Q31	shows how human body can adapt
Q34	it showcases advancement that better human life
Q43	because the exhibit is about enhancement to human senses
Q44	because it's about augmentation
Q49	because it's about human life and how we can improve it
Q50	it makes you to throw farter and jump higher
Q77	it adds to our limited human strength and abilities
Q85	Thinking outside bounds of what we assume humans are capable of.
Q94	It's all about extra ordinary humans.
Q95	To expand the possibility of human potential
Q96	because it shows human characteristics plus enhancements
Q97	because the exhibit was a plus for humans
Q98	because it allows you to increase abilities
Q104	Exhibits demonstrate aids to humans that enable humans to go beyond human boundaries
Q106	It's adding to the capabilities that humans already have
Q108	because it is an extension of human capabilities
Q119	because it helps humans do more

	About the Human Body (Body **Only)**
I3	f7 some structures of the human body; t's about people's bodies and how they got that thing; different parts of the body
I5	f11 humans and their bodies
I7	M: cause we're humans
I8	f5: cause a lot of humans have different bodies
I11	f14: about the human body and how it works;
I13	f9: because you're moving your body
I18	m9: because it's how humans get around
I20	f10: because it's about humans
I21	m10: because you can move your body
I22	m11. It's about what's in your body and how it interacts It's about how people have different amounts of strength
I25	f10: It's all about humans and what they do
I27	f10: referring to body parts so you can learn how your body develops
Q30	it incorporates the human body and how it can function
Q32	how the human part
Q33	human body/genes
Q38	the exhibit is all about human
Q42	learn about the different body parts/how the body works
Q72	human movements
Q87	So we can learn what we don't know about our body's capability
Q105	the extra circumstance that create the modern human

	Engineering for Expanding Human Capability and Potential (Engineering & Improvement)
I2	m9 it's about humans and how it helps them
I10	m9: because it's how humans try to make better things for other people
I12	M: superhuman technology. There were exoskeletons!
I24	m12: It's a lot of showing how we can make humans better. Helping people add to their bodies so they can do certain things.
I28	m11: It's all about humans and what you do with the body, and it's more about new stuff for the body, like feeling the music, and what's happening to improve it--human added.
Q14	the exhibit shows what humans are capable of and shows how humans can use technology to better their lives
Q39	the exhibit shows specially designed prosthetic parts that extend the ability to human bodies to perform difficult tasks
Q41	displays technology that enhances human abilities
Q51	because the things they show you help people with disabilitys (sic) are helped by those things so it's a plus for them
Q71	because humans can use extra devices, assists to do extra-ordinary things
Q74	it shows ways science can augment the human body
Q76	he explains how technology and science can expand or benefit the human body and overall experience
Q82	because its humans, plus robotics/things to help human that are made
Q84	a celebration of what people can achieve as a result of added technology
Q88	The powers/abilities of humans when assisted by tools
Q93	Because it is about that is design to help a person
Q119	because it helps humans do more
Q124	They gave it that name because they want to show a relationship with technologies and people.

	Engineering for Expanding Capability and Potential for People with Disabilities
I11	f10: how it helps the humans, like the cane helps keep blind people from running into things
I19	f13: It's about people who are impaired and have extra things to make their lives easier or more normal.
I26	f8: There's making that machine that can help humans. Everything in here is helping people and we feel what it feels like [to have a disability]. m10:They're all sharing different ways that machines can help people do things you think you can't do. Like skiing with no legs and feeling and seeing things while blind. m10: Teaching you that you use things you never could use and showing you technology.
Q13	due to the addatives (sic) for adaptability, "plus" in adding assistance
Q15	this exhibit explores ways science can help people move and live beyond limitations or disabilities, hence Human Plus
Q35	it depicts adaptive techology used to assist individuals with physical impairments
Q36	new body parts for the disabled
Q37	the plus is using prosthetics and things to enhance handicaps
I37	lot of machines all the enhancements you could add to bodies to help disabled people in their daily lives
Q73	to give people an opportunity to better use computers if they are physically challenged
Q75	it demonstrates the additions and adaptations human create to function and thrive with any perceived limitations they may have
Q80	biotic limbs, assisted body parts for the handicapped
Q86	to encourage visitors to consider that the users of these tools are not lesser but more
Q107	They're disabled people with access to extraspecial manmade parts
Q121	Because people with different techniques or engineered devices to perform certain functions or enjoy certain experiences

	Understanding People with Disabilities (Disability only)
30	f10: shows different ways that people could interact--like dancing--even if it's hard for them
31	f10: It's like being in other people's shoes
69	so people who do not have any disabilities can see life through a person who has a disability
79	positive outlook on physical disabilities
81	because it shows how much harder people with physical disabilities have to work at some things and that they have additional skills
83	because life is hard without limbs and everybody has to know it. We can give them a plus.
Q118	for people that part of ADA
Q122	They call it a human plus because it is mostly about humans' disabilities

	Expanded human potential for people with disabilities (Improvement and Disability)
I29	f14: It's about people who have disabilities and ways they can still have fun or overcome their disabilities
I32	F: disability awareness--people with disabilities can do what people without disabilities can do. m16: It's about addition to what humans are capable of doing (expanding possibilities, overcoming disabilities and obstacles)
Q70	it reflects the nature of the exhibit "Plus" in the title is for the "add on" features that enable disabled people to do what humans normally can

	Engineered Products for People with Disabilities (Engineering and Disability)
I3	f9 how you can design people's wheelchairs and help them
I4	M most of the inventions are additional things people have where they don't have certain parts.
I22	m11: It's about how different things are for people with disabilities;

	Engineering Only
I2	m9: it's about humans and how it helps them; m9: plus the future and how people will live; M: humans plus ingenuity going over and above, brain stimulus linking cyber to brain
I36	m12: it helps humans with tools
I34	M, m18 because your body and engineering, and they put mechanical devices in us

	Associations with the Exhibit Space
I16	m7: because the chair looks like a plus
I33	m8: It looks like a bus;

	Other
I9	f10: you're using your abilities to play the games
I33	m8: It looks like a bus;

	How people with Disabilities Use their Bodies (Disability and Body)
I14	M: interact with body parts, see how the handicapped handle things
I23	m9: how physical people get and how much help they need; because some people might have special needs. Everyone's body is not made the same way.