# Designing for others: the roles of narrative and empathy in supporting girls' engineering engagement



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## Abstract

**Purpose** – Science museums provide a context for developing and testing engineering activities that support visitors in creating personally meaningful objects. This study aims to propose that narrative design elements in such engineering activities can foster empathy to support engineering engagement among girls ages 7–14.

**Design/methodology/approach** – Taking a constructionist approach to engineering design, the authors present results from an observational study ($n$ = 202 girls) of engineering activities across three museums that were designed to foster girls' engineering engagement by integrating narrative elements aimed to foster empathy in activities. Using quantitative counts from observation protocols, the authors conducted statistical analyses to explore relationships between narrative, engineering and empathy.

**Findings** – Linear regression demonstrated a statistically significant relationship between empathy and increased numbers of engineering practices within museum activities. Additionally, this led us to explore the impacts the potential narrative design elements may have on designing for empathy – multiple linear regressions found both narrative and empathy to be independently associated with engineering practices. Overall, the authors found that using narrative to design activities to elicit empathy resulted in girls demonstrating more engineering practices.

**Originality/value** – The authors offer design ideas to foster aspects of empathy, including user-centered design, perspective-taking, familiarity and desire to help.

**Keywords** Narrative, Empathy, User centered design, Out-of-school learning, Museums, Design projects

**Paper type** Research paper

This project was a collaborative effort that brought together a team of researchers, educators, and activity developers from four informal learning institutions: The New York Hall of Science (NYSCI), The Tech Interactive, The Scott Family Amazeum, and The Creativity Labs at University of California, Irvine.

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## Introduction

Supporting girls' engineering engagement is important because girls remain underrepresented in the engineering field (Bix, 2014), yet they express interest in engineering activities when they are posed as personally meaningful and connected to people and communities (Bennett, 2000). When engineering problems are posed as personally and socially meaningful, they can tap into learners' interest in helping others, supporting more human-centered conceptions of engineering (Cunningham and Lachapelle, 2014). Such forms of empathy are valuable for engineering education (Capobianco and Yu, 2014; Fila *et al.*, 2014; Hynes and Swenson, 2013; Walther *et al.*, 2017, 2020). For instance, constructionist perspectives of learning consider that by engineering personally meaningful projects, learners develop interpersonal connections with designed objects and empathy with those for whom they are designing (Bers, 2008; Papert, 2000). Central yet implicit to this constructionist perspective (Papert, 1990, 1993) is a multidimensional definition of empathy that highlights emotional responses and an understanding of self and others reflexively (Decety and Jackson, 2004; McDonald and Messinger, 2011). Within engineering educational activities, such aspects of empathy translate into observable behavior, such as perspective-taking and expressing a desire to help (Letourneau *et al.*, 2021). However, the relationship between empathy and engineering and how to support that relationship through educational design remains underspecified.

Building on constructionist approaches, our work aims to understand how designed engineering activities can foster empathy and how this may relate to girls' engineering engagement. We analyzed correlational relationships between empathy and engineering through observations of two conditions of three engineering activities in one museum and two conditions of one activity in three museums. The conditions were named *guided narrative* and *visitor-generated narrative*, situated within a larger design-based research project to develop strategies for integrating narratives into engineering activities to foster empathy. In the guided narrative version of one of the activities, visitors used an assortment of construction materials to design an invention to help a *grandma* with tasks, from opening a jar to hearing the doorbell. Within the visitor-generated narrative condition of this same activity, visitors were asked to design an invention to solve a real-world problem, but the activity design did not mention particular characters for whom visitors were designing. In this paper, we first provide background on the underrepresentation of girls in engineering and describe how constructionism framed our design and analysis in the context of a museum setting. We then describe findings that demonstrate how activity designs related to girls' (ages 7–14) engagement with engineering. Overall, we found that using narrative to design activities to elicit empathy resulted in girls demonstrating more engineering practices. We end with a discussion of design ideas to foster empathy using the tools of narrative to create more inclusive engineering spaces.

## Background

### *Underrepresentation of girls in engineering and the role of museum settings*

The underrepresentation of women in engineering is, in part, linked to girls' early experiences, during which youth form gendered assumptions about Science, Technology, Engineering, and Mathematics (STEM) (Meiksins *et al.*, 2016). This trend extends to the broader field of engineering as women are consistently underrepresented in science and engineering professions (Bix, 2014; Buse, 2018; Sax *et al.*, 2016; Varma, 2018). Middle school and the years leading up to it are a particularly fitting time to intervene because this is when girls begin to lose interest in science and math (Corbett and Hill, 2015).

One potential barrier to entry for young girls in out-of-school settings is that engineering activities typically focus on robotics and electronics experiences that draw on a history of predominantly white male tinkerer cultures (Bennett and Monahan, 2013; Halverson and

Sheridan, 2014; Reisslein *et al.*, 2012). Engineering design spaces where youth engage in personally meaningful ways have become prevalent in museums (Keune *et al.*, 2019; Kalil, 2012; Vossoughi and Bevan, 2014). Yet, without attention to intentionally creating more inclusive designs targeted for those underrepresented in engineering, these settings can replicate existing inequities (Buchholz *et al.*, 2014; Buechley *et al.*, 2013; Dawson *et al.*, 2015). Science museums aim to serve a broad range of visitors (Bell *et al.*, 2009; Dawson, 2014). Thus, they play a particularly important role in understanding how to design engineering activities for girls because they are key points of access.

*Designing for empathy to foster girls' engagement with engineering*

Girls' engagement in engineering may be supported by contextualizing engineering problems in relation to personally meaningful contexts, people and communities (Bennett, 2000; Dorie and Cardella, 2013; Eccles, 2005; Eccles and Wang, 2016; Wigfield and Eccles, 2000). Contextualizing engineering problems to support caring about those for whom designs are intended cultivates empathy, which can support girls' persistence within activities and critical phases of engineering design (Atman *et al.*, 2007).

We recognize that social structures, such as gender, class and race shape the choices, aspirations and identities of individuals in relation to science (Archer *et al.*, 2012). Aligned with the notion that gender is performed through what a person does (Butler, 1990), femininity in science often comes into conflict with popular notions that position science as masculine (Archer *et al.*, 2012). However, regardless of whether their performance of the doing of science are viewed as feminine or masculine, girls can better learn science in spaces where their identities are valued (Dawson *et al.*, 2020). Empathy may be a particularly important design consideration within an engineering context aligned with a push from the engineering education field to design inclusive engineering spaces that center communal goals and helping others with the aim of inviting more women and girls to the field (Boucher *et al.*, 2017, for a longer discussion of communal goals).

In contrast to problematic notions of "help" in the engineering literature (Schneider *et al.*, 2009), in the present study, the activity designs evoked girls' desire to engage in helping behaviors in a range of contexts from familiar to more imaginative situations. In activity designs, this included imaginative scenarios that offered opportunities for girls to engage with *familiar* contexts in which the engineering girl is an insider, such as an imaginary scenario that's close to home, a friend's home or a situation observed in their neighborhood. Additionally, imaginative scenarios that left room for identifying who was in need of protection also supported girls' desire to engage in helping behaviors. The design of these activities also allowed for variation but were not overly prescribed. Help in the present study is of an interpersonal level of support, designing around interpersonal problems and deeply connected to empathy.

In fact, in addition to being aligned with more communal and humanistic goals of engineering spaces, empathy is an embedded part of what it means to be an engineer (Walther *et al.*, 2017; Engineering Accreditation Commission, 2015; Walther *et al.*, 2012), and empathy shapes how aspiring engineers make sense of the engineering field (Walther *et al.*, 2016, 2020). Moreover, regardless of gender identity, experienced engineers are more likely to note empathy and care as an important part of their work as engineers, as compared to those with less experience (Hess *et al.*, 2017). The engineering design process presents opportunities for practicing multifaceted aspects of empathy while tinkering and improving design solutions (Battarbee *et al.*, 2014; Hess and Fila, 2016). For instance, engineering that invites designers to demonstrate empathy may involve imagining multiple solutions based on users' needs (Preston and de Waal, 2002; McDonagh *et al.*, 2011).

Although empathy and engineering are linked and girls' engagement in engineering can be supported through personally meaningful problems, it remains unclear how to cultivate empathy through engineering activity design. To better understand how connections between engineering and empathy can foster girls' engagement with engineering in museum-based settings, we draw on empathy as a multidimensional construct (Davis, 1983; Decety and Jackson, 2004; McDonald and Messinger, 2011) involving specific markers of empathy, such as expressing the desire to help, perspective-taking by talking about how another person might use something, as well as considering challenges with familiar situations (Batson, 1990; Decety and Jackson, 2004; Gerdes and Segal, 2009). These aspects of empathy have been observed in narrative-based engineering activities in informal settings (Letourneau *et al.*, 2021).

### *Constructionism as a guiding frame for supporting empathy through narrative*

Constructionist perspectives of learning can support new thinking about creating engineering activities that foster empathy. As museum visitors manipulate materials toward personally meaningful and shareable projects, the process can lead toward discovering formalisms of materials. Materials become "objects-to-think-with" (Papert, 1990, p. 11), the real material that museum visitors manipulate and ideas that are embedded in the materials that become internalized in design. In constructionist learning environments, people can develop interpersonal connections and "establish personal relationships with ideas" (Bers, 2008, p. 25).

Developing interpersonal connections and the concept of empathy are embedded within the constructionist theory, as Ackermann (2001) explains, "becoming one with the phenomenon under study is, in [Papert's] view, a key to learning. It's the main function is to put empathy at the service of intelligence" (p. 8). Learning is situated and happens when people are fully immersed in the context of what it is they are learning, including its embedded ideas and relationships. Objects-to-think-with are linked to a multidimensional perspective of empathy. They make it possible for museum visitors to think about their designed object, who it is for, what it does and how certain aspects of the design address particular challenges (Bers, 2008; Papert, 2000). Thinking of empathy as developing interpersonal connections in relation to objects-to-think-with makes it possible to consider concrete design elements that are intended to evoke empathy within engineering design.

One way to support girls' engineering design problems by way of empathy may be through the design of engineering activities with narrative elements (Pruitt and Adlin, 2006). Incorporating narrative elements within engineering problems can support developing empathy because narrative framing of problems can explain how characters relate to design problems. For instance, considering how a grandma could open a jar, a narrative frame of one of our activity designs, may provoke empathy in the form of perspective-taking as designers think about situations in which the grandma wants to open a jar. Following constructionist notions of objects-to-think-with and related interpersonal connections, narrative design elements promise to introduce empathy into engineering activities.

## Research questions

To explore the connections between narrative design elements, empathy and engineering in the context of museum-based engineering activities, we asked as follows:

*RQ1.* How many different *narrative* practices do girls engage with across conditions, activities and museums?

*RQ2.* How many different *engineering* practices do girls engage with across conditions, activities and museums?

*RQ3*. How many different *empathy* markers do girls demonstrate across conditions, activities and museums?

*RQ4*. What are the relationships, if any, between the demonstrated number of different narrative practices, engineering practices and empathy markers and dwell time?

## Methods

This study includes several key terms that require explanation up front. Table 1 includes an overview of the key terms used across the paper and explains what they mean. Examples from the museum floor contextualize their relevance to the study.

### *Museum settings*

With support from the National Science Foundation, this evaluation study was part of our larger design-based research study investigating how narrative elements could be integrated into informal engineering design activities to promote girls' empathy and engagement in engineering practices. The New York Hall of Science (NYSCI), a science center in Queens, NY was the primary site leading the design-based research to iteratively develop and test narrative-based engineering activities to increase girls' empathy and

| Key term | Explanation | Example from the museum floor |
|---|---|---|
| Activity | *Engineering design exhibits implemented at museum sites* | *Activities included Help Grandma/Invention Challenge, Chain Reaction and Air-Powered Vehicles* |
| Guided narrative condition | *The version of the activity that called for visitors to engage with a particular narrative element focused on a character or setting* | *In the Help Grandma/Invention Challenge activity, visitors created an invention for a specific grandma character; in the Air-Powered Vehicles activity, visitors created a vehicle to move across a specific setting such as a desert landscape* |
| Visitor-generated narrative condition | *The version of the activity that did not call for visitors to engage with a specified narrative element yet was not void of narrative* | *In the Help Grandma/Invention Challenge activity, visitors created an invention to solve a social or real-world problem; in the Air-Powered Vehicles activity, visitors created a vehicle to move across different textured surfaces* |
| Narrative practices | *Practices with which visitors engaged linked to narrative-related elements of activity* | *Narrative practices included referencing narrative, elaborating narrative, inventing narrative and inventing user*<br>Inventing a user: As Rica makes her vehicle, she explains, "It's going to be something for a robot, it brings stuff to you" |
| Engineering practices | *Practices with which visitors engaged that linked to engineering-related elements of activity* | *Engineering practices included imagination, iteration, persistence, problem scoping, solution finding, testing and tinkering*<br>Iteration: While making something for grandma, Laura explains: "I've got another idea to keep it straight" and begins working on the new concept |
| Empathy markers | *Markers that indicated visitors expressed empathy through how they engaged with the activity* | *Empathy markers included affective (user and designer), desire to help, familiarity, perspective-taking, societal issue and UCD criteria*<br>Affective (user): Mia explains, "The dog feels lonely" |
| Dwell time | *The length of time visitors engaged with an activity* | *Visitors were timed from the moment they entered the activity space until they left; a visitor's total dwell time was cumulative if a visitor re-entered the space at a later time while the team was still observing* |

**Table 1.**
Key terms

engagement in the design process, with input from two collaborating partner sites as follows: The Tech Interactive and Scott Family Amazeum. This evaluation study examined how a selected set of these activities affected the outcomes of interest across all three museum sites. The primary activity design site, NYSCI, is a science center in Queens, New York that serves a racially and ethnically diverse population of approximately 500,000 visitors per year. NYSCI offers facilitated engineering design activities, following its Design-Make-Play approach to STEM learning (Honey, 2013). Tech Interactive is a science center located in San Jose, CA that serves the surrounding tech community, also including about 500,000 visitors per year. At The Tech, facilitators follow a high-energy approach to facilitation that aims to support visitors as they engage in design challenges. Amazeum in Bentonville, augmented reality makes connections to local industry communities through exhibits. Amazeum serves about 250,000 visitors per year.

*Engineering activities*

Activity developers and researchers at NYSCI worked with partner sites to iteratively develop narrative framings for engineering activities, refining the activities in ways that would evoke empathy and encourage engineering design practices, and creating comparison activities that used similar materials and goals but lacked an explicit narrative frame. Six activities were developed at NYSCI, one of which was implemented across all three museum sites for the purposes of the evaluation. Activity designs were informed by constructivist and constructionist theories of learning, following the tradition that materials and activities ought to support the development of personal relationships within domain learning (Piaget, 1976; Harel and Papert, 1991). By centering relationships and personally meaningful problems in the design, the needs of others were an embedded part of creating user-centered design (UCD) experiences (Nelson and Stolterman, 2014). In the guided narrative condition, narrative elements were explicitly incorporated in activity design through a genre of characters (e.g. pets, grandparents) and settings (e.g. a desert, a tundra). In the visitor-generated narrative condition, activities did not explicitly mention narrative elements, but visitors could still generate their own.

Two activities (Help Grandma/Invention Challenge and Chain Reaction) were only observed at NYSCI; one activity (Air-Powered Vehicles) was implemented and observed across all three museums. In Help, Grandma/Invention Challenge the guided narrative condition (Figure 1, left) invited visitors to use construction materials, including wooden blocks, colorful discs and nuts and bolts to design an invention. The invention was intended to "help grandma" with tasks, which were displayed at the entrance of the exhibit through task cards that included a drawing of a grandma, her name and difficult tasks. The provided narratives were designed to evoke empathy for grandma through observable behaviors such as expressing the desire to help and demonstrating UCD. The visitor-generated narrative version of the activity (Figure 1, right) asked visitors to design an invention to solve a real-world problem without reference to a particular character. Materials for both activity versions were similar.

In Chain Reaction, the guided narrative condition (Figure 2, left) asked visitors to create Rube Goldberg machines using everyday objects, such as skates, balls, pipes and boots to feed or play with a pet (i.e. represented by life-sized models of dogs), a provided narrative that was intended to evoke observable empathetic behaviors (e.g. perspective-taking). The goal was to trigger the circuitry embedded in the dog character so it would wag its tail. In the visitor-generated narrative condition (Figure 2, right), the goal was to create a Rube Goldberg machine to ring a bell or push a ball without reference to a character.


**Figure 1.** Guided narrative condition (left) and visitor generated narrative condition (right) of Help Grandma/Invention Challenge

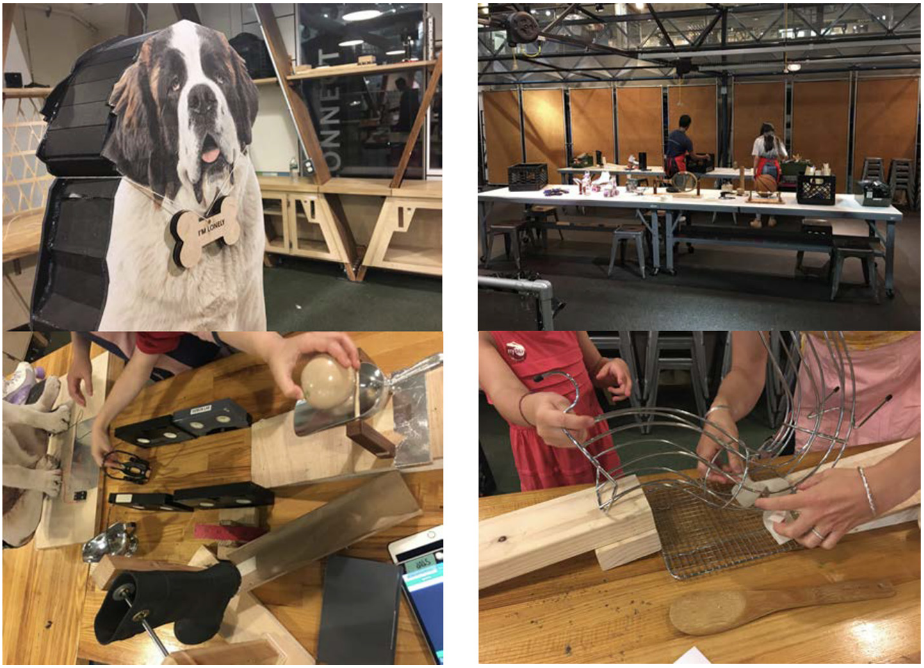


**Figure 2.** Guided narrative condition (left) and visitor generated narrative condition (right) of Chain Reaction

In Air-Powered Vehicles, the guided narrative condition (Figure 3, left) asked visitors to design vehicles to travel over a variety of landscapes such as an uneven grass terrain or a slippery arctic icescape. The visitor-generated narrative condition (Figure 3, right) asked to create and test vehicles on a variety of textured surfaces with a range of friction, including a thick carpet and a smooth surface. Building materials included sewing bobbins, oversized buttons and cut up pipes, small paper and fabric pieces, and connecting materials (e.g. rubber bands).

*Participants*

This study focused on designing engineering activities for girls because they are under-represented in engineering contexts, and there is a need for new educational approaches that prioritize girls' perspectives to invite more identities into the field. We decided to focus on girls' because the partnering museums needed to design new engineering exhibits to attract girls. Given the limited resources and activity designs, designing engineering activities that support girls in engaging with engineering practices became one of the aims of the activity designs and the present study. In the future, the investigation can be expanded to all. We observed 202 girls ages 7–14 (Table 2), museum visitors who entered the activity spaces with family members or peers. A researcher approached the girls and the adults they were with to ask for assent/consent to be observed and interviewed in a study related to engineering engagement for girls. Although the participants were not explicitly asked about their gender identity, we assume that they or the adults they were with would have declined participation if they did not identify as part of the target group (i.e. girls ages 7–14).

At NYSCI, observations included 38 girls for Help Grandma/Invention Challenge and 60 girls for Chain Reaction. For Air-Powered Vehicles, we observed 40 girls at NYSCI, 37 girls at The Tech and 27 at Amazeum. Differences in numbers of observations were due to visitor dwell time variances and visitor flow.

**Figure 3.**
Guided narrative condition (left) and visitor generated narrative condition (right) of Air Powered Vehicles at NYSCI

*Data sources*

Research instruments included observation and semi-structured interview protocol (Appendix). The instrument included space for a pseudonym, the exhibition and condition, and check-boxes for all narrative and engineering practices and empathy markers. We also tracked the participants' dwell time using a stopwatch, which started once the participants physically entered the exhibition area and ended once they left. We recorded qualitative notes, including girls' design moves, verbal utterances and responses to semi-structured interview questions. Questions included "Is there a backstory to this [what you made]?" and "How will anyone use your design?" When possible, we photographed girls' in-process and final engineering designs.

Keune (Author 2) and NYSCI museum educator-researchers Bennett and Letourneau (i.e. Authors 4 and 5) agreed upon the engineering practices, narrative practices and empathy markers, their definitions, and how they would be observed in action prior to the observations. This included an extended discussion of observation and interview protocols developed during the iterative design-based research process, and pilot observations gathered at the start of the evaluation to further define the practices and markers included in the protocol (see descriptions and examples in Table 3). This was done because it was not possible to video record the participants at the museums. It was not logistically possible for additional researchers to travel to the museums for observations because of the multisite nature of the study.

## Narrative practices, engineering practices and empathy markers

Narrative can be a powerful tool to engage girls in engineering design problems (Pruitt and Adlin, 2006) as it can cultivate perspective-taking and invite girls to generate engineering solutions to meet others' needs (Bennett, 2000; Bennett and Monahan, 2013; Bennett *et al.*, 2016; Dusold, 2008). We were interested in the extent to which visitors engaged with narratives as they participated in museum activities. We observed four narrative practices, which concerned whether visitors referenced and elaborated on narratives that were part of the activity design (i.e. referencing, elaborating) or invented narratives and users outside of the activity designs (i.e. inventing narrative, inventing user; see Table 3 top, for examples, rooted in our data).

Table 3 (center) presents an overview of the observed engineering practices. We drew from pilot data examples and data gathered by museum researchers throughout activity development, the collective design sensibilities of museum partners, and engineering literature to support the development of the protocol. We drew on frameworks describing the engineering design process (ASEE, 2020; Katehi *et al.*, 2009; NAE, 2019), emphasizing how Moore *et al.* (2014) distilled the engineering design process to a set of indicators for K-12 learners. Their indicators included framing the problem, planning and implementing a prototype and testing and evaluating to improve it based on evidence. Additionally, problem

| | Help Grandma/ Invention Challenge (NYSCI) | | Chain Reaction (NYSCI) | | Air-Powered Vehicles (All museums) | | Total |
|---|---|---|---|---|---|---|---|
| Descriptors | Guided | Visitor-generated | Guided | Visitor-generated | Guided | Visitor-generated | |
| Observations (n) | 19 | 19 | 41[1] | 19 | 52 | 52 | 202 obs. |
| Observation hours | 11.5 | 10 | 15 | 8 | 18 | 21 | 83.5 h |
| Total | 38 obs./21.5 h | | 60 obs./23 h | | 102 obs./39 h | | |

**Table 2.** Observations and observation hours by activity

**Table 3.** Observed engineering and narrative practices and empathy markers

| Practice/ marker | Explanation | Example from the museum floor |
|---|---|---|
| *Narrative practice* | | |
| Referencing narrative | References narrative in the activity prompt | Sara touches the collar of the dog and explains, "It's lonely" as she begins her design |
| Elaborating narrative | Elaborates and extends the given activity narrative | Zahara explains that her grandfather teaches karate and does not need help opening jars |
| Inventing narrative | Creates own narrative based on prior knowledge or experiences | As she is making something, Traci explains that she saw an art piece that made music with rainwater so that's her inspiration |
| Inventing user | Creates a user for whom the project is intended | As Rica makes her vehicle, she explains, "it's going to be something for a robot, it brings stuff to you" |
| *Engineering practice* | | |
| Imagining | Imagining new projects and possibilities | As Yesenia creates vehicle, she explains: "If I had actual wheels, it would be better" |
| Iteration | Improving a design function through implementing | While making something for grandma, Laura explains: "I've got another idea to keep it straight" and begins working on the new concept |
| Persistence | Solving problems with materials | As Natalie tries to connect plastic sticks, she asks, "How do you connect this?" and tries herself three times then gathers additional materials to help |
| Problem scoping | Multiple aspects of a problem | London explains that her vehicle "did not work because of the wheels they would not move in the wind" |
| Solution finding | More than one solution (ideas) | As Ava is building her vehicle she settles on a mix of her ideas: "It's going to be a car with a sail" |
| Testing | Testing a design function | While building a vehicle, Maria tries different ideas and explains, "I am learning how, once I test it and it does not work I can try again and modify it, change it to make it better" |
| Tinkering | Elaborating, adding features | As Lucy makes a structure, it falls so she adds wood to try to make it stand |
| *Empathy marker* | | |
| Affective (designer) | How designer feels | While making something, Bella explains, "I would like to keep adding to it and see what it turns into" |
| Affective (user) | How user feels | Mia references the dog and explains, "The dog feels lonely" |
| Desire to help | Expressing a wish to help | Sonia explains about what she made: "It will probably help people with disabilities lift something up to help themselves" |
| Familiarity | Prior experience or knowledge | Trinity makes a connection: "My grandma has a hard time opening jars" |
| Perspective-taking | Talking about/acting out design | Valerie acts out how grandma would use what she made: "If it were real the person would push it up" |
| Societal issue | Related to societal issue | Malia makes a vehicle and explains that it's "better for the environment" |
| UCD criteria | UCD criteria | Olivia adds a "painstick" as a handle so "grandma can hold this" |

scoping and gathering information around problems are fundamental to developing engineering expertise (Atman *et al.*, 2007). In a science center context, certain aspects of the engineering design process were especially visible in children's interactions with their family groups, including problem scoping (e.g. identifying constraints, contextualizing the problem), idea generation (e.g. brainstorming and planning designs), design evaluation (e.g. reflecting on the entire design after testing) and revision (e.g. iterating and optimizing the design; Dorie *et al.*, 2014). Importantly, although frameworks of science and engineering practices (e.g. Next Generation Science Standards) emphasize different facets of engineering, our conversations about which practices to include led to a focus on practices that we considered most *observable* either through talk or action within the locally-constructed activities. Using the broader literature base along with pilot observations to discern how girls actually participated within the designed activities at the local museum, we identified seven engineering practices to include in our protocol – imagining, iteration, persistence, problem scoping, solution finding, testing and tinkering.

Our aim to support the theoretical development of interpersonal connections was operationalized through empathy markers that demonstrated interpersonal connections and empathy either through talk or action. The empathy markers we observed (Table 3 bottom) are rooted in psychology and neuroscience that defines empathy as a multifaceted process that includes affective responses (e.g. concern, compassion), cognitive processes (e.g. perspective-taking, imagining someone else's point of view) and prosocial behaviors (e.g. taking action to help others) (Baron-Cohen and Wheelwright, 2004; Decety and Jackson, 2004; McDonald and Messinger, 2011; Preston and De Waal, 2002). This framing aligns with recent studies that emphasize the need for engineers to understand users' needs, listen to others' perspectives (i.e. when working on teams, imagining how clients might use and respond to designed solutions) and take social responsibility (i.e. designing solutions to care for others or that consider ethical and societal implications of their work) (Capobianco and Yu, 2014; Fila *et al.*, 2014; Hynes and Swenson, 2013; Segal, 2011; Walther *et al.*, 2017, 2020). Based on this literature, protocols developed during activity development to document empathy and our pilot observations, we observed seven empathy markers – affective (designer), affective (user), desire to help, familiarity, perspective-taking, societal issue and UCD criteria.

Data from observation protocols were organized by noting all engineering practices, narrative practices and empathy markers per visitor and transcribing all qualitative notes in a single spreadsheet. Data was organized by different configurations of museums, activities and conditions for analysis.

### *Analytical approach*

Our analytical focus lay on identifying correlations and promising relationships. Frequencies of narrative practices, engineering practices and empathy markers were counted across conditions, activities and museums. This presented whether and how girls engaged in narrative and engineering practices and demonstrated empathy markers.

A linear regression model explored whether the diversity of the overall levels of engineering practices differed by activity at the one museum where all activities were observed (i.e. NYSCI). This presented a comparative understanding of how girls engaged with engineering practices across conditions and activities. A linear regression model also explored the relationship between activities, dwell time and engineering practices. The dependent variable was the number of different engineering practices a visitor demonstrated (an integer from 0 to 7) and the independent variable was total minutes spent within the activity.

To statistically test the relationship between engineering and empathy, the Spearman correlation coefficient was used to assess monotonic associations (i.e. strength of the correlation) between the number of engineering practices and the number of empathy markers visitors demonstrated. Specifically, the Spearman correlation assessed whether the number of empathy markers and engineering practices changed together over time, yet not necessarily at a constant rate.

### *Statistical methods*

Phi correlation coefficients were calculated across all data on narrative practices, engineering practices and empathy markers to determine how often constructs co-occurred. Multiple linear regression analysis was conducted to examine the relationship between the diversity of engineering practices with empathy and narrative practices. Multicollinearity between explanatory variables was checked and found to be absent. For all models, the fit was assessed and found to be adequate. *P*-values less than 0.05 were considered statistically significant. Analyses were performed on Stata software (StataCorp. 2019. *Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC).

### *Methodological limitations*

Constraints on video data collection at the museum sites and logistics prevented multiple researchers in the activity space at once, it was not feasible to formally calculate interrater reliability. We attempted to address this limitation by having repeated discussions about what practices could look and sound like on the museum floor based on pilot data. Additionally, with one observer in the museum activity space, we had to decide how to operationalize observations of narrative practices, engineering practices and empathy markers, ultimately choosing to focus on how many different practices and markers were demonstrated. The observer may have missed some demonstrations of these practices and markers and so to supplement the quantitative measures, the observer took qualitative field notes to describe specifics of how girls demonstrated the constructs on the observation protocol. These qualitative notes guided our interpretations of how specific aspects of the narrative activity designs supported girls' engineering engagement.

## Findings

As a baseline to anchor our exploratory work, we calculated Phi correlation coefficients across all data on narrative practices, engineering practices and empathy markers to determine how often constructs co-occurred (Tables 4–6). We did this to better understand the relationships between constructs to see if they were separately observable and if not, to identify which practices/markers co-occurred with one another.

In terms of narrative practices, inventing narrative and inventing users had a strong relationship, which means that visitors often created characters and stories related to those

**Table 4.** Phi correlation coefficient for each pair of narrative practices across all museums and all activities

| Narrative practice | Elaborating narrative | Inventing narrative | Inventing user |
|---|---|---|---|
| Referencing narrative | 0.37 | 0.01 | 0.08 |
| Elaborating narrative | | 0.21 | 0.26 |
| Inventing narrative | | | 0.54 |

**Notes:** Scale: 0.70 – 1.00 very strong relationship; 0.40 – 0.69 strong relationship; 0.30 – 0.39 moderate relationship; 0.20 – 0.29 weak relationship; 0.01 to 0.19 no or negligible relationship; −1 to 0 no relationship characters. For engineering practices, we found a number of strong relationships between constructs (i.e. iteration and scoping, testing and iteration), especially between persistence and other practices (i.e. between persistence and scoping, solution-finding, iteration, testing and tinkering). This means that many engineering practices often co-occurred and that persistence was a common thread through different engineering practices. The empathy marker of desire to help was strongly correlated with the UCD, meaning that visitors often wanted to design solutions to meet the specific needs of users to help those with challenges. Identifying relationships between constructs helped cluster engineering practices and prompted further discussion on the future refinement of the observation tool through a psychometric analysis method. There were not strong relationships among most of the empathy markers. We assume they are distinct constructs that can be observed separately.

*Narrative practices across conditions, activities and museums*

We investigated how girls engaged with narrative practices because narrative practices were an integral component of our design-based research and because narratives were developed with the goal of evoking empathy in these activities. Frequency counts of narrative practices observed across the guided and visitor-generated narrative conditions indicated differences in the narrative practices (Table 7). Visitors demonstrated more narrative practices in the guided narrative condition – girls invented narratives while engaging in design activities but were more inclined to elaborate on those narratives in the guided narrative condition. Several visitors also invented narratives ($n$ = 14) and users

| Engineering practice | Solution finding | Imagining | Iteration | Persistence | Testing | Tinkering |
|---|---|---|---|---|---|---|
| Scoping | 0.32 | 0.08 | 0.48 | 0.45 | 0.38 | 0.31 |
| Solution finding | | 0.44 | 0.44 | 0.40 | 0.32 | 0.29 |
| Imagining | | | 0.30 | 0.33 | 0.24 | 0.21 |
| Iteration | | | | 0.53 | 0.45 | 0.38 |
| Persistence | | | | | 0.43 | 0.52 |
| Testing | | | | | | 0.39 |

**Notes:** Scale: 0.70 – 1.00 very strong relationship; 0.40 – 0.69 strong relationship; 0.30 – 0.39 moderate relationship; 0.20 – 0.29 weak relationship; 0.01 to 0.19 no or negligible relationship; −1 to 0 no relationship

**Table 5.** Phi correlation coefficient for each pair of engineering practices, across all museums and all activities

| Empathy marker | UCD criteria | How designer feels | How user feels | perspective-taking | Familiarity | Societal issue |
|---|---|---|---|---|---|---|
| Desire to help | 0.61 | −0.05 | 0.16 | 0.22 | 0.18 | 0.37 |
| UCD criteria | | 0.07 | 0.26 | 0.34 | 0.27 | 0.16 |
| Affective (designer) | | | −0.03 | 0.12 | 0.09 | −0.03 |
| Affective (user) | | | | 0.29 | 0.14 | −0.03 |
| Perspective-Taking | | | | | 0.23 | 0.02 |
| Familiarity | | | | | | 0.14 |

**Notes:** Scale: 0.70 – 1.00 very strong relationship; 0.40 – 0.69 strong relationship; 0.30 – 0.39 moderate relationship; 0.20 – 0.29 weak relationship; 0.01 to 0.19 no or negligible relationship; −1 to 0 no relationship

**Table 6.** Phi correlation coefficient for each pair of empathy markers across all museums and all activities

($n$ = 9) in the guided condition. The guided narrative condition did not preclude visitors from inventing narratives and users even though a narrative was presented.

*Engineering practices across conditions, activities and museums*

Engineering practices were observed at similar frequencies across all activities and museums (Table 8). This is surprising, given the wide variation in narrative designs. For all data, the frequencies of engineering practices clustered around persistence ($n$ = 114; 56.4%), testing ($n$ = 116; 57.4%) and tinkering ($n$ = 156; 77.2%). Thus, both conditions supported a diversity of engineering practices. Visitors performed several engineering practices with any of the activities and across both conditions.

Linear regression assessed the association of engineering practices with each exhibit at NYSCI to analyze whether any differences occurred at the one museum that implemented all three activities. Overall, across activities at NYSCI, there was variation in the diversity of engineering practices that visitors demonstrated. Help Grandma/Invention Challenge inspired the most diverse engineering practices of all three activities, followed by Chain Reaction, followed by Air-Powered Vehicles. The linear regression showed that the difference in the mean number of engineering practices in Chain Reaction compared to those in Air-Powered Vehicles was not significant (MD = 0.4; $p$ = 0.3504; 95% confidence interval [CI] [−0.5, 1.3]). Also, the mean number of engineering practices between Help Grandma and Chain Reaction was not significant (MD = 0.6; $p$ = 0.1716; 95% CI [−0.3, 1.6]). Yet, the difference in the mean number of engineering practices between Help Grandma/Invention Challenge and Air-Powered Vehicles was statistically significant (MD = 1.1; $p$ = 0.0374; 95% CI [0.1, 2.1]).

**Table 7.** Counts and percentages of observed narrative practices, across all activities and museums

| Narrative practices | Guided narrative ($n$ = 112) n | % obs. | visitor-generated narrative ($n$ = 90) n | % obs. |
|---|---|---|---|---|
| Referencing narrative | 51 | 45.5 | 1 | 1.1 |
| Elaborating narrative | 16 | 14.3 | 2 | 2.2 |
| Inventing narrative | 14 | 12.5 | 24 | 26.7 |
| Inventing user | 9 | 8.0 | 10 | 11.1 |

**Table 8.** Counts (and percentages) of observed engineering practices within activities and museums combining conditions

| Engineering practice | Help Grandma/ Invention Challenge $n$ = 38 $n$ (% of obs.) | Chain Reaction $n$ = 60 $n$ (% of obs.) | Air-Powered Vehicles (NYSCI) $n$ = 40 $n$ (% of obs.) | Air-Powered Vehicles (The Tech) $n$ = 37 $n$ (% of obs.) | Air-Powered Vehicles (Amazeum) $n$ = 27 $n$ (% of obs.) | Air-Powered Vehicles (all museums) $n$ = 104 $n$ (% of obs.) |
|---|---|---|---|---|---|---|
| *Scoping* | 15 (39.5) | 14 (23.3) | 7 (17.5) | 14 (37.8) | 12 (44.4) | 33 (31.7) |
| *Solution finding* | 14 (36.8) | 21 (35.0) | 7 (17.5) | 12 (32.4) | 9 (33.3) | 28 (26.9) |
| *Imagining* | 13 (34.2) | 14 (23.3) | 6 (15.0) | 7 (18.9) | 5 (18.5) | 18 (17.3) |
| *Iteration* | 20 (52.6) | 20 (33.3) | 17 (42.5) | 22 (59.5) | 9 (33.3) | 48 (46.2) |
| *Persistence* | 27 (71.1) | 25 (41.7) | 17 (42.5) | 27 (73.0) | 18 (66.7) | 62 (59.6) |
| *Testing* | 15 (39.5) | 38 (63.3) | 18 (45.0) | 27 (73.0) | 18 (66.7) | 63 (60.6) |
| *Tinkering* | 32 (84.2) | 45 (75.0) | 28 (70.0) | 30 (81.1) | 21 (77.8) | 79 (76.0) |

These results were surprising because we anticipated that Air-Powered Vehicles would lead to a greater diversity of engineering practices compared to the Help Grandma/Invention Challenge because the activity called for the design of a vehicle, a more typical engineering activity according to the museum educator-researchers on our team. However, seeing more engineering practices such as ideation by centering a grandma in the design problem led us to consider the UCD aspects of both conditions of the Help Grandma/Invention Challenge that may have been connected to performed engineering practices.

*Empathy markers across conditions, activities and museums*

Like engineering practices, empathy markers were consistent across activities. Frequencies clustered around perspective taking ($n$ = 55; 27.2%) and familiarity ($n$ = 37; 18.3%; Table 9). Additional markers with higher frequencies included the desire to help ($n$ = 17; 8.4%) and UCD ($n$ = 17; 8.4%). Overall, empathy markers were fairly consistent across conditions. However, there was a much higher occurrence of visitors demonstrating empathy within the Help Grandma/Invention Challenge relative to the other activities. This may be because Invention Challenge used real-world scenarios, so even in the absence of a specific character to think about, the problems were still issues that somebody might need help with or that would help people in general (e.g. cleaning dirty water or amplifying sound).

To illustrate how empathy markers materialized, one case serves as an example. One visitor (Lexi, a pseudonym) in the guided narrative condition of Help Grandma/Invention Challenge pulled an activity card about inventing something to help a grandmother open jars. Lexi demonstrated the *familiarity* empathy marker when she explained, "my grandma has a hard time (opening jars)." As Lexi used rubber bands, a spatula, nuts and bolts and a metal hook to construct her invention and to show how a grandmother might try to open a jar by demonstrating how her invention may be used, Lexi demonstrated *perspective-taking*. Chain Reaction also called for visitors to design for others – a nearly life-sized, mechanized cardboard cutout of a dog that wagged its tail in response to a Chain Reaction action (e.g. delivering a ball). One visitor (Ava, a pseudonym) began by stating her technical understanding of the challenge: "Oh I get it, you're supposed to connect [the circuit] and it makes the dog move." As she designed, Ava referenced the dog repeatedly, drawing on her prior understanding of dog behavior. She showed *familiarity* when she explained, "dogs usually eat bones and bones are white so I am trying to make it look like that." She demonstrated the empathy marker *affective-user* when she said, "the dog is getting really hungry. . .it's actually having trouble finding its way to the bone because it's so hungry." Ava's participation was driven by the relatable challenge as she described what and why she was making, creating a meaningful context for her activity.

| Empathy markers | Help Grandma/Invention Challenge N (% of obs.) | Chain Reaction N (% of obs.) | Air-Powered Vehicles N (% of obs.) |
|---|---|---|---|
| Total | 38 | 60 | 40 |
| *How designer feels* | 2 (5.3) | 1 (1.7) | 1 (2.5) |
| *Societal issue* | 4 (10.5) | 0 (0.0) | 1 (2.5) |
| *How user feels* | 1 (2.6) | 0 (0.0) | 0 (0.0) |
| *Desire to help* | 11 (28.9) | 2 (3.3) | 2 (5.0) |
| *UCD criteria* | 12 (31.6) | 1 (1.7) | 2 (5.0) |
| *Familiarity* | 15 (39.5) | 6 (10.0) | 3 (7.5) |
| *Perspective-taking* | 18 (47.4) | 11 (18.3) | 5 (12.5) |

**Table 9.** Counts (and percentages) of observed empathy markers within activities at NYSCI

The Help Grandma/Invention Challenge activity had a statistically significant mean difference in engineering practices from the Air-Powered Vehicles activity and also prompted more empathy. This finding supported the idea that empathy could help explain something about the difference in engineering practices.

*Relationships between demonstrated narrative practices, engineering practices and empathy markers and dwell time*

To better understand the relationship between narrative, engineering and empathy, we disentangle the associations from our prior results. Table 10 shows the descriptive relationship between engineering practices, empathy markers and dwell time across data. Demonstrating no empathy corresponded with a mean of 2.3 engineering practices and an average dwell time of 13:20 min. The presence of any empathy (one marker or more as noted on the observation protocol) corresponded to a mean of 4.5 engineering practices across visitors and an average dwell time of 29 min, 49 s. Designing engineering activities to support visitors in demonstrating empathy – even just a little – seems valuable for how they engaged with engineering and how long they stayed with activities.

Overall, at all museums and all activities, the Spearman correlation between the diversity of engineering practices and empathy markers was 0.48 (a moderately strong association). When stratified by condition, the estimated correlation was slightly stronger among visitors at the guided narrative condition (0.53) than at the visitor-generated narrative condition (0.41). Overall, we found that there was a moderately strong relationship between empathy and engineering regardless of condition, museum context and activity. We further explored the relationship of engineering and empathy through a linear regression model with all data with the number of engineering practices as the dependent variable and the number of empathy markers as the independent variable. We found statistically significant linear associations between empathy markers and engineering practices. The details showed that among all visitors, the mean number of engineering practices was estimated to be 0.8 higher among visitors demonstrating one additional empathy marker (95% CI [0.6, 1.1]; $p < 0.0001$). Among visitors at all NYSCI activities, the mean number of engineering practices demonstrated was estimated to be 0.9 higher among visitors demonstrating one additional empathy marker (95% CI [0.6, 1.2]; $p < 0.0001$). The association was not substantively different when the model was adjusted for the condition. This suggests that empathy is a strong driver of cultivating a range of engineering practices.

Additionally, we modeled the number of engineering practices on the diversity of empathy markers and narrative practices in a multiple linear regression across museums ($n = 202$). The diversity of empathy markers and narrative practices were independently associated with the number of engineering practices (Table 11). Overall, our findings suggest that designing for empathy can play a role in deepening engineering engagement.

**Table 10.** Relationship between mean engineering practices, dwell time practices, dwell time and presence of empathy markers across all conditions, activities and museums

| Empathy | Mean empathy markers (0–7 markers) | Mean engineering practices (0–7 practices) | Average dwell time (minutes) | Frequency N (% of obs.) |
|---|---|---|---|---|
| No empathy | 0 markers | 2.3 engineering practices | 13:20 min | 122 (60.4) |
| Some empathy | 1.8 markers | 4.5 engineering practices | 29:49 min | 80 (39.6) |
| Total | 0.71 markers | 3.2 engineering practices | 19:51 min | 202 |

Narrative elements can support empathy while also independently contributing to increased engineering practices.

Observations also showed that like with engineering practices, when participants demonstrated empathy markers, their mean dwell time was higher. To statistically test how much dwell time mattered, linear models were used to assess the association between the number of engineering practices and the number of empathy markers, controlling for visitors' dwell time at the activities. Among all visitors, one additional empathy marker was associated with a 0.3 higher mean number of engineering practices, when comparing visitors with the same dwell time at the activities. The 95% CI for this estimate was (0.1, 0.6), with $p = 0.0009$. This means that even when controlling for dwell time across activities, the difference in engineering practices between those who demonstrated empathy and those who did not was statistically significant. Visitors who demonstrated empathy markers also demonstrated a higher number of engineering practices.

## Discussion and implications

The findings outline the impact of designing for narrative, engineering and empathy across conditions, activities and museums. Activities were designed to evoke empathy through the inclusion of particular materials and narrative activity frames. Overall, the links between engineering and empathy showed that engineering practices are positively impacted when visitors demonstrate empathy. This was the case regardless of whether narrative design elements were explicitly embedded in activities or visitors invented their own narratives. For this study, we focused on observing the relationships between narrative, engineering and empathy. Further studies should look to understand the directionality between constructs and how these factors are informed across diverse contexts and with other populations.

This study highlights the roles of narrative and empathy within constructionist perspectives of learning, providing touchpoints for a more nuanced understanding of objects-to-think-with that integrates thinking about others into domain engagement. The role of empathy as an integral part of domain-related design practice (i.e. engineering) expands current theorizations of design in constructionism. In particular, our results highlight that objects-to-think-with need to evoke opportunities for empathy and interpersonal connections as observed when visitors designed inventions for familiar users, in addition to being connected to domain concepts (e.g. engineering practices) and the possibility to create personally meaningful projects. Acknowledging empathy as part of the constructionist design process promises to broaden epistemological sense-making processes by inviting thinking about others to direct the engagement with domain practices. Including empathy as part of the constructionist design process and conceptualizations of objects-to-think-with invites us to consider how people can make connections between their own interests emotions, and understanding of others when creating artifacts. This further

**Table 11.** Linear regression models of diversity of engineering practices on diversity of empathy and narrative practices

| Variable | Unadjusted estimate (95% CI) | $p$-value | Adjusted estimate (95% CI) | $p$-value |
|---|---|---|---|---|
| *Number of empathy markers* | 0.83 (0.57–1.09) | <0.001 | 0.56 (0.34–0.87) | 0.001 |
| *Number of narrative practices* | 0.94 (0.63–1.25) | <0.001 | 0.54 (0.16–0.92) | 0.006 |

**Note:** CI = confidence interval

clarifies the central role of empathy in engineering and challenges designers of new exhibits and engineering toolkits to leverage empathy to deepen engineering learning.

The present study focused on girls as participants and their engagement with engineering practices in relation to empathy and narrative elements. This does not mean that activities that work for girls would exclude boys. To the contrary, the work is based on the premise that activity designs that are inclusive of girls can generate opportunities for all to engage in domain learning (Buchholz *et al.*, 2014; Letourneau *et al.*, 2021). The findings presented in this study only apply to our study's population of girls. However, anecdotal evidence of museum staff who observed boys engage with the activities supports the hypothesis that the activities could lead to increased design behaviors among boys as well (Cage, 2019; Dancstep and Sindorf, 2018). Thus, future studies that investigate the activities for engineering practices for all are intended.

*Design recommendations for fostering empathy in museum-based engineering activities*

We offer design recommendations as implications for fostering empathy within museum-based engineering activities through activity frames and choice of characters and settings. These design recommendations that center empathy are aimed toward the broader social goal of bringing more people – with a targeted interest in girls – into engineering and, thus to create more inclusive learning spaces.

*Designing for UCD.* Visitors engaged in a higher number of engineering practices with those activities that supported UCD. Inviting visitors to create something to help a character can evoke empathy and support UCD. Our study suggests that when visitors are engaged in thinking about a user in the prompt of the activity, whether offered explicitly or implicitly by the activity design, we observe more empathy markers, which leads to more diverse engineering practices.

*Designing for perspective-taking.* When visitors were able to imagine themselves in the place of a character through perspective-taking, such as a grandma, they could consider multiple solutions. Designing for a range of ways to support perspective-taking can make it possible for visitors to imagine the inner state of the person or group of people for whom they are designing. The example of Lexi in the Help Grandma/Invention Challenge activity speaks to the usefulness of the explicit inclusion of relatable characters to support perspective-taking within engineering activities to cultivate empathy.

*Designing for familiarity.* Informal engineering activities can be designed to cultivate empathy by purposefully choosing activity frames with characters that are connected to familiar experiences and common relationships of museum visitors. One example of this is asking learners to design something to help a familiar character (e.g. pets, grandparents) as an inroad to support girls' engagement in engineering challenges. Small changes to shift design challenges toward situations that are relatable and familiar to museum visitors can cultivate empathy. Other activities developed in this project extended this idea to include opportunities for visitors to invent their own familiar characters whom they could help. Inventing one's own characters may present opportunities for perspective taking and design to help more easily, therefore, to bring about empathy more readily within engineering activities because of the increased familiarity.

Importantly, because the Help Grandma activity had a much higher occurrence of empathy markers compared to the other activities, we imagine that the grandma character and associated narratives were particularly compelling to museum visitors, which may have been due to a number of factors, including the prominence of the display of the grandma cards, the specificity and personal choice of which task to solve (i.e. visitors selected a task from a variety of grandma cards) and the familiarity of the grandma character. In contrast, though the animals were likely familiar, perhaps they did not visually stand out to visitors and the tasks were not as specific or personalized (e.g. get a dog to wag its tail). Future studies could aim to iterate on the design of these activities to better understand how to design for differentiated narratives that are compelling for different audiences within a particular context.

*Designing for the desire to help*. Invitations to help others empowered participants to come up with practical ideas and solutions to alleviate challenges in a person's (or animal's) life. Designing to emphasize the desire to help as a motivator for engineering inventions could foster engagement with engineering in ways that would center empathy.

Collectively, our analysis shows that designing for empathy within museum-based engineering activities can be done through subtle, yet nuanced changes in narrative framing that can have a significant impact on how visitors engage with engineering. Furthermore, we did not find any evidence that suggested empathy precludes visitors from engaging in engineering; on the contrary, empathy was only found to be an additive element contributing to engineering engagement for girls. Overall, we consider that inviting visitors to empathize with others through the use of narrative activity frames can broaden what may be perceived and experienced as engineering and, thus offer more inclusive pathways to participation in engineering design activities in museums.

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## Appendix

| | | |
|---|---|---|
| Exhibit: | | |
| Girl: | Condition: N NN | Interview: Y N |
| Date: | Crowdedness: H M L | Exhibition: __ppl. __groups. __ girls. |
| Exhibition time: | Facilitation: H M L | Group: __ppl. __ girls. |
| Group Composition (start): | | ☐ Changed: |

| Narrative | Quotes and Notes | H-on/ H-off |
|---|---|---|
| ☐ Referencing narrative | | |
| ☐ Elaborating narrative | | |
| ☐ Inventing narrative | | |
| ☐ Inventing user | | |
| Empathy | | |
| ☐ Desire to help | | |
| ☐ UCD criteria | | |
| ☐ How DESIGNER feels (affective) | | |
| ☐ How USER feels (affective) | | |
| ☐ Perspective-taking: Talking about/acting use | | |
| ☐ Familiarity: Prior experience of knowledge | | |
| ☐ Societal issue mentioned | | |
| Engineering | | |
| ☐ Problem scoping: Multiple aspects | | |
| ☐ Solution finding: More than one idea | | |
| ☐ Imagining new projects/possibilities | | |

☐ **Iteration: Implementing improved function (larger cycle)**

☐ **Persistence: Repeating attempts to solve problems with materials**

☐ **Testing**

☐ **Tinkering: elaborating and adding**

**Other practices**

☐ **Adding to prior projects** ☐ **Capturing (also adults)** ☐ **Decorating** ☐ **Joking** ☐ **Showing** ☐ **Singing**

☐ **Close to adults** ☐ **Close to peers**

☐ **Watching materials** ☐ **Watching participants** ☐ **Watching projects/copying**



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