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Using narratives to evoke empathy and support girls' engagement in engineering

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Abstract

Reframing engineering activities to emphasize the needs of others has the potential to strengthen engineering practices like problem scoping, while also providing more inclusive and socially relevant entry points into engineering problems. In this design-based research project, we developed novel strategies for adding narratives to engineering activities to deepen girls' engagement in engineering practices by evoking empathy for the users of their designs. We describe a set of hands-on engineering activities developed through iterative development and testing with 190 girls (ages 7-14) at the New York Hall of Science. Findings show how elements of narrative (like characters and settings) evoked learners' empathy, and how learners' expressions of empathy related to practices like problem scoping and iteration. A set of design principles summarizes critical features of the narrative activities for evoking empathy and supporting the engineering design process. Finally, we offer recommendations for practitioners who would like to use narratives to engage learners in approaching engineering problems from a user-centered perspective. This work has implications for the development of inclusive and engaging engineering activities that appeal to elementary and middle school learners in a wide range of settings.

Using Narratives to Evoke Empathy and Support Girls' Engagement in Engineering

A long line of research has shown that students in general, and girls in particular, are more engaged in engineering when they are invited to solve problems with personal and social relevance (Bennett 2000; Eccles and Wang 2016). Tackling complex, real-world problems also requires understanding the human side of engineering. To design effective solutions, engineers must consider the needs and priorities of the people who will use their designs, as well as the societal and ethical implications of their work (National Academy of Engineering 2004). Yet, engineering education (especially in the early grades) provides few opportunities for learners to define the constraints of engineering problems based on the needs of end users. Instead, engineering problems often use predefined parameters and focus on the objects being designed, rather than the people those objects are being designed for (e.g., build the highest tower). This decontextualized approach can lead many students to opt out of pursuing engineering in favor of career paths that resonate more strongly with their desires to help others. This pattern not only perpetuates inequities in the field; it also does a disservice to those who remain in the pipeline.

One critical step in reframing engineering education is introducing younger learners to engineering as a discipline that involves empathizing with and helping others (Hynes and Swenson 2013; Walther, Miller, and Sochacka 2017). Focusing on the needs of end users makes it possible for learners to practice problem-scoping, a part of the engineering process that is extremely important and considered an essential practice by the *Next Generation Science Standards* (NGSS Lead States 2013). Integrating empathy into engineering education has the potential to open the field to people who have been persistently underrepresented by highlighting the social and emotional aspects of the work that engineers do, counteracting stereotypes of engineering as a masculine, object-focused, and competitive field (Capobianco and Yu 2014).

More research is needed to develop evidence-based strategies for integrating empathy into engineering education for elementary and middle school students. One promising strategy involves using narratives; prior research and development in informal settings has found that narratives can provide real-world contexts for engineering problems and help learners imagine the needs, desires, and intentions of the people involved (Bennett and Monahan 2013). In the present study, we aimed to develop strategies for using narratives to evoke empathy, and to determine whether this approach led seven- to 14-year-old girls to engage more deeply in the engineering design process. This three-year project involved iterative activity development and design-based research conducted by the New York Hall of Science (NYSCI) in Queens, New York, in collaboration with the Scott Family Amazeum in Bentonville, Arkansas; the Tech Interactive in San Jose, California; and the Creativity Labs at the University of California, Irvine.

Drawing on iconic engineering design activities often used in formal and informal education settings (e.g., vehicle design activities), the project team developed six pairs of engineering activities. Each pair included one version of the activity that incorporated a *narrative frame* (a user-centered situation conveyed through narrative elements such as characters, settings, or problems/scenarios), and one that did not use a narrative frame. We iteratively developed and tested the two versions of each activity, gathering observations and conducting semistructured interviews with a total of 190 girls (ages 7–14). We coded these data to identify

- what engineering practices girls engaged in (including problem-scoping, ideation, testing, and iteration),
- the length of their engagement, and

- behavioral expressions of empathy (including emotional responses, taking others' perspectives, and expressing a desire to help).

Researchers analyzed when and how these behaviors occurred. They then compared patterns of findings across the six activities to understand how narrative elements evoked empathy and how experiencing empathy supported engineering practices. A summative evaluation was then conducted on a subset of the activities across the three museums. The evaluation found that empathy was the driving factor supporting girls' use of engineering practices in the narrative condition; girls who expressed at least one indicator of empathy showed longer engagement times with the activities and demonstrated the implementation of more engineering practices (Peppler et al. 2020).

This article summarizes the principles that emerged from our design-based research process, including:

- the aspects of narratives that evoked empathy most effectively,
- how physical materials and facilitation strategies worked together to reinforce narrative frames for engineering problems, and
- the importance of leaving space for learners to decide who they want to help and the problems they want to solve.

Finally, we offer recommendations for educators and activity developers who wish to integrate narratives into their engineering activities to make them more inclusive and engaging.

Context

Activity development took place at NYSCI. NYSCI's mission is to nurture generations of passionate learners, critical thinkers, and active citizens through *Design, Make, Play*—an approach to learning that emphasizes hands-on experimentation and problem-solving (Honey and Kanter 2013). The museum bridges formal and informal education and serves a large school-group audience, welcoming approximately 250,000 students annually through school or other organized groups, and offering free afterschool STEM (science, technology, engineering, and math) enrichment activities to families who live in the local community. This project took place in *Design Lab,* a 10,000-square-foot space that offers hands-on engineering and design experiences to families and school groups. This area was specifically designed to serve teachers who bring their classes to the museum for field trips, as well as teachers who turn to NYSCI for professional development experiences and curricular resources related to engineering and design-based learning. The activities offered in Design Lab were codeveloped by museum staff in partnership with K–12 teachers (called Teacher Design Fellows), incorporating the expertise of exhibit developers, science and engineering experts, education researchers, educators, and facilitators of STEM exhibits and programs. The engineering activities that resulted from this process served as the basis for the current study. By developing and iteratively refining strategies for layering narratives onto these activities, we aimed to create a set of inclusive activities that could be implemented by practitioners at other institutions, and to articulate generalizable design principles that educators could use to add narratives to the kinds of engineering activities that they use in their classrooms.

To develop and test the activities, we observed and interviewed 190 girls (ages 7-14) who participated in either narrative or non-narrative versions of the activities during their museum visits. Data were gathered on weekends and school holidays; based on audience surveys, during these times 31% of museum visitors were white, 22% Hispanic or Latino, 18% Asian or Asian American, 11% Black or African American, 1% Native American, 9% identifying with multiple ethnicities, and 9% preferring not to report their ethnicities. We selected children randomly in order to obtain a representative sample (beginning each observation by selecting the next visitor in the target age to begin the activity after the prior observation was complete).

Figure 1. Examples of narrative-based activities**.** *Top left:* "Help the Pets" included life-sized models of dogs and cats. *Top right:* A sample persona card from "Help Grandma." *Bottom left:* Children create a shelter with dowels and rubber bands in "Emergency Structures." *Bottom right:* One of the terrains used as a testing station in "Around the World."

What did the narrative-based activities look like?

We intentionally incorporated narratives in different ways across the set of activities we developed, varying how narratives were integrated into the activities (through characters, settings, and/or problem frames), whose point of view we asked learners to take (imagining themselves in a novel situation, or in someone else's shoes), and how the narratives were communicated (via materials, facilitation, the name of the activity). This variety allowed us to test which strategies were effective in evoking empathy and supporting engineering practices, and to develop overarching design principles through ongoing prototyping and collaboration between researchers and activity developers.

The activities below were iteratively developed and tested in NYSCI's Design Lab (see Figure 1). In later phases of the project, Amazeum and the Tech Interactive implemented a subset of these activities for the summative evaluation.

- *Dowel Structures/Emergency Structures:* Children use three-foot dowels and rubber bands to construct a stable structure that can fit everyone in their group (non-narrative) or that can protect their group from an earthquake (narrative). In this case, learners take the point of view of their families or their group, by imagining themselves in a novel situation. The narrative is located primarily in the problem framing, and it is communicated by facilitators (who introduce the activity) and materials (signage/written prompts).
- *Chain Reaction/Help the Pets:* Children use a sequence of simple machines to accomplish a goal, such as ringing a bell or landing a ball in a cup (non-narrative), or to take care of a pet by, for example, feeding or playing with it (narrative). Learners take the point of view of a bored or hungry pet. The narrative is located in the characters and problem framing, and is communicated through materials (realistic models of pets, written prompts about problems

learners can solve) and facilitation (introduction to the activity and prompting on how to use various simple machines).

- *Invention Challenge/Help Grandma:* Children design and build models of novel inventions to solve physical challenges, such as lifting a heavy object (non-narrative), or to solve problems that grandparents may face in everyday life, such as carrying groceries or climbing stairs (narrative). Learners take the perspective of a grandmother, a character with a problem, and the narrative is communicated through materials (persona cards with details about the user's preferences and needs), facilitation (verbal instructions), and other learners (via display of learners' inventions).
- *Dropped Calls/Safe Landing:* Children use recycled and repurposed materials to protect a cell phone from a 20-foot drop (non-narrative), or to help an alien or astronaut land safely on a planet (narrative). In both conditions, learners use a cell phone accelerometer app to measure the force of the impact to improve their designs. In the narrative version, learners choose and personalize a character (by naming and/or decorating a picture of the character). Learners take the perspective of their character, and the narrative is communicated through the materials (character cards, a space-themed backdrop near the testing station) and facilitation (verbal instructions and prompting about the characters' needs and safety).
- *Air-Powered Vehicles/Around the World:* Children design a vehicle that can use air to move over different textured surfaces (non-narrative) or that can help them travel around the world over different landscapes (narrative). Both conditions have multiple testing stations with different levels of difficulty (from smooth to bumpy). The narrative condition includes model terrains resembling a tundra, desert, grassland, and forest. Learners take the perspective of themselves in each setting. The narrative is communicated through the materials (the settings

depicted at the testing stations) and facilitation (verbal instructions/prompts about what learners might need in each place).

- *Light and Shadow/Shadow Stories:* Learners create effects with light and shadow (non-narrative) or create shadow puppets and scenes (narrative) using everyday materials. In this activity, we explored ways of allowing learners to create their own narratives by building characters and/or settings. The narrative is communicated by learners themselves (through the shadow puppets and backgrounds they create) and materials (through scenery added by facilitators).

How did narratives support empathy and engineering engagement?

To analyze our data, researchers coded observations and interviews to identify specific indicators of empathy that arose during the activities; the coding schemes were based on previous research (Walther et al. 2017). These indicators included:

- emotional responses (such as concern or compassion for the users of a design),
- cognitive perspective-taking (imagining what it would be like to experience a problem or use a designed solution), and
- prosocial behaviors (such as wanting to help).

We also coded which engineering practices learners engaged in throughout the activities, including:

- *ideation* (generating potential solutions to a problem),
- *problem-scoping* (defining the constraints of the problem),
- *testing* (trying out a completed design or part of a design to see how it functions),
- *iteration* (revising a design based on some form of feedback).

We then analyzed individual observations and interviews in detail to understand how expressing these indicators of empathy supported different parts of the engineering process, and synthesized patterns that emerged across our dataset.

We found that the narrative-condition activities prompted girls to engage in user-centered thinking during problem-scoping, and while testing and iterating their designs (e.g., considering the user's comfort or feelings, imagining how someone would use the design, adding features to make designs safer or more convenient). We also observed them alternating between emotionally connecting with the problem and using more analytic problem-solving to work with materials and decide on solutions—a process that has been termed "mode switching" in research on user-centered design (Walther et al. 2017). For example, in the Help the Pets activity, children designed a contraption using simple machines and repurposed objects to take care of a dog or cat (represented by life-sized models of different animals). We frequently observed girls empathizing with pets who looked "lonely" or "sad" before beginning to build. While building, however, they tended to focus on perfecting the mechanics of each step, troubleshooting and adjusting individual pieces. Then, while testing whether their contraption worked or not, they often shifted their attention back to the pet and its feelings. In interviews, children often described wanting to make the pet happy as the primary problem they were trying to solve, rather than wanting to use a specific object (which children were more likely to mention in the non-narrative condition that lacked the pet props). This contrast shows that, when they were given the opportunity to do so, empathizing with the users of their designs was the most salient aspect of this engineering challenge for girls, and that this context helped them persist in completing their designs. An independent summative evaluation confirmed that when girls expressed at least one indicator of empathy, they engaged in a greater range of engineering practices (Peppler et al. 2020).

Design principles: Critical features of narrative-based activities

By analyzing when and how specific behaviors occurred, we examined which qualities of the activities affected how often and how deeply learners expressed empathy and engaged in engineering practices. We used ongoing data analysis to adjust the design of individual activities and observed the impact on learners' behavior. This process allowed us to identify critical features of each activity that evoked empathy and supported the engineering design process. We then compared the findings across the six pairs of activities to develop and refine design principles for creating evocative narratives. The key ideas that emerged from these analyses are summarized below.

Integrate characters and settings into design problems to evoke empathy in different ways

Depictions of characters representing end-users were most effective in evoking empathy, as compared to settings and narrative-problem frames alone. Characters tended to evoke emotional expressions of empathy such as concern, as well as expressions of a desire to help; these were powerful motivators for children to begin tackling the design problem and to improve their designs. For example, in Help Grandma, children were introduced via persona cards to characters who had different everyday problems (for example, one kept losing her glasses, and another needed help carrying groceries). These cards included an illustration of the person, as well as information from a first-person perspective about her daily routine and preferences. After reading these descriptions, children often empathized with Grandma's emotions (mentioning her frustration, for example) and took her perspective when describing how she might use the designs they created (for example, adding features to make their designs more comfortable or convenient).

Settings did not evoke as broad a range of empathic responses when used on their own (as in Air-Powered Vehicles), compared to when they were combined with characters (as in Safe Landing). However, settings did prompt perspective-taking, in which children used aspects of the setting to imagine what it would be like to experience a problem or use a designed solution there. For example, in Air-Powered Vehicles, children designed vehicles to travel across different terrains, and sometimes described what someone might want or need in a desert or on an arctic tundra when creating their designs (for example, adding protection from the Sun). Settings also invited girls into activities and sparked their interest. Observations of girls engaging in Air-Powered Vehicles, for example, showed that children were more enthusiastic and less hesitant to begin activities when the terrains were visible within the space. These findings suggest that using characters alone or in combination with setting was an effective strategy for evoking a wide range of empathic responses and supporting engagement in engineering practices.

Provide choice in defining users and their problems

We found that it was important for narrative versions of the activities to provide options that allowed children to choose who they were designing for and/or the problems they could solve, rather than use narratives that relied on a single user or situation. For example, in Help Grandma, children could decide whom they wanted to help from a group of six possible characters with different names and different problems. In Safe Landing, children designed a way to protect a space traveler landing on the surface of a planet. Children chose their own character from a set of illustrated astronauts and aliens, and personalized their chosen character by giving their character a name. When children dropped their designs, which had their characters on board, from a 20-foot ledge, they often expressed concern that their characters might be injured. Children were thus motivated to make their designs "safer" by adding padding or parachutes to slow the descent. In other instances, we found that providing a starting point for a story supported problem-scoping by encouraging children to elaborate on the provided characters and the problems those characters were facing. In Emergency Structures, children designed a large-scale structure to protect themselves and their family members from an earthquake. This activity prompted children to discuss what features they needed their dwellings to have (one group created separate rooms for each person in their family, for example). These open-ended ways of anchoring a narrative without overprescribing it increased girls' overall engagement and their expressions of empathy, as they were more invested in narratives that they had a hand in creating and defining. In particular, giving learners a choice in defining who they were designing for encouraged problem-scoping, a critical part of the engineering design process that is often neglected in engineering activities.

Reinforce narrative frames with materials and facilitation

The facilitation and materials were both critical in reinforcing the narrative frames and using them to constructively guide the design process. Facilitators used the narrative to introduce the problem, setting the stage for children to further elaborate on and define it. The narrative also prompted problem-scoping and iteration, reminding children to think about who would use their design or to imagine themselves in the situation at hand. These conversations provided many opportunities for children to identify other aspects of the problem or features they could add to make their designs more user friendly. In addition, having visible, physical reminders of the design problem from the user's point of view was helpful in keeping children focused on the needs of the users of their designs. For example, in Help the Pets, when the animal models wore collars that suggested some possible problems ("I'm hungry!" or "I want to play!"), we observed children mentioning the pets' feelings when starting to build. When children worked on designs in Help Grandma with the persona cards in front of them, we observed them referring to this information to guide their design decisions.

Materials were also carefully edited so that they did not distract from the engineering problem at hand. For example, in Emergency Structures, the engineering problem focuses on stability and structural engineering. We first tested a narrative frame involving a hurricane, with tarps and fans to set the scene, but this was abandoned by the project team because children became focused on covering their structures to block the wind, rather than on the stability and size of what they were building. The result was that many children made small tents that were easy to cover, and we did not observe much divergence or iteration in the process of creating them. Asking children to protect everyone in their group from an earthquake focused their efforts on creating larger, more stable structures, which in turn resulted in greater divergence in the structures and solutions we observed. This example shows the importance of aligning the narrative frame and the materials provided with the engineering practices that activities are meant to support.

Recommendations for creating narrative-based engineering activities

Narrative elements were effective in evoking empathy and deepening engagement with critical aspects of the engineering design process, such as problem-scoping and iteration—

practices that are advocated for by the *NGSS*, but are not always easy to support in the classroom. Our findings offer strategies that educators and activity developers can use to develop their own narrative-based engineering activities by layering elements of narrative onto the engineering challenges they are already using in their learning environments. This project offers many practical suggestions for how to approach this process, as well as critical questions to consider:

1. *What are the parameters of the engineering problem? What types of engineering concepts are we aiming to support?* Identifying the crucial aspects of the engineering problem (such as stability and fit in the Emergency Structures example above) and working backward to find an evocative human or real-world analogy was the most successful approach for finding a workable narrative frame. In addition, we left room for problem-scoping and divergent solutions by ensuring that narratives were open-ended and not overly constrained.
2. *Does the narrative frame lend itself to a character, a setting, or both?* All of our narrative activities involved a shift in the framing of the problem, but characters and settings could be used alone or in combination with one another to reinforce the narrative posed in the problem framing. If selecting a setting on its own, however, consider how to make the setting more evocative and how it might convey a user-centered problem.
3. *Should narrative elements be realistic or fantastical?* Our activities included examples of both realistic and whimsical scenarios, and we found that both can be effective for evoking empathy. A more important consideration was choosing narrative elements that had a broad appeal without adhering to gendered stereotypes (for example, designing for pets or for traveling around the world).

4. *Whose point of view will learners take? Are they imagining themselves in a novel situation or taking the perspective of someone else?* Although empathy involves considering someone else's needs, designing for oneself can also be engaging and approachable for younger children, who are still learning to take other points of view. Asking them to think about their families or friends (as we did in Emergency Structures) helped broaden children's thinking beyond their own needs while keeping the problem personally relevant.
5. *How will the narrative be communicated? Is the narrative frame established through the materials, facilitation, children's own work, or name of the activity itself?* As described above, materials and facilitation did not have to be heavy handed to support children's engagement with the narratives. Subtle and open-ended narratives, rather than fully elaborated storylines, provided a starting point to spark ideas and conversations at each stage of the engineering design process. We chose materials and prompts that allowed for divergent solutions and supported learners' agency in defining problems to solve.

Implications for broadening participation and engagement in engineering

With the inclusion of engineering design in the *NGSS*, there is a critical need for evidence-based strategies for presenting engineering in ways that appeal to a wide range of learners in elementary and middle school, when students establish early interests in STEM. In this study, narrative-based activities that evoked girls' empathy were approachable and engaging, and directly supported engineering practices such as problem-scoping and iteration. The findings have practical implications for educators seeking to reframe engineering activities they are currently implementing. The value of light-touch, open-ended narratives in this study shows that changes to existing activities do not need to be elaborate to have a meaningful and measurable impact on girls' engagement. Providing visual representations of end users and their problems, allowing children to choose whom to help and how, and using the narrative frame to scaffold each step of the design process were effective in evoking empathy and engaging learners in considering the users of their designs. These are strategies that could be implemented in a variety of education settings, but are particularly needed in formal classrooms, where students often encounter engineering problems that are highly constrained and separated from personal and social contexts. This project provides strategies for centering the human dimensions of engineering, inviting more learners into the field and better preparing students to solve engineering problems in complex real-world settings.

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