Using Narratives to Support Empathy and Engineering: A Guide for Museum Practitioners

New York Hall of Science

Project Team and Acknowledgments

This project was a collaborative effort that brought together a team of activity developers, educators, and researchers from four informal learning institutions.

The New York Hall of Science (NYSCI) led activity development and research efforts. NYSCI is located in Queens, NY, in one of the most diverse counties in the U.S., and is recognized for developing, studying, and implementing inclusive STEM learning experiences. Activities were developed and tested in NYSCI's Design Lab space, which includes four areas for hands-on engineering design activities and serves as a laboratory for research on STEM learning.

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The Tech Interactive, located in San Jose, CA, contributed to activity development throughout the project, and tested activities with their audiences. The Tech Interactive's mission is to inspire the innovator in everyone, offering hands-on activities, experimental labs, and design challenge experiences that empower people to solve problems with creativity, curiosity, and compassion.

Partners: *Prinda Wanakule, Lauren Cage, Katherine Ozawa*

The Scott Family Amazeum, located in Bentonville, Arkansas, contributed to activity development and tested activities in its 3M Tinkering Hub, a creative workshop space emphasizing engineering design, where guests are inspired to create something uniquely their own. The Amazeum's hands-on and learning spaces engage visitors with the land, industries, and people who built Arkansas and sustain it today.

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Creativity Labs at University of California, Irvine, directed by Kylie Peppler, served as the external evaluator for the project. Creativity Labs brings together educators, designers, artists, and learning theorists interested in supporting learning by leveraging youths' interests in digital culture, design, and making.

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HOW TO USE THIS GUIDE

This guidebook is designed for informal educators and activity developers in museums and after school settings, and K – 12 educators interested in creating more inclusive hands-on engineering design experiences for children and youth, especially those who may not think of themselves as "engineers," "makers," or "techies." Making engineering more inclusive requires considering how to support all types of learners in identifying problems they find worth solving, and providing opportunities for them to generate design solutions that build on their unique perspectives and life experiences. The intention behind our work was not only to open up pathways into engineering for more young people, but also to begin to make engineering as a whole more reflective of the needs, interests, and perspectives of those who have been consistently left out of the discourse on engineering and innovation.

The guidebook highlights lessons learned from our design-based research project, funded by the National Science Foundation and conducted in three museums that have dedicated, drop-in spaces for engineering activities. We investigated the idea that the empathy evoked by narratives can invite a broader audience of learners into engineering. We focused on girls ages 7 – 14, in response to mounting evidence that engineering education provides few opportunities for this group of learners to use social and emotional ways of thinking as an entry point into the engineering design process. The heart of our work involved developing, testing, and iteratively refining six engineering activities that used narrative to provide a human context for engineering problems. Challenging tried and true ways of framing engineering design activities, we reimagined activities in ways that would prioritize empathy and care for others. By focusing on how girls interpreted and responded to these narrative-based activities, we were able to surface low-cost but high-impact strategies for fostering empathy and deepening girls' engagement in engineering practices. This guidebook contains practical advice for developing more inclusive and effective engineering design experiences that emerged from this process.

We hope the resources offered within this guidebook will inspire you to create your own narrative-based engineering activities, or to adapt your existing activities by adding narrative elements. To support you in this process, we describe the research-based framework that guided our thinking about the role of narratives and empathy in the engineering design process, as well as activity examples, practical strategies, and tools that you can use in your own work. The guide is organized in the following sections to help you on your way to providing inclusive design experiences.

About the Project provides a summary of our goals, driving concepts, activity development process, and key research findings. It includes the evidence we gathered as we tested different approaches to integrating narrative into engineering activities, and the impact narrative and empathy had on girls' engagement.

Design Principles offers questions to ask and strategies you can use to guide you in integrating narrative effectively into your own engineering design activities for children, youth, and families.

Facilitation Guidelines offers high level facilitation strategies educators can use to leverage narratives in engineering activities to support empathic thinking and engagement in engineering design practices.

Documenting Indicators of Success includes an observation tool with behaviors to look for, and follow-up questions to ask learners as you develop and test your own activities. You can use these tools to record whether learners are expressing empathy and using specific engineering design practices, and identify opportunities to strengthen your activity designs.

Six Activity Case Studies offer examples of what our activity development process looked like — how we added narratives to each activity, what we noticed throughout our testing, troubleshooting we needed to do to make sure narratives were not distracting or confusing, and the decisions we made to strengthen empathy and engineering practices.

Why reimagine engineering education?

Women and people of color remain significantly underrepresented in engineering courses and careers (NSF, 2019). Research over the past twenty years has shown that this is in part because of how engineering is taught. Engineering activities often present engineering as predominantly about "working with things" rather than "working with people" (Capobianco & Yu, 2014; Su & Rounds, 2015). This leads many learners, particularly girls and women, to the conclusion that engineering is impersonal and disconnected from their interests and the communities they care about (Ceci & Williams, 2010; Diekman et al., 2010). This work highlights the need to rethink how engineering is presented in order to invite more diverse identities and points of view into the field.

On a parallel track, recent advances in research and educational policy advocate for more human-centered approaches to engineering education that place others' needs at the center. Researchers argue that social and emotional skills like empathy are a critical but often neglected part of engineering education (Walther et al., 2017; 2020). In order to tackle real-world problems with societal and ethical implications, engineers must understand the perspectives of clients and colleagues whose experiences might differ from their own (Hynes & Swenson, 2013). Reframing engineering to prioritize empathizing with and helping others has the potential to connect to the lived experiences of a much broader audience of learners, while also strengthening the skills that engineers need to tackle a broad array of complex problems.

In this project, we focused specifically on girls' experiences in response to these bodies of research. This work suggests that girls' needs and interests are not currently being met by traditional approaches to engineering education, and that what may be missing is an intentional emphasis on the intersections between the things being designed and the people involved. Social and emotional skills are vital tools for learning, not only for girls but for all learners. Inspired by universal design for learning approaches, we believed that expanding our approaches to activity development with girls' needs and interests in mind would also support many other groups of learners who tend not to be engaged by traditional engineering challenges. Nurturing empathic and human-centered approaches to the design process can provide new invitations into engineering, ensuring that the broadest possible audience of learners can access and engage in engineering practices in personally meaningful and effective ways.

In recent years, researchers and educators in museums and other informal learning environments have explored ways of using narratives to create these kinds of invitations. This work suggests that using characters, settings, and narrative descriptions of engineering problems can provide evocative contexts that engage learners in thinking about who they are designing for and why (Bennett & Monahan, 2013). Yet more research is needed to help practitioners and developers understand how narratives can be integrated into engineering activities in effective ways. By developing narrative-based activities and documenting their impact, we hope our findings will help expand how the engineering design process is framed and enacted, welcoming a wider range of voices and perspectives.

Driving Concepts

In this project, we drew on research across fields to understand how we could use narratives to evoke empathy and support specific engineering design practices.

Narrative

Narratives are a fundamental mechanism for meaning-making and cognition. We use stories and storytelling to make sense of our own experiences and to integrate new ideas into our understanding of the world (Bruner, 1986; Clark, 2010; Egan & Judson, 2015). Narratives tend to have multiple common elements: characters, settings, a point of view, and a plot or problem frame — a conflict that must be resolved. These elements of narrative can evoke empathy by prompting learners to imagine others' perspectives, intentions, and feelings. In addition, narratives invite learners to extend the story or fill in details based on their own imaginations and prior experiences (Bruner, 1986; 1991). Both aspects of narratives can help learners make personal connections to engineering problems. In fact, engineers and designers use narratives in their professional practice — to understand design problems from their clients' perspectives and generate creative solutions that meet others' needs (Grimaldi et al, 2013; Hunsucker & Siegel, 2015). In this project, our goal was to layer narratives onto our existing engineering activities in open-ended ways. Rather than using these elements to create detailed or constrained storylines, we left room for learners to use their imaginations to elaborate on the situations we presented and the problems that could be solved.

Empathy

Humanistic approaches to engineering education argue that engineers must empathize with their clients and other stakeholders in order to design solutions that meet their needs. Research across fields has shown that empathy itself is multifaceted and includes three related processes (Batson, 2009; Decety & Jackson, 2004; McDonald & Messinger, 2011):

- Affective or emotional responses, which include emotional contagion (e.g., contagious laughter or sadness) and expressing compassion or sympathy. In engineering activities, this may involve expressing concern or compassion for the users of a design.
- Cognitive perspective-taking, which involves imagining someone else's point of view. In engineering tasks, this can involve imagining what it would be like to experience a problem or use a designed solution.
- Prosocial behaviors, which involve altruism and taking action to help others. This could include expressing or acting on a desire to help someone in an engineering challenge.

Throughout this project, we focused on using narrative elements to evoke one or more of these facets of empathy, providing a range of ways for learners to consider others' needs throughout the design process.

Engineering design practices

According to ASEE's Framework for P-12 Engineering Learning (2020), engineering education in the elementary and middle school grades focuses on developing key habits of mind and engineering practices that can support children in learning more complex forms of engineering knowledge and professional practices. In this project, we targeted engineering design practices that are advocated in national and state-level standards (NGSS, 2013). Engineering design is a cyclical process of defining a problem and iteratively building and improving solutions (ASEE, 2020; NAE, 2019). Although there are many skills that are involved in engineering design, in this project we observed whether girls engaged in any of the following key practices in our activities:

- Ideation: generating potential solutions to a problem
- Problem scoping: defining aspects of the problem that the design should address
- Testing: trying out a completed design or part of the design to see how it functions
- Iteration: revising a design based on some form of feedback or testing

Research Questions and Approach

We brought together these bodies of work to investigate how we might leverage narratives to support engineering learning for our target audience (girls 7 – 14). First, we explored how narratives could be layered onto informal engineering activities. We focused on a few narrative elements that could be readily added to activities and combined in different ways (character, setting, problem frames). Within these elements, we also explored subtler variations (such as taking different points of view, using realistic vs whimsical scenarios), and strategies for communicating them within the activity design (through materials, facilitation, props). Second, we asked how narrative-based activities could evoke empathy, and which aspects of empathy we might observe. Finally, we wanted to better understand how narratives and empathy influenced the ways girls approached engineering problems, and the practices that they were using to define the problem, generate ideas, and test and iterate solutions.

Driving Concepts and Research Questions

Narrative Elements

- Characters
- Settings
- Problem frames

How can narrative elements be integrated into engineering activities?

Empathy

- Affective
- Cognitive
- Prosocial

How can narratives evoke different facets of empathy within engineering activities?

Engineering Design Practices

- Problem scoping
- Ideation
- Testing
- Iteration

Do narratives and empathy support girls' engagement in engineering design practices?

Activity Development Process

We used a design-based research process to answer our research questions. In design-based research, researchers and practitioners work together to iteratively develop a new learning experience. In the process, the team tests and revises both the design of the experience and their understandings about how and why certain design choices work. This project brought together a collaborative project team that included activity developers, facilitators, and researchers at NYSCI, as well as educators, designers, and researchers from our partner sites. Together, we drew on prior research and practice-based knowledge about how to create open-ended and engaging learning experiences. Past and recent studies have documented qualities of museum experiences that can support engagement among museum visitors (Humprey & Gutwill, 2016), and girls in particular (such as the EDGE project at the Exploratorium, conducted by Dancstep & Sindorf, 2018; and prior research at Children's Museum of San Jose by Crowley et al., 2001 and Callanan, Frazier, & Gorchoff, 2015). This work suggested strategies that we could explore in the context of informal engineering activities. We also grounded our work in the expertise of educators and activity developers about how to welcome and support visitors' learning in informal engineering spaces. Though each of our institutions has a unique mission, we all value experiences that invite visitors to tinker and experiment, and that support learners' agency in solving problems that they define for themselves.

From this starting point, we identified promising drop-in activities that were already being run in our museums, and classic engineering challenges that could be reimagined and updated. We discussed how narratives could be added to these activities in feasible ways that allowed room for divergent thinking and creativity. NYSCI's activity development and research teams worked together to develop initial prototypes. Next, we prototyped the activities with visitors in NYSCI's Design Lab exhibition, focusing on our target audience of girls ages 7 – 14. We conducted observations and interviews, and debriefed with facilitators and activity developers after each testing session to talk about how visitors were engaging with the narratives, whether and how the activities were evoking empathy, and how the activities were supporting engineering practices. We iteratively revised each activity based on these findings, documenting the changes we made to strengthen and refine narrative elements. We also met monthly with project partners and yearly with project advisors to discuss emerging findings and make final tweaks to the activity designs.

Over the three-year project, we used this process to develop six activities that incorporated narratives in many different ways. Narrative elements included problem frames (e.g., designing a structure to protect yourself from an earthquake), characters representing the end users of a design (e.g., asking learners to design something for a grandparent or a pet), and settings in which designs would be used (e.g., an alien planet, landscapes, or habitats). We also communicated the narratives in a range of ways — through materials that evoked the idea of a "client" or real-world scenario, through facilitation prompts, signage, or the name of the activity, or through the creations that other visitors created and left behind. By combining these elements in intentional and unique ways, we investigated how narratives could be seamlessly integrated into different types of engineering activities.

Finally, we compared the narrative activities with non-narrative versions that involved similar materials and engineering goals, but lacked the narrative elements. NYSCI researchers conducted interviews and observations with 190 girls (ages 7 – 14) who participated in either the narrative or non-narrative condition in Design Lab, and Creativity Lab researchers observed over 200 girls across the three museum sites involved in the project (Peppler, Keune, & Dahn, 2020). This allowed us to determine how the addition of narratives affected the ways girls engaged with engineering challenges.

Key Research Findings

By comparing narrative and non-narrative activities, we found that the addition of narrative elements (like choosing a character to focus on in your design) evoked empathy in many different ways — learners often expressed a strong desire to help others with their designs, showed compassion and emotional connection with those they were trying to help, and imagined how someone might use a designed solution (Letourneau et al., 2021). Narratives also deepened girls' engagement throughout the engineering design process. We observed that girls used more engineering practices in the narrative than the non-narrative condition. In particular, girls were more likely to engage in problem scoping and iteration when activities had a narrative framing (Letourneau & Bennett, 2020). We also found that empathy was the driving factor in these findings — when participants expressed empathy, they stayed longer and used a greater range of engineering practices (Peppler et al., 2020).

By analyzing the qualities of the narrative-based activities that allowed them to successfully evoke empathy and foster girls' use of engineering practices, we identified design principles that could guide future activity development efforts. These principles are described in the next section to guide you in developing or adjusting your own activities.

By analyzing the iterative revisions we made to the activities in response to our observations, our project team identified specific strategies for integrating narratives in effective ways. We also learned that narratives can sometimes "break" the activities — either by hindering visitors' creativity or by limiting the engineering practices that they were engaged in. The design principles below summarize the lessons learned from this work. These principles can guide you in creating or adapting your own narrative-based engineering activities. We also include a range of strategies to choose from when implementing each principle, and examples from the set of activities that we developed. The activity case studies that follow provide more details that show each strategy in action.

1. Start with engineering goals.

What are the parameters of the engineering problem? What types of engineering concepts and practices are you aiming to support?

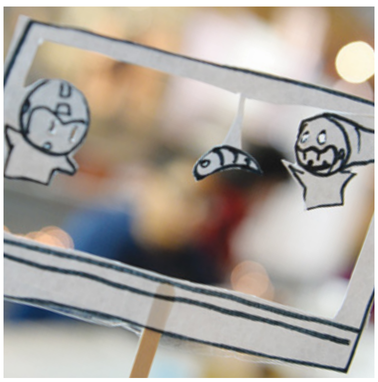
In our activity development process, we brainstormed many possible narratives that could be added to each engineering activity. In testing out different options, we found that in some cases, the narratives could overshadow the core engineering concepts and practices in the activity. When this happened, we noticed that learners were interested in the narratives but were not necessarily using engineering design practices or thinking about key parameters of the engineering problem. In these cases, we took a step back and refocused on the engineering goals at the heart of the activity, which could be concepts like gravity, weight, balance, stability, as well as our core engineering design practices (ideation, problem scoping, testing, and iteration). We then worked backwards to find an evocative human or real-world analogy that gave learners a compelling reason to use the concepts and practices that we wanted to support. When adapting your own activities, consider what kind of learning outcomes are most important in your setting and with your audience.

Strategies and examples from our activities

- *Emphasize central parameters of the engineering problem:* Some of our activities involved specific kinds of engineering challenges, such as building stable structures (see the Emergency Structures case study for an example), using wind power (see Around the World), or protecting a falling object (see Safe Landing). We chose narratives that would keep learners focused on these key ideas as they created and iterated their designs.
- *Emphasize key engineering design practices:* Other activities primarily focused on the engineering design process, rather than any specific engineering concept (see Help Grandma, Help the Pets, and Shadow Stories as examples). These activities foregrounded practices like scoping out a problem from a user's point of view, generating creative solutions, and iteratively changing a design.

2. Use characters and settings to evoke empathy in different ways.

Does the activity lend itself to adding a character, a setting, or both? How can learners relate to these narrative elements and design with them in mind?



All of the narrative activities that we tested involved a shift in the framing of the problem, but most activities used characters and settings either alone or in combination with one another to support the narrative posed in the problem framing. We found that characters were most effective in evoking emotional expressions of empathy, which was a powerful motivator for learners to engage in problem scoping and iteration to plan and improve their designs. Settings were beneficial in inviting girls into the activities and supporting perspective-taking, and combining both characters and settings tended to evoke empathy in multiple ways. That said, some activities naturally lent themselves to adding characters rather than settings, or vice versa. We recommend experimenting with different strategies to see what works best for the activity you are developing.

Strategies and examples

- *Use characters to evoke emotional aspects of empathy:* Some of our activities involved sympathetic characters (see Help the Pets and Help Grandma), which focused learners on others' needs and the problems that characters were facing.
- *Use settings to provide an invitation in and evoke perspective-taking:* Settings prompted learners to think about where their designs might be used and imagine what it might be like there (see Around the World for an example).
- *Combine characters and settings to evoke empathy in multiple ways*: Using both strategies helped reinforce the narratives and evoked multiple facets of empathy (see Safe Landing and Shadow Stories).

3. Choose a point of view.

Whose point of view do you want learners to take? Are they imagining themselves in a novel situation, or taking someone else's perspective?

Because empathy involves understanding how others feel, many of our activities asked learners to design something to help someone else. This prompted learners to imagine the problems others were facing and what they might need, want, or like. For younger children, who are still learning to take other points of view, designing something for themselves was also an approachable entry point. In these cases, we asked learners to imagine themselves in a novel situation (like surviving an earthquake, or traveling through a desert), and think about what it would be like and what they might want or need in that situation. Asking children to include their families or friends was also helpful in broadening their thinking beyond their own needs while keeping the problem personally relevant. As you develop activities, think about whose perspective learners might imagine, and how that might motivate them to solve the problem.

Strategies and examples

- *Taking someone else's perspective:* Activities that involved someone else's point of view typically involved characters who needed help in some way (see Help Grandma, Safe Landing for examples).

- *Imagining yourself in a novel situation:* Other activities invited learners to design something for themselves, but presented novel or real-world situations to think about (see Emergency Structures, Around the World).

4. Use the narrative to spark learners' own ideas.

How can the narrative tap into learners' prior knowledge and imagination? Should narrative elements be realistic or fantastical?

In developing our activities, we used narrative elements as a way to connect to and build on learners' own ideas, and experimented with framing engineering problems in either realistic or whimsical ways. Prior research suggests that both strategies can support girls' engagement with STEM — realistic narratives can leverage learners' past experiences and cultural practices, while whimsical situations can invite creative approaches to problem solving and support girls' interest and engagement. More important was finding narratives that were approachable to most learners, without adhering to gendered stereotypes. We found that both realistic and fantastical narratives provided compelling entry points into the engineering design process that aligned with other learning experiences in our museums. You can experiment with different types of narrative scenarios, depending on your educational goals and audiences.

Strategies and examples

- *Realistic problems, characters, or settings:* Some of our activities involved realistic characters or settings that learners could consider in their designs (see Emergency Structures, Help Grandma for examples)
- *Using whimsy to spark imagination:* Other activities used fantastical characters (see Safe Landing), or familiar characters and whimsical uses of materials to solve the problem (see Help the Pets).
- *Leaving the content open:* In some cases, learners were invited to tell their own stories through their designs, leaving room for stories to be either realistic or whimsical (see Shadow Stories, Around the World).

5. Provide choice in defining users and their problems.

Is there room for learners to decide who to help, what problems to solve? Can learners elaborate on the narrative to make it their own?

The word "narrative" often suggests a complete story, but we found that open-ended elements of narrative, rather than fully elaborated storylines, helped inspire ideas and invite conversations at each stage of the design process. When narratives were too constrained, we noticed that the problems learners were solving and the designs they came up with were very similar to one another — there was little problem scoping and ideation taking place. We focused on providing ways for learners to decide who they were designing for and the problems they could solve, rather than using narratives that relied on a single "client" or that suggested a single solution. These open-ended ways of anchoring a narrative without overprescribing it increased girls' engagement in engineering practices (particularly problem scoping) as well as their expressions of empathy for users that they intentionally chose or created. We recommend using narrative elements to provide a context for the engineering problem, while using one of the strategies below to leave space for learners to make choices based on their interests.

Strategies and examples

- *Choosing from a set of problems or users to design for:* Some activities provided multiple options for different users, settings, or problems that learners could choose to focus on with their designs (see Help the Pets, Help Grandma, Around the World for examples).
- *Personalizing or inventing a character:* Others invited learners to invent or personalize a character to help (see Safe Landing).
- *Elaborating on a narrative or telling your own story*: In some activities, we either explicitly invited learners to tell a story with their designs (see Shadow Stories for an example), or the narratives encouraged learners to extend the story through role playing and imaginative play (see Emergency Structures).

6. Reinforce narratives with both materials and facilitation.

Is the narrative frame established through the materials, facilitation, the work that learners create and leave behind, the name of the activity, or some combination?

Materials and facilitation do not have to be heavy-handed to support learners' engagement with narratives, but we found that it was helpful to include reminders at multiple points throughout an activity so that learners were prompted to consider who they were designing for while planning, building, and improving their designs. Our activities incorporated visible, physical reminders of users and their problems, and facilitators used the narrative frame to introduce the problem and encourage learners to imagine who would use their design. In some situations, we provided opportunities for learners to leave their designs behind as inspiration for others, and this showed how different visitors interpreted and extended the narrative. Finally, the names of the activities, which were usually posted outside of our spaces, often referenced the narrative and invited visitors to help someone with their designs. Feel free to experiment with combining different strategies to communicate and reinforce the narrative, being sure to include both verbal and visible reminders.

Strategies and examples

- *Materials represent characters:* See Help the Pets and Help Grandma for examples of visuals and props that represent the users of a design.
- *Materials represent settings:* See Safe Landing and Around the World for examples of activities that use backdrops or scenery to create a setting for engineering problems.
- *Facilitators reference the narrative:* See Facilitation Strategies section, and all activities for examples of facilitation prompts that leverage narratives.
- *Examples of others' work are available as inspiration:* See Help Grandma and Shadow Stories for activities that put learners' work on display.
- *Name of the activity references the narrative:* All of our activities had names which referred to the narrative in some way.
- *Signage summarizes the narrative problem frame:* See Emergency Structures and Safe Landing for examples of different ways you can use signage to convey the problem.

7. Test, observe, and iterate.

Do learners talk about the narratives or elaborate on them? When and how do they express empathy? Which engineering practices do they use, and how often?

In order to tell whether our narrative-based activities were "working," we watched how learners approached the activity and talked with them about how they solved the problem and what they were thinking about. To determine if the narratives that we chose were engaging, we observed whether girls talked about the narratives we suggested, elaborated on them or created their own narratives. To see if the narratives evoked empathy, we looked for each of the three facets of empathy, how they were expressed, and what prompted them. We also noted whether the activities supported a range of engineering design practices. Sometimes we found that the design of the activity needed to be adjusted to evoke empathy more strongly, or to provide more opportunities or guidance to support specific engineering practices like problem scoping or iteration. Our observations helped us tweak the activities and understand how well the narratives were working. You can use the Observation Tool and Follow-up Questions in this guide to observe and refine activities that you are developing.

Strategies

- *Observe while learners engage in the activity:* Note indicators of engagement with the narrative, expressions of empathy, and use of engineering practices (see the Observation Tool in this guide)
- *Talk to learners while they're working on their designs or afterward:* Asking learners questions about who their design is for and how it works can reveal whether they are considering others' needs while solving the problem (see Follow-up Questions).
- *Adjust materials, facilitation prompts, or the narrative frame:* Based on your observations, make changes to further support empathy and scaffold engineering practices. Revisit the Design Principles and strategies above as needed to decide what changes to make.

DESIGN PRINCIPLES	STRATEGIES
Start with engineering goals. What are the parameters of the engineering problem? What types of engineering concepts and practices are you aiming to support?	Emphasize central parameters of the engineering problem Emphasize key engineering design practices
Use characters and settings to evoke empathy in different ways. Does the activity lend itself to adding a character, a setting, or both? How can learners relate to these narrative elements and design with them in mind?	Use characters to evoke emotional aspects of empathy Use settings to provide an invitation in and evoke perspective-taking Combine characters and settings to evoke empathy in multiple ways
Choose a point of view. Whose point of view do you want learners to take? Are they imagining themselves in a novel situation, or taking someone else's perspective?	Take someone else's perspective Imagine yourself in a novel situation
Use the narrative to spark learners' own ideas. How can the narrative tap into learners' prior knowledge or imagination? Should narrative elements be realistic or fantastical?	Use realistic problems, characters, or settings Use whimsy to spark imagination Leave the content open
Provide choice in defining users and their problems. Is there room for children to decide who to help, what problems to solve? Can children elaborate on the narrative to make it their own?	Choose from a set of problems or users to design for Personalize or invent a character Elaborate on a narrative or tell your own story
Reinforce narratives with both materials and facilitation. Is the narrative frame established through the materials, facilitation, the work that learners create and leave behind, the name of the activity, or some combination?	Materials represent characters and/or settings Facilitators reference the narrative Examples of others' work are available as inspiration Name of the activity and/or signage references the narrative
Test, observe, and iterate. Do children talk about the narratives or elaborate on them? When and how do they express empathy? Which engineering practices do they use, and how often?	Observe while children engage in the activity Ask follow-up questions during the activity or afterward Adjust materials, facilitation prompts, or narrative frame

Facilitation Strategies for Narrative-based Engineering Activities

We noted throughout our research that facilitation was critical in supporting the narrative frames in our activities. Here are some common strategies that helped integrate narrative and empathy into each phase of the engineering design process.

Helping learners get started:

- Use the narrative to introduce the problem. Point out the characters and/or settings and describe the situation and the type of problem learners can solve (e.g., Can you design something to help with X?)
- Help learners choose who to help and how based on their interests.

Supporting problem scoping:

- While learners are building, ask who they are designing their creation for. Ask what this person/user might want, need, or like, and how their design idea will help.
- Remind learners of any parameters of the problem that they might not be thinking about, using human-centered language. (e.g., Is your design safe? Comfortable? Easy to use? Fun?)
- Encourage learners to personalize the narrative or invent more details about the person/user (e.g., What is their name? What do they like/dislike? etc.)
- Connect with learners' own experiences. If the narrative relates to pets, family members, travel, weather, or other familiar situations, children's past experiences with those topics can help them understand the problem, think of ideas, and empathize more deeply with the people they are helping with their designs.

Encouraging testing and iteration:

- Use human-centered language to prompt iterations after each test (e.g., What would make this better for this person/user? Do you think this would solve their problem? How do you think they would like using this invention?)
- Encourage small-scale iterations by asking learners to describe or act out how someone would use their design.
- Use the narrative to suggest a new challenge (e.g., What might you do next? Who else could you design for? What are they going to do? What else might they need?)
- If the narrative involves a setting, encourage learners to think about what it would be like to be in that environment and what else might make their design work better there, or what would allow their design to be adaptable in different kinds of settings.

DOCUMENTING INDICATORS OF SUCCESS

This page summarizes the indicators of empathy and engineering practices that we looked for when developing and testing the activities in this guide. We noted whether learners showed each of these indicators, and if so, what evidence we observed (what learners said or did that fell into each category), and what aspects of the activity prompted these behaviors. This page also includes some follow-up questions that we used in our interviews to determine whether and how learners empathized with others while tackling each engineering challenge. You can use these tools to guide you in developing and testing your own activities.

Observation Tool

Activity: ______________________ Child's age/gender: ______ Start time: ______ End time: ______

Group composition/context: ____

Indicators: Which indicators did you see?	Quotes and notes: What did learners say or do? What parts of the activity did they respond to?
☐ Describing/referencing the narrative in the activity (or inventing a narrative in a non-narrative activity) ☐ Elaborating on or adding to the narrative/story	
☐ Affective responses: Talking about how the user feels, concern for their well-being, or expressing how you might feel in response to the problem/situation ☐ Perspective-taking: Talking about/acting out how someone will use the design or what it's like for them ☐ Prosocial behaviors: Expressing or acting on a desire to help ☐ Familiarity: Identifying connections to personal experiences or prior knowledge	
☐ Problem-scoping: Identifying multiple aspects of the overall design problem ☐ Ideation: Identifying more than one possible solution to the overall design problem ☐ Testing: Conducting either large or small tests of a design's function ☐ Iteration: Improving a design after a test (large or small)	

Follow-up Questions

What problem are you trying to solve here? What are you trying to make this do?
What did you have to change or fix while you were working on this?
What were you thinking about while you were making this?
Who did you make this for? What do you think would be helpful for them? How would they use this design?

ACTIVITY CASE STUDIES

In each case study that follows, we describe how the narrative-based activity was developed from start to finish, including:

- Where we started — either a classic or abstract engineering challenge that we adjust to integrate narrative elements, or an idea for a narrative-based activity that we developed from scratch
- The engineering goals that we focused on, and the narrative elements that we added
- The backstory behind the development of each activity, and key decisions that we made as we iteratively revised it to better support empathy and engineering practices
- The final activity design that we found to be most effective, including the practical ways that we implemented each of our design principles

NARRATIVE-BASED ACTIVITY		NON-NARRATIVE COMPARISON
	**1. Emergency structures:** Use dowels and rubber bands to construct a stable structure that can protect your group from an earthquake	**Dowel Structures:** Use dowels and rubber bands to construct a stable structure that can fit everyone in your group
	**2. Help The Pets:** Design a contraption using simple machines to take care of a bored, hungry, or lonely pet	**Chain Reaction:** Design a contraption using simple machines to accomplish a goal, like ringing a bell or landing a ball in a cup
	**3. Help Grandma:** Design and build models of novel inventions to solve problems grandparents face in everyday life, like carrying groceries or climbing stairs	**Invention Challenge:** Design and build models of novel inventions to solve different physical challenges, like lifting a heavy object
	**4. Around The World:** Design a wind-powered vehicle that can help someone travel around the world over different landscapes	**Air-powered Vehicles:** Design a vehicle powered only by air that can travel over different textured surfaces
	**5. Safe Landing:** Use recycled and repurposed materials to design something to help an alien or astronaut land safely on a planet	**Dropped Calls:** Use recycled and repurposed materials to design something to protect a cell phone from a 20-foot drop
	**6. Shadow Stories:** Create shadow puppets and scenes with everyday materials	**Light and Shadow:** Create effects with light and shadow using everyday materials

1. Emergency Structures

Changing the problem frame

ABOUT THIS ACTIVITY

In this activity, learners use three-foot-long dowels and rubber bands to design and build a structure that could protect their entire group in an earthquake.

Where we started

In the original, non-narrative version of this activity at NYSCI, facilitators prompted learners to use dowels and rubber bands to build a stable structure that they could fit inside of. Making stable structures is a classic engineering challenge, often done at a smaller scale. We thought that this activity could be adjusted slightly by changing the problem frame to suggest a reason for needing to make your structure stable and large enough for everyone.

Engineering goals

This engineering activity focused on stability and fit (being able to fit everyone in your group inside). We wanted to keep the focus on these two concepts, and also encourage learners to come up with creative ideas for their structures and iteratively make changes to improve them.

Narrative elements

This was the first activity that we developed in this project, and we decided to shift only the problem frame to create the narrative-based activity. The materials and parameters of the problem remained the same, but rather than prompting learners to build a large structure, facilitators and signage prompted learners to build a structure that could protect them and their group in an earthquake. We left other details about the narrative up to visitors to decide, in order to see how a simple change in the prompt might affect learners' engagement.

Backstory and key decision points

Getting buy-in for the narrative: In the first iteration of this activity, we initially asked children to design a structure to protect their group from a hurricane. Facilitators bolstered the narrative by wearing raincoats and umbrellas, offering sheets of mylar that groups could use to cover their structures, and using large fans to simulate the hurricane. While this narrative was deeply evocative — provoking a sense of urgency as visitors felt the wind and heard the mylar sheets flapping — the core engineering goal of building a stable structure was somewhat lost. Learners tended to focus on covering their structures with mylar to shield themselves from the wind, rather than making their structures large or stable. We observed many small tent-like structures and few divergent solutions.

Fine-tuning the problem frame and materials to keep the narrative from being distracting: When we revised this activity design, we pivoted to a narrative about an earthquake, and removed the mylar and fans. Instead, facilitators prompted visitors to test their structures by shaking, tipping, and wobbling them. Reframing the narrative in this way refocused learners' attention on the structural stability of their designs, and we saw more diverse solutions and more frequent iteration.

FINAL ACTIVITY DESIGN

Problem frame
"Build a structure that can protect your whole group from an earthquake."

The final iteration of the activity integrated narrative into the problem frame to emphasize the key engineering goals of structural stability and fit. We asked learners to take a different point of view by imagining themselves in a real-world situation. The facilitation strategies described below kept learners focused on the idea of an earthquake while building, testing, and improving their structures, which we found was effective in supporting collaborative planning and iteration of their designs.

Design Principles in Action

Design Principle	*Implementation in Emergency Structures*
Start with engineering goals	Stability and fit, engineering design process
Use characters and settings	Real-world situation posed in the problem frame (protecting one's group from an earthquake)
Choose a point of view	Learners imagine themselves in a novel situation (trying to survive an earthquake)
Spark learners' own ideas	Learners can extend the story through imaginative play or their prior knowledge about earthquakes
Provide choice	The size and type of structure is open for learners to decide
Reinforce narratives	Facilitation prompts and signage reference the narrative
Test, observe, iterate	Narrative frame revised from hurricane to earthquake in response to our observations

Time
15 minutes +

Constraints
Each group of 4 – 5 needs a nine-square-foot space in which to build (alternatively, groups can work together); young children (under 6) may have difficulty fastening rubber bands and need help from older children or adults

Physical Setup
Open space for building

Signage
Whiteboard or other signage with the problem frame written on it ("Build a structure that can protect your group from an earthquake"). Be sure to put this in the line of sight of where visitors are building, not just at the entrance to the space

Materials
- Dowels (3/8" x 36")
- Large bin to hold a supply of dowels
- Rubber bands (latex free, size 64)

Options and Alternatives

If you don't have a large space to build: You can use chopsticks and smaller rubber bands (like hair ties) to make smaller, tabletop structures. If you do this, add figures of some kind (like Lego figures or cardboard cutouts of people) to show the scale of the structure they should build and prompt empathy for what people might need or feel in an earthquake. However, we recommend using large dowels if possible, because building a structure that learners themselves could fit inside created a more immersive and embodied learning experience. This activity could be also done outdoors (e.g., in a playground or park) or in a gymnasium or cafeteria.

Additional materials to support the narrative: You can add other props, such as hardhats or construction vests, to extend the narrative and encourage more imaginative role playing in this activity. You can also provide a whiteboard to let visitors plan out their designs or show how they might be used. The Tech Interactive tested these approaches and found they helped deepen learners' engagement with the narrative.

Facilitation

Helping learners get started

- Briefly introduce the activity: *Your job is to build a structure to protect your group in an earthquake.*
- Point out some examples of other structures people have left behind as inspiration.
- Get adults or other members of the group involved in the story: *Is there room for everyone? Remember, you all have to fit inside to stay safe!*

Supporting problem scoping and ideation while building

- Check in with learners as they are building, and remind them that everyone needs to be safe inside their structure.
- Prompt learners to think about what they would need in an earthquake and what features they would want their structure to have: *Do you need space for supplies? Do you want windows or exits? Do you each need your own room?*

Encouraging testing and iteration

- Ask visitors if they are ready to test their structure to see if it will survive the earthquake, and prompt visitors to get inside of their structures while you shake and tip it in different directions.
- Ask how they could make their structure safer or stronger: *Do you think this would have stayed standing if this was a real earthquake? What else would make it stronger?*

TIPS AND TRICKS:
How to connect dowels

There are many ways to connect dowels with rubber bands. Here's one easy way: Make an X with the ends of two dowels. Loop the rubber band around the end of one of the dowels. Wrap the rubber band around the X a several times. Loop the rubber band onto the other dowel to hold it in place.

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners talk about the earthquake, and even role play by imagining what it might be like.
- Elaborating on the narrative: Learners extend the narrative by making up details about where they are and what is happening.

Empathy indicators

- Emotional responses: Learners express worry or concern for their own or others' well-being.
- Cognitive perspective-taking: Learners imagine what someone would need in an earthquake, or what it would be like to experience it.
- Prosocial behaviors: Learners describe wanting to protect their families, or ensure that their structures are safe or comfortable.

Engineering practices

- Ideation: Learners come up with divergent types of designs, brainstorming aloud by stating what they want their design to look like or features they want it to include.
- Problem scoping: Learners consider how many people will fit inside, how sturdy the structure is, and other needs or functions (like space for supplies, bedrooms, etc.).
- Testing: Learners test their structures on their own or with the help of facilitators — including trying to fit inside and tilting/shaking their structures to see if they are wobbly.
- Iteration: Learners change or add to their structures after testing, making them bigger or more stable. Groups of learners who were working separately may try to combine their structures.

2. Help The Pets

Integrating realistic characters and whimsical materials

ABOUT THIS ACTIVITY

This activity involves using simple machines and props made from everyday items to construct a chain reaction contraption that can help take care of a pet by feeding it, playing with it, grooming it, etc.

Where we started
Building chain reactions or Rube Goldberg machines with everyday objects is an open-ended engineering activity conducted at many museums. In the original, non-narrative version of this activity, learners built contraptions to reach a goal like ringing a bell or landing a ball in a cup. This activity naturally encourages testing and iteration, but we noticed that it also required a great deal of facilitation to get people started. We wanted to change the activity by adding characters to provide a compelling problem to solve.

Engineering goals
Learners explore concepts related to simple machines and mechanisms, (e.g., inputs and outputs, cause-and-effect relationships), by creating and design with repurposed materials that they are encouraged to use in unexpected ways.

Narrative elements
In the narrative-based activity, we added sympathetic characters (realistic and interactive models of dogs and cats), and a narrative problem frame (caring for a pet).

Backstory and key decision points

Making pets realistic to support empathy: We prototyped this narrative quickly and cheaply using stuffed animals, but the toys did not evoke empathy very strongly. Instead, activity developers built life-sized models of dogs and cats, and added motors so that when switches were triggered by objects in a chain reaction, the pets would wag their tails or wave their paws. Learners could incorporate the pets into their chain reactions and see whether they had "helped" the pet with their designs. Many learners described being motivated to make the animals happy because of this evocative feedback.

Having visible reminders of the problem to reinforce the narrative: At first, we found that learners were engaged by the pets but were not always sure how to help without suggestions from facilitators. We decided to give the pets collars with different kinds of problems written on them ("I'm hungry," "I'm lonely," "I want to play!"). Since these prompts were written from the pet's point of view, they helped evoke empathy and provide a starting point for learners' ideas.

Making problems open-ended to encourage divergent solutions: In early prototyping, we noticed that if too many ramps were available, we saw many ball ramps, and few contraptions that used other kinds of props. Likewise, if a food bowl was near the pets, most children would try to get something in the bowl and would seldom create other kinds of contraptions. In the next iteration, we curated the materials that were available (fewer bowls, ramps, and balls) and set up examples of creative uses of props (using string to pull a spoon handle, knocking over dominoes to complete a circuit) to inspire a wider range of design ideas.

FINAL ACTIVITY DESIGN

Problem frame

"Make a chain reaction contraption to take care of a pet!"

The most effective iteration of Help the Pets integrated characters in the form of realistic dogs and cats with collars that described how the pets were feeling. We provided a variety of props that inspired learners to build creative and whimsical contraptions. If you create your own version of this activity, keep in mind that we found it was important to select materials that remind learners of who they are designing for, and that do not suggest a single solution to the problem.

Design Principles in Action

Design Principle	*Implementation in Help the Pets*
Start with engineering goals	Engineering design process, inputs & outputs
Use characters and settings	Narrative in the characters (models of dogs and cats) and problem frame (taking care of a pet)
Choose a point of view	Learners imagine the point of view of a bored, hungry, or lonely pet
Spark learners' own ideas	Props spark creative and whimsical solutions; Learners can connect to their experiences with pets or other animals
Provide choice	Multiple pets are available to design for; problems are open-ended and materials allow for a variety of solutions
Reinforce narratives	Facilitation prompts, materials, and signage reference the narrative frame
Test, observe, iterate	Materials revised to be more interactive and realistic to better evoke empathy

Time
30 minutes +

Constraints
Facilitation intensive (requires some assistance to get started), some types of props must be built in advance (see Tips and Tricks section)

Physical Setup
2 – 4 large tables, arranged in L-shapes for greater challenge; Supplies table or counter with extra pieces/parts

Signage
Whiteboard or other signage with the problem frame ("Make a chain reaction contraption to take care of a pet!")

Materials
- Building materials can include a variety of repurposed objects, such as: cardboard ramps, balls with different sizes and weights (golf balls, baseballs, ping pong balls), masking tape, aluminum foil and alligator clips (for creating switches out of objects to activate the animal models or other circuits), VHS tapes, wooden blocks (to stack or knock over like dominos), clamps.
- You can also create props from everyday items so that it is easier to integrate them into a chain reaction. See the Tips and Tricks section for ideas about how to hack sports equipment, kitchen utensils, toys, and other objects to make movable props that learners can use in their chain reactions.
- Animal models (see call-out box and Tips and Tricks section for more information about the key features of the models).

Options and Alternatives
We created models of dogs and cats, but you can create models of other kinds of animals as well (birds, reptiles, fish, etc.). The important thing is making the pets realistic and interactive in some way. Experiment with different ways of making the pets move or respond to help evoke empathy and encourage iteration.

Facilitation

Helping learners get started

- Briefly introduce the challenge: *There's a pet at each table — some of them are hungry or lonely, or they want to play. Can you make a contraption to help? You can use any of the things you see in the room.*
- Help learners choose a pet to help, and if they want to, give the pet a name.
- Show some examples of contraptions that use materials in creative ways to help the pets, or set up one step for learners to use as a starting point.

Supporting problem scoping and ideation while building

- Ask learners to think about their pet's personality and what kinds of things they might like to see, do, or play with.
- Encourage learners to check out lots of materials and think about what might help their pet.
- If learners have pets of their own, ask what their pets like or need. If they don't have pets, ask them to think about other animals that they are familiar with.

Encouraging testing and iteration

- Encourage learners to test part or all of their chain reaction and make changes.
- Help learners troubleshoot, and suggest further challenges once they have had an initial success: *Now can you figure out how to give them a toy or a treat? Can you help two pets with one contraption?*

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners talk about the pets while planning or building.
- Elaborating on the narrative: Learners may invent other details about the pets such as their names, their personalities, or what they like or want.

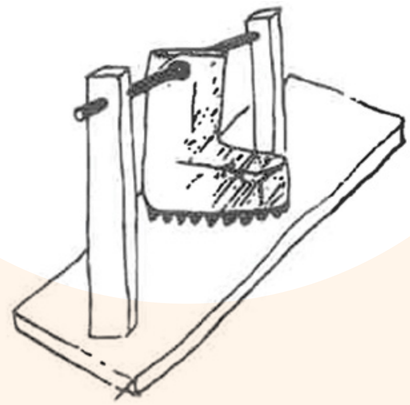
Empathy indicators

- Emotional responses: Learners respond to the pets with sympathy, or express interest or concern for the pet's happiness.
- Cognitive perspective-taking: Learners imagine what would be fun, interesting, or good for the pet or how it would use or play with the invention. Learners think about their own pets or what they know pets usually like.
- Prosocial behavior: Learners express a desire to make the pets happy or take care of them.

Engineering practices

- Ideation: Learners think of creative ways to take care of the pets by using or combining materials in different ways, stating goals or ideas about how to help out loud, or brainstorming with others.
- Problem Scoping: Learners consider the features that the design needs to have or goals it should accomplish (e.g., deliver food and be fun to play with).
- Testing: Learners test individual steps in the chain before adding on, or test the entire contraption.
- Iteration: Small scale iterations might include making small adjustments in individual steps in the chain, or adding one piece at a time and troubleshooting it. Larger scale iterations might follow tests of the entire contraption from start to finish, fixing any steps that fail or swapping materials, and trying again. Sometimes learners might disassemble their entire contraption and start from scratch with a new design.

Tips and Tricks: How to Make Props out of Everyday Objects



Why

- Using off-the-shelf objects in your chain reaction is exciting and compelling for visitors. While objects like kitchen utensils, toys, and sports equipment offer a lot of promise to make amazing things, it is often difficult to make them deliver on that promise. So we hack the items to make them easier to perform the tasks visitors imagine. When selecting materials, think of everyday items that can spring other things into action or move something from one point to the next.

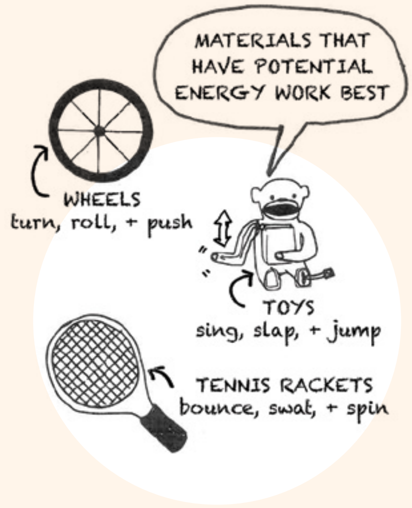
"Hackable" everyday items that work well:

- Sports equipment: balls with different weights and sizes, tennis or badminton rackets, baseball mitts, roller skates
- Kitchen items: measuring cups, spatulas, wooden spoons, pans, ladles, ice scoops
- Toys that move: dolls, action figures, electronic toys with switches
- Other random objects that can tilt, scoop, or swing: boots, trophies, pails, wheels, pipes, dryer tubing, pull switches, etc.

SMALL ITEMS CAN PERFORM SIMPLE TASKS. NOT EVERYTHING HAS TO BE FANCY!

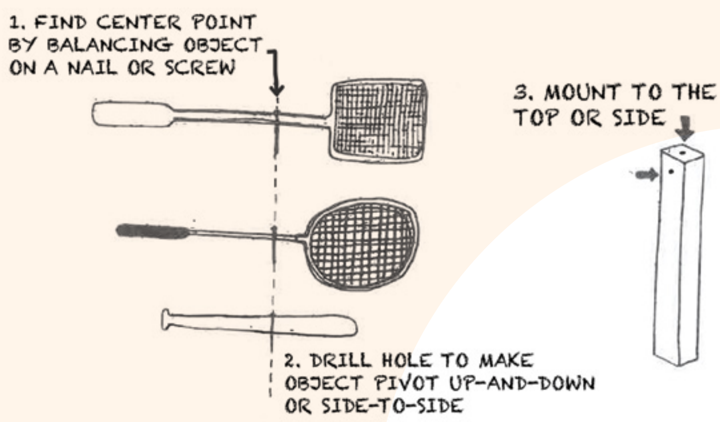
What do you mean by "hack everyday items"?

- Mount things like boots, utensils, and sports equipment so that they balance when at rest, but move easily when tapped by a ball. Find the center point by balancing the object on a nail or a screw.
- Electronic toys that move are awesome for chain reactions. Find the switch and cut the wires leading to the switch. Solder alligator clips to the wire so that you can trigger the switch with other conductive objects.
- Offer a limited number of "special" items: Every step doesn't have to use a fancy or unusual prop like a mounted and moveable racket. Simpler items like ramps, tubes, and string can also help perform tasks in the chain reaction.



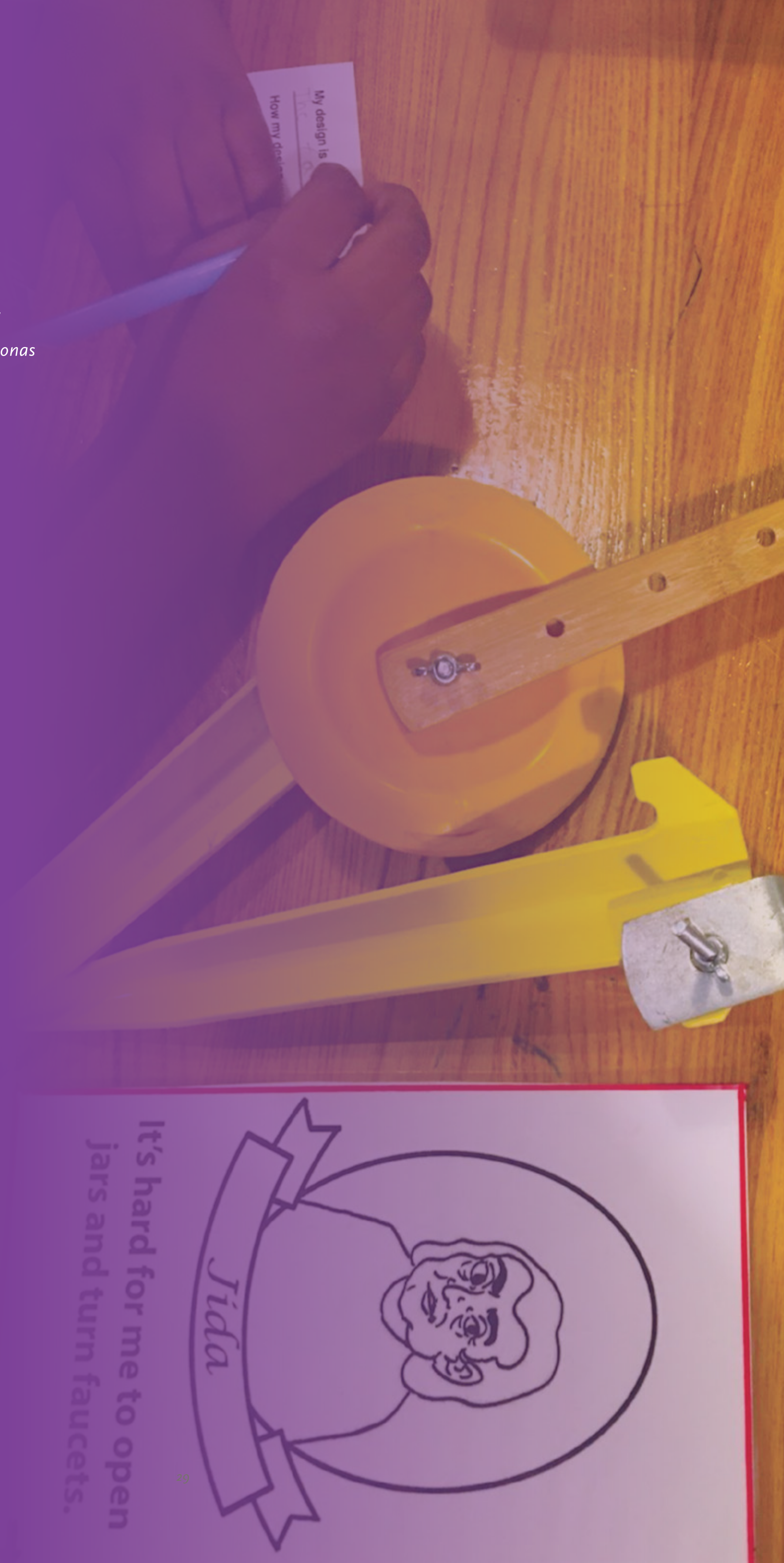
Building pet models: What are the most important things to keep in mind?

- Use what you have: We used foam core, toy motors, and printed images of animals to construct our models, but you could use other materials (cardboard, fabric, Makey Makeys, etc.).
- Make the pets realistic looking: Use realistic images and scale the model so that the pets are life-sized.
- Make the pets interactive: Think about how the animal moves, especially when it's happy. What parts of the animal move (tail, paw, beak, flipper), and how do they move (back and forth, up and down, around in a circle)? Use motors, levers, or other mechanisms to make parts of the model move when triggered by another object.
- Offer multiple options: Include a few different animals in your activity so that individual learners can pick a pet to help based on their interests.



3. Help Grandma

Adding characters with realistic personas



ABOUT THIS ACTIVITY

Help Grandma is a human-centered design activity in which learners use repurposed and everyday objects to design something to help grandparents with everyday tasks.

Where we started
In years prior to this project, NYSCI had run a version of this activity using three-dimensional papier-mâché grandmothers, but we noticed that visitors weren't especially empathetic toward them because they lacked any personal details. We wanted to improve this activity by leaning into human-centered design as practiced at the Stanford d.school, which includes "empathize" in its description of the design process. In this kind of design practice, designers often interview clients to better understand their needs. To adapt this approach for a drop-in museum activity, we invented realistic personas that learners could choose to help with their designs.

Engineering goals
This activity focuses on the design process, and especially the beginning stages of problem scoping (deciding what aspects of the problem your design should address) and ideation (generating ideas to solve the problem). Learners also work to iteratively improve their designs.

Narrative elements
We generated persona cards that introduced a character (a grandparent with a nickname like Nonna, Grams, Abuela, etc.), and an everyday problem that she encountered (carrying groceries, answering the doorbell, climbing stairs, etc.).

Backstory and key decision points

Adding personal details to encourage perspective-taking: We set out to create realistic personas that reflected everyday people and their problems. As we refined the activity, we added personal details to the grandma personas (where she lives, her hobbies and routines, etc.) to make them feel like real people. This helped learners imagine their "client's" point of view as they designed an invention to help her.

Offering choice in people to help and problems to solve: To ensure that learners could find a problem they were interested in solving, we created a wide range of persona cards with different people and problems to choose from. We used nicknames for grandmothers that we gathered from people with a range of cultural backgrounds, and translated the cards into three languages. We also encouraged learners to design for someone else if they wished (perhaps someone in their own family or neighborhood).

Prompting iteration by building, demonstrating, and sharing invention ideas:
Originally, we asked learners to sketch their ideas before building, but we found that they often skipped this part of the activity or drew ideas that were challenging to build. We found that asking learners to focus on building prototypes of their designs helped them think about how to improve and iterate on their ideas. We also encouraged learners to explain how their designs would work and leave their inventions on a display shelf for others to see.

FINAL ACTIVITY DESIGN

Problem frame

"These grandmothers all have problems that they need help with. Choose a person that you want to help, and design something to solve her problem."

The final iteration of this activity included six different persona cards with different grandmothers from a range of cultures and with different types of everyday problems. This activity could be adapted in a wide range of ways, by creating your own persona cards or by inviting learners to design something to help people they know. We provide examples of our persona cards as inspiration, and options for adapting this activity to suit your audience and setting.

Design Principles in Action

Design Principle	*Implementation in Help Grandma*
Start with engineering goals	Engineering design process
Use characters and settings	Character narative (*persona cards describing grandmothers with different needs*) and problem frame (*helping them with everyday tasks*)
Choose a point of view	Learners imagine the point of view of a grandmother with an everyday problem
Spark learners' own ideas	Learners can connect to their experiences with their own family members
Provide choice	Multiple personas with different problems are available to design for; problems are open-ended with multiple possible solutions
Reinforce narratives	Facilitation prompts, materials, and signage reference the narrative frame; Other learners' work is available for inspiration
Test, observe, iterate	Personal details added to persona cards to better evoke empathy

Time
15 minutes +

Constraints
Some facilitation is required to encourage learners to make a label to explain their inventions at the end of the activity and leave their designs on display.

Physical Setup
1 Table at entrance with prompt cards,
plus 2 – 4 tables with materials for building
Display table/shelves (optional)

Signage
Whiteboard or signage stating the problem frame ("Help solve Grandma's problem.")

Materials
- Laminated persona/challenge cards with different people and problems
- Building materials can include: rubber bands, binder clips, nuts and bolts, washers, hinges, chopsticks, wooden pegboard (cut in different shapes), scrap fabric
- Any other materials that can be repurposed in a variety of ways beyond their intended function, and that might spark creative ideas for prototypes (such as PVC connectors, plumbing hardware, kitchen utensils, etc.). Use whatever you have on hand!
- Blank labels for finished inventions

Options and Alternatives
Feel free to adapt this activity to make it your own by thinking about other groups of people that learners might relate to, and the kinds of everyday problems they might face. It is most important for the characters that you choose to be sympathetic and relatable to the children you work with. You could also invite learners to think of someone they know to help with their designs, perhaps even asking them to actually interview a family member or friend.

Facilitation

Helping learners get started

- Briefly introduce the activity: *Each person here has a different problem that they need help with. Choose a person that you want to help and design something to solve her problem.*

Supporting problem scoping and ideation while building

- Ask learners what they learned from the persona card about their "client": *Which person are you helping with your design? What made you choose that one? What do you know about her so far?*
- Ask how their design will help solve grandma's problem: *Tell me about your idea for your design. How will your invention help her?*
- Remind learners to pay attention to all of the information on the card about what grandma needs and likes.

Encouraging testing and iteration

- Because learners make a model of their invention, this activity primarily focuses on ideation and problem scoping, two parts of the engineering process that are often neglected in more constrained engineering challenges. Learners can iterate their designs by imagining how they would be used and by talking about their designs with facilitators or other visitors/family members.
- Ask learners how their invention would work to prompt them to improve their design, for example by adding new features: *How will this help grandma with her problem? Can you show me how she would use it? Is there anything else you could add to your design to make it better for her?*

Help Grandma

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners talk about the person they are designing for, or look back at the persona card while coming up with ideas or building their prototypes.
- Elaborating on the narrative: Learners invent other details about their client, or create their own characters to think about when planning and iterating their designs.

Empathy indicators

- Emotional responses: Learners express concern for grandma, think about how it would feel to have the problem that she has, or how it would feel to have a solution to the problem.
- Cognitive perspective-taking: Learners imagine what grandma needs or would like, or tell or act out how she would use their invention.
- Prosocial behavior: Learners express a motivation to help grandma, or talk about wanting to make their design safe, pleasant, or comfortable for her to use.

Engineering practices

- Ideation: Learners think about different ways to solve grandma's problem, or creative ways of using the materials to represent their ideas.
- Problem scoping: Learners identify multiple aspects of the problem that their design should address (e.g., the design needs to be easy to use, portable, or able to be used both inside and outside).
- Testing: Learners talk with others about how their design would work, how it solves the problem, or how it meets grandma's needs, or they might show how the design would be used to test their ideas or get feedback from others.
- Iteration: Learners change their idea, add features to improve their designs, or adjust the materials they use to build their model/prototype.

4. Around The World

Adding evocative settings

ABOUT THIS ACTIVITY

This activity is based on a classic air-powered vehicle engineering challenge. Learners design a vehicle that can help them travel across different landscapes using only the wind as power.

Where we started
Designing air- or wind-powered vehicles is a relatively common engineering activity in many museums, including ours. NYSCI had done this activity with vehicles traveling over surfaces with various textures (smooth mylar, bumpy plastic grates, soft carpeting), but not with a consistent narrative frame. We thought this activity could give us a chance to use settings as the primary narrative element to encourage ideation and iteration by providing a context for the engineering problem.

Engineering goals
This activity touches on multiple concepts, including aerodynamics, friction, drag, weight, and balance. We kept the focus on wind power and encouraged learners to come up with creative designs and iteratively improve them as they tested them on one or more surfaces with different physical properties.

Narrative elements
We added narrative to this activity in the form of settings — textured terrains and backdrops that illustrated different kinds of landscapes (arctic, grassland, forest, and desert) in which learners could design and test their vehicles. Facilitators also supported the problem frame by prompting learners to think about what they might need in each environment.

Backstory and key decision points

Leaving the narrative open-ended and encouraging learners to extend the story:
We initially considered more elaborate narratives like asking learners to design something to go on a family vacation, or delivering supplies or packages to someone, but these seemed too constrained. Based on what we had learned from prior activities, we knew it was important to offer learners more choice in deciding what problems to solve. Ultimately, we decided on a more open-ended narrative about traveling around the world, provided multiple landscapes that learners could choose to travel to, and asked learners to think about where they wanted to go and why.

Offering choice in people to help and problems to solve: We first tested this activity with only textured surfaces that looked like different landscapes. We noticed that the surfaces encouraged iteration, but the narrative was not especially compelling for learners (they often ignored it after a while). In response to these observations, activity developers added backdrops for each testing station that showed realistic photographs of each place. These improved landscapes were visible from a distance, capturing learners' attention and drawing them in. The compelling scenery also supported iteration; the more eye-catching and evocative landscapes motivated learners to choose a landscape for their first test, and we saw iteration both to improve their design for one landscape and then to test their designs across multiple settings.

FINAL ACTIVITY DESIGN

Problem frame
"Design a vehicle to help you travel around the world using only the wind as power."

The final iteration of this activity included four different landscapes with different textures, from smooth to bumpy. If adapting this activity, feel free to choose any combination of settings that are evocative and that offer different levels of challenge. We include Tips and Tricks for creating testing stations at the end of this chapter.

Design Principles in Action

Design Principle	*Implementation in Around The World*
Start with engineering goals	Air flow, balance, weight; Engineering design process
Use characters and settings	Narrative in settings (*testing stations representing a variety of landscapes*) and problem frame (*traveling with wind power*)
Choose a point of view	Learners imagine themselves in a novel situation (*traveling through different landscapes*)
Spark learners' own ideas	Learners can extend the story by imagining where they are going and why
Provide choice	Multiple landscapes with different textures are available; materials selected to allow for multiple possible solutions
Reinforce narratives	Facilitation prompts, materials, and signage reference the narrative frame
Test, observe, iterate	Settings made more detailed and realistic to draw learners in and support iteration across settings

Time
15 minutes +

Constraints
Requires sufficient tabletop or floor surface for multiple testing stations; Low facilitation needs (many visitors can get started on their own)

Physical Setup
Tables or counters with 4 testing station surfaces,
plus 2 – 4 large tables for building
Supplies table or counter with extra pieces/parts
Display shelf for examples of vehicles (optional)

Signage
Whiteboard or other signage with the problem frame ("Travel around the world in wind-powered vehicles.")

Materials
- 4 surfaces for testing stations with different textures and backgrounds, resembling natural landscapes (see Tips and Tricks section)
- 4 tabletop fans (one per testing station)
- Building materials can include (but are not limited to): Take-out containers, straws (regular and bubble tea straws, with some cut in half to facilitate making axles), pink insulation foam (cut into 3 – 4" squares and triangles), corks, round chopsticks (bamboo skewers can also be used but are more easily broken), film cases, washers, CDs and thread spools (see options below — too many wheel-like objects might limit divergence, but feel free to use sparingly), plastic ball-pit balls, sections of pool noodle foam, pieces of vinyl or fabric cut into 3 – 4" squares or triangles

Options and Alternatives
Many repurposed and recycled materials work well with this activity. Light materials and those that catch the wind are as important as materials with some weight to maintain balance. We found that it was important not to include too many materials that look like wheels, in order to encourage more creative and divergent solutions to the problem like sleds, boats, gliders, etc.

Facilitation

Helping learners get started

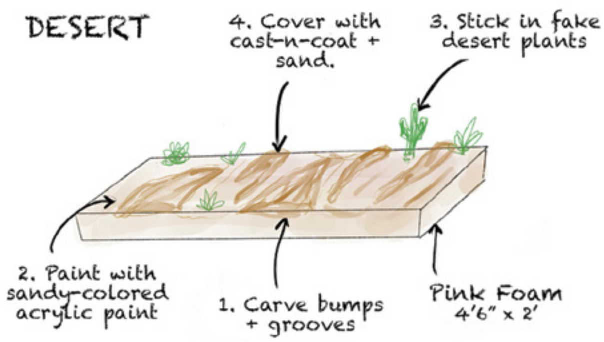
- Introduce the problem: *Make a vehicle to help you travel across different landscapes using only the wind as power.*
- Point out the different landscapes and ask learners to pick one that they want to travel to: *There's a desert, grassland, forest, and glaciers. Where do you want to travel to? Which part of the world do you want to go to first?*
- Encourage learners to touch the surfaces of the landscapes to think about how they should design their vehicle.
- Show some examples of other vehicles to help learners get ideas for their own designs.

Supporting problem scoping and ideation while building

- Ask learners about which landscape they are designing for, and how their design will help them travel there: *What do you think it's like in the landscape you chose? What parts does your vehicle have? How will your vehicle help you travel safely there?*
- Prompt learners to extend the story: *Who's coming with you? What do you need to bring with you? What are you going to do there?*

Encouraging testing and iteration

- Help learners turn on or direct the fan to test their vehicle, and ask them to describe what happened.
- Ask if their vehicle worked the way they wanted, what they could change to help them travel more safely or comfortably, or what would make their trip better.
- Encourage learners to make changes and test again in the same landscape, or suggest trying the other settings to make their vehicle more adaptable in different places.



TIPS AND TRICKS: Making landscapes

You can choose a variety of landscapes and environments for this activity. Here are some key considerations:

Choose landscapes that suggest a range of "difficulty levels" — from smooth to bumpy. Our landscapes included a glacierc, desert, grasslands, and forest, and we used epoxy resin, fake grass and plants with different textures to cover our testing surfaces. Feel free to experiment with different kinds of settings and textures based on the materials you have available.

Surfaces should be about four feet long to allow for a good testing surface. We used sheets of pink foam, but cardboard, foam core, or any other stable surface would work well, as long as you have a sturdy table for your testing stations.

Create realistic backdrops: We used realistic photographs that showed the kinds of settings we had in mind, and glued large-scale photos to sheets of foam core or posterboard. This allowed the settings to be immediately recognizable and eye-catching from a distance.

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners talk about the setting they chose, and what happened when they tested their designs on a given landscape.
- Elaborating on the narrative: They may invent other details about where they are going and why.

Empathy indicators

- Emotional responses: Learners express concern or worry if their vehicles crash or tip over when tested, or happiness if they travel well.
- Cognitive perspective-taking: Learners imagine what it is like to be in one of the settings/landscapes, or what they might need or want if they were traveling there.
- Prosocial behavior: Learners think about safety or protection when designing their vehicles, for themselves and any other passengers, or think about a larger desire to help the environment or the climate with wind-powered vehicles.

Engineering practices

- Ideation: Learners brainstorm different types of vehicles or ways of traveling with the wind.
- Problem scoping: Learners consider the constraints and qualities of each setting (e.g., temperature, surface texture), or think about multiple design features (safety, speed, stability).
- Testing: Learners test their design on one surface or on multiple surfaces before making changes.
- Iteration: Learners devise improvements to make their design work well in one environment, or tweak the design so that it can move across multiple landscapes. After testing one design, learners might also start over to compare with a new design.

5. Safe Landing

Adding personalized characters and evocative settings

ABOUT THIS ACTIVITY

In this activity, learners choose and personalize a character, before designing something to help them land safely, and use an accelerometer app to generate numeric feedback about the impact of the fall.

Where we started
Protecting a falling object (like the classic egg drop challenge) is a common engineering activity in museums and classrooms. NYSCI had run an activity called "Dropped Calls," in which visitors designed something to protect a cell phone from a 20-foot drop, and used an app on the phone to measure its acceleration. We wondered if we could evoke empathy in this activity by asking learners to protect a person rather than an object. Inspired by space-themed artifacts at NYSCI, we shifted the problem frame to focus on helping an astronaut or alien land safely on a planet. We chose a whimsical narrative based on the EDGE project, which found that playful or whimsical elements can support girls' engagement with STEM exhibits (Dancstep & Sindorf, 2018). This activity also gave us a chance to experiment with allowing learners to not only choose a character, but also to personalize it in some way.

Engineering goals
This activity involves concepts like gravity, force, and acceleration. We incorporated an accelerometer app to encourage iterative improvements based on data learners gathered after each test.

Narrative elements
To create the narrative-based activity, we added characters (aliens and astronauts), a setting (a space-themed testing station), and a narrative problem frame (protecting characters landing on a planet).

Backstory and key decision points

Developing quick and easy ways to personalize a character: We wanted to give children a chance to choose characters as passengers in their designs, and personalize the characters to make them their own. One option was designing an avatar on the phone itself, but we didn't want this part of the activity to take over and limit the amount of time learners spent designing and iterating their vessel. Instead, we opted for simple paper cards that learners could choose, name, and decorate quickly with pencils, spending only a few minutes to create a character. We then attached the cards to the phones with rubber bands. Though this approach was very low-tech and simple, it worked surprisingly well to get learners thinking about their characters.

Using data to guide iterations: We initially offered two ways for learners to get feedback about their designs: using the accelerometer app, or recording a video of the fall with the phone's camera (thinking this might encourage perspective-taking). When given the choice, most learners chose to use the app. To keep the activity from being competitive, we told learners to compare data from each iteration of their own designs, rather than comparing their results with others. We also tried recording videos of each test from a distance. This helped learners notice how their design fell and think of ways to make it land more softly or slowly.

FINAL ACTIVITY DESIGN

Problem frame
"Design something to help our space friends land safely on a planet."

This activity invites learners to name a character and imagine their point of view as they design a way to ensure a safe landing on the planet. You can adapt this activity by dropping other objects besides phones, but be sure to incorporate ways for learners to create or name their characters, and ways for them to get feedback to iteratively improve their designs (for example, by recording a video of the fall and thinking about whether the landing looked safe for their character, or watching how high it bounces).

Design Principles in Action

Design Principle	*Implementation in Safe Landing*
Start with engineering goals	Gravity, force, acceleration; Engineering design process
Use characters and settings	Character narative(*astronauts, aliens*), setting (*space-themed testing station*), and problem frame (protecting the characters landing on the planet)
Choose a point of view	Learners take the point of view of the characters that they choose and personalize
Spark learners' own ideas	Whimsical narrative encourages imaginative solutions
Provide choice	Learners choose and personalize characters; materials allow for multiple possible solutions
Reinforce narratives	Facilitators and materials reinforce the narrative
Test, observe, iterate	Ways of personalizing characters and using data to guide iterations adjusted based on observations

Time
20 minutes +

Constraints
Requires vertical space to drop (at least 10 feet high), facilitation intensive (requires assistance to get started)

Physical Setup
1 table for learners to choose and personalize their characters,
1 table for materials, and 1 table for buildingA drop of least 10 feet for the testing station, for example from a stairway landing, mezzanine, or balcony (we used a 20-foot drop from a mezzanine level)

Signage
White board or sign with the name of the activity and illustrations of sample characters. We drew a speech bubble next to one of the characters saying "Help us land safely!" to communicate the problem frame.

Materials
- Android phones with *Arduino Science Journal* application: This app can graph linear acceleration, which will show a spike when the phone lands on the testing surface. The average and maximum acceleration tend to be higher with a harder impact than a softer impact. The goal was for learners to use these values as one source of feedback to iteratively improve their own designs (in combination with others, like observing the fall).
- Building Materials: recyclables (e.g., plastic bottles, cartons, toilet paper tubes, oatmeal and yogurt containers, plastic bags), string, rubber bands, scissors, binder clips
- Paper templates of astronaut and alien characters (see templates)
- Testing station: Trampoline, space-themed backdrop

Options and Alternatives

Finding a place for the testing station: We recommend at least a 10-foot drop for this activity. If you don't have a room with a ledge for dropping, try a stairwell or find a place outdoors with more space.

Instead of dropping phones with an accelerometer app, you could drop another object and film a video of the fall to give learners a chance to make observations about how their design landed. If you do not have numeric data for learners to use to improve their designs, you can focus on human-centered aspects of the design (e.g., by asking learners to imagine what it would have been like for those inside and how to make the landing safer or more pleasant.)

1.

2.

After choosing and naming an alien character (1) and starting the accelerometer app (2), this child worked diligently to build her design (3), a capsule and parachute (4). She tested it and immediately checked the results to see the force of the impact (5 – 6). She went on to improve her first design, and to create another design for a second alien friend.

3.

4.

5.

6.

Responding to questions about acceleration, velocity, gravity

We often redirected these questions by asking learners to think about the measurements in the app as representing the “force of the impact” based on how fast their design was falling when it hit the surface, and asked them to change their design to try to make this measurement as low as possible. This helped keep the focus on the process of improving their own design.

Facilitation

Helping learners get started

- Help learners choose a character, give them a name, and personalize their character however they would like.
- Explain that the goal is to build something to help their character land safely on a new planet, and that you will use an app to record the impact of the landing.
- Using a rubber band, attach the child’s character to a phone running the app. (Note: this is a low-tech option. You can also use avatars on the phone itself.)
- Make sure the app is turned on before learners start building.

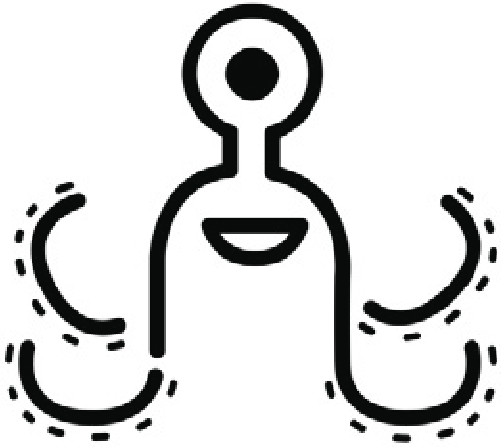
Supporting problem scoping and ideation while building

- Check in with learners occasionally while they plan and build their designs, asking how their design will protect their character.
- Reference learners’ characters by name: *Do you think [name of child’s character] will be safe?*

Encouraging testing and iteration

- After each test, ask learners about how well they think their design worked: *What happened when it fell? Do you think [name of character] landed safely? Did your space friend survive the fall? Did your design work like you wanted it to?*
- Help learners remove the phone and check the results in the app, and use the results to motivate iteration, keeping in mind that the numbers in the app are meant to allow for gradual improvement of designs (rather than the success or failure of an egg-drop challenge): *Do you think you can get a lower number than that in the app? How could you make it safer for your character? Could you make it land more softly/slowly?*

All icons at below are from the Space2 Collection by Nook Fulloption from thenounproject.com



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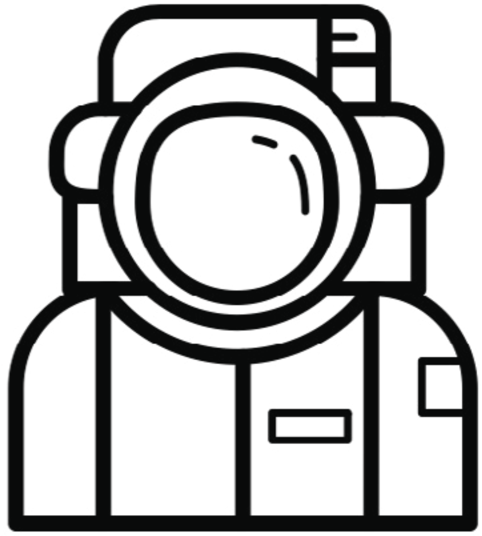

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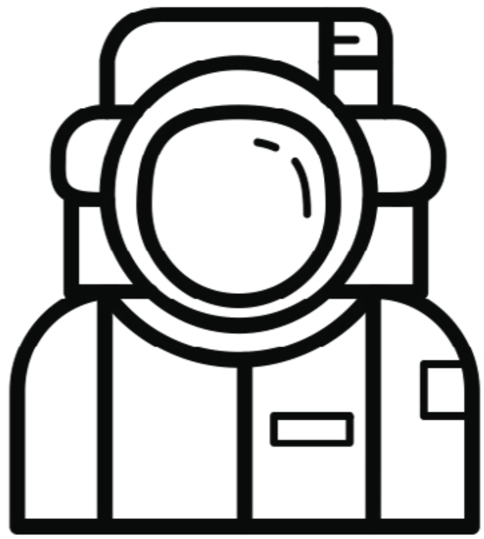

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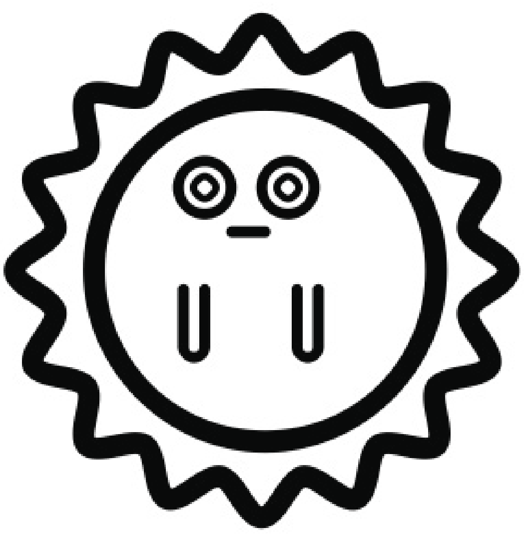

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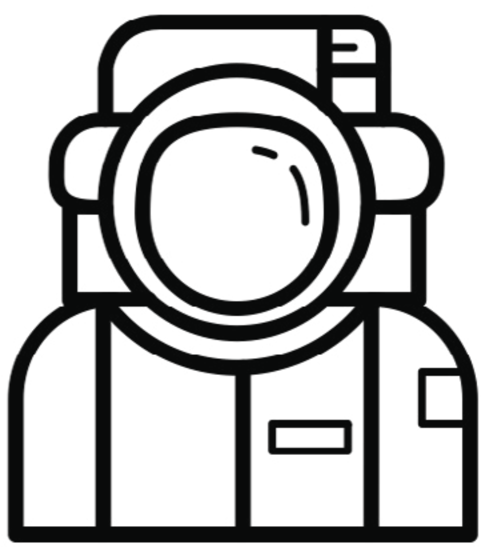


NAME: ______________

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners talk about their character while building or testing their designs.
- Elaborating on the narrative: Learners create additional characters, or extend the story by inventing other details about their character and where they are going.

Empathy indicators

- Emotional responses: Learners express concern for their character's safety or well-being (for example, being hesitant to drop them off the ledge, or being concerned for their characters after a rough landing).
- Perspective-taking: Learners talk about or act out how their characters would use their designs or imagine what it might be like to be inside of a spaceship or land on a planet.
- Prosocial responses: When learners are asked about the rationale for their design decisions, they might describe wanting their structures to be safe/ secure for their characters.

Engineering practices

- Ideation: Learners generate divergent ideas for different kinds of designs, or brainstorm how their design might look or function.
- Problem scoping: Learners consider the force and speed of the fall, their character's comfort, or other design features (e.g., windows, seatbelts).
- Testing: Learners test one or more prototypes by dropping them from the testing station, or conduct small-scale tests by dropping designs onto the table or the floor.
- Iteration: Learners change or add to their designs to make them more stable, safe, or comfortable, or try a completely new design. Groups of learners might decide to combine or compare their ideas.

6. Shadow Stories

Integrating narrative through learner-centered storytelling

ABOUT THIS ACTIVITY

This activity invites learners to tell their own stories using shadow puppets, scenery, and backgrounds.

Where we started
Many of our spaces had offered light and shadow activities in the past, and we noticed that this activity naturally encouraged storytelling as visitors created shadow puppets or scenes with light, color, and shadow. We did not have to alter this activity very much to turn it into a narrative-based engineering activity; it gave us an opportunity to amplify the storytelling that already occurred and to explore the impact on empathy and engineering practices. It also allowed us to experiment with combining characters and settings in a different way than in our previous activities — through the characters and settings that learners created, rather than those that we suggested.

Engineering goals
Learners explore and manipulate a range of transparent, translucent, and opaque materials to create effects with light and shadow. The focus is on generating ideas (ideation) and testing and iteratively improving their designs to create a scene or story of their own design.

Narrative elements
This activity combined characters (shadow puppets made from different kinds of materials) and settings (props or backdrops that set a scene). We encouraged learners either to invent their own story or add to scenes that other learners had started.

Backstory and key decision points

Using materials that encouraged storytelling: To spark learners' ideas for their stories, we used materials that were familiar and evocative — fake plants made from plastic or fabric, and cookie cutters shaped like animals, stars, and flowers that learners could trace onto translucent or opaque materials and cut out to create silhouettes. We used backdrops and props representing trees, clouds, or buildings to create a setting (such as an underwater scene, a city, or a scene related to a holiday like Halloween) to inspire ideas for stories.

Using facilitation to prompt learners to extend and add to their own or others' narratives: In our initial prototyping, we found that many learners created a single puppet or character. Facilitation was essential in prompting learners to think about who else might be in their story, where they might go, what they might do, and what the scene included.

Prompting testing and iteration with light and shadow: We also noticed that sometimes learners did not test their puppets in the light at various stages of the design process without prompting. Facilitators encouraged testing in many ways — by inviting learners to explore materials in the light before building, by asking learners if they had tested their puppets yet, or by encouraging them to change the direction or distance of the light and use these effects to tell a story involving something shrinking or getting larger.

FINAL ACTIVITY DESIGN

Problem frame
"Use any of the materials that you see to tell a story with light and shadow."

This activity included a range of materials and facilitation prompts to encourage storytelling and iteration as learners designed and tested their shadow puppets and scenery. There are many options for adapting this activity to include various materials, prompts, and backdrops. Keep the focus on how learners can use light and its interactions with different materials to create effects that help tell the story they have in mind.

Design Principles in Action

Design Principle	*Implementation in Shadow Stories*
Start with engineering goals	Engineering design process; Properties of materials, light, and shadow
Use characters and settings	Narrative in the settings and characters that learners create or elaborate
Choose a point of view	Learners take the point of view of the characters they create
Spark learners' own ideas	Materials and backdrops inspire ideas for stories
Provide choice	Learners decide on their own stories and scenes; materials allow for multiple possible solutions
Reinforce narratives	Facilitators and materials encourage storytelling
Test, observe, iterate	Materials and facilitation prompts adjusted to support ideation and iteration and extend learners' stories

Time
15 minutes +

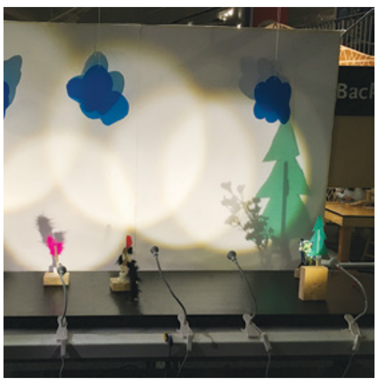
Constraints
Requires a somewhat dark space (see options below), materials intensive (uses a lot of consumable materials)

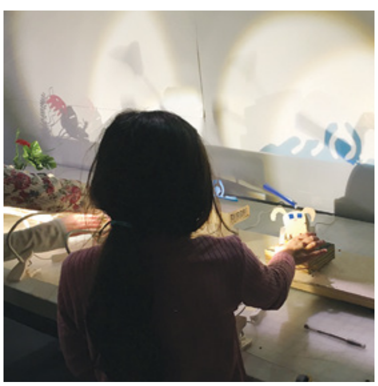
Physical Setup
1 or 2 large tables with multiple clip lights with bendable necks mounted along the edge (see image below); a blank wall, projection screen, or foam core pieces taped to the wall

Signage
Whiteboard or sign with the name of the activity ("Shadow Stories"). In this case, facilitators introduced the problem frame to learners individually as they began the activity.

Options and Alternatives

If you do not have a dark enough space for shadows to be visible on a large screen, individual stations may work better. To create individual stations, build small screens or cubicles with corrugated cardboard, with white foam core or paper as a projection surface, and clip one or two lights at each station (see images below). If you use a translucent material that allows shadows to pass through, you can also place a mirror at an angle behind the projection surface to allow the designers to see how their shadow images might look to others, or ask them to make their shadow puppets perform for others in their group.





Materials

- Clip lamps with bendable necks
- A variety of transparent, translucent, and opaque materials (e.g., gels, thin paper, plastic, fabric, gauze, netting)
- Other building materials can include (but are not limited to): cardstock, string, craft wire, pipe cleaners, cookie cutters for tracing shapes, fake flowers/leaves, ribbon, etc.
- Hole punches, scissors
- Wood blocks, chopsticks, popsicle sticks, and masking tape to create stands, props, or platforms for shadow puppets

Facilitation

Helping learners get started

- Show some examples of puppets or scenes that others have created.
- Invite learners to use any of the materials they see to tell their own story or add to one of the scenes they see.
- Groups can work together to create a set of characters to tell a story, or work on a background and the characters who might be there.

Supporting problem scoping and ideation while building

- Help learners find and use materials (e.g., giving permission to cut up gels and cardstock, showing how to trace shapes or attach pieces together as needed).
- Ask learners to tell you about their ideas for their characters.
- Ask learners about the story they have in mind: *Where would your characters be going? What would they be doing? Is anyone else there too?*
- Encourage learners to think about the mood for their story, and how they can use light, props, or other elements to communicate the mood: *Is the scene cheerful, spooky, sad, adventurous? How can you show that with light and shadow?*

Encouraging testing and iteration

- Encourage learners to test out their puppet often by placing it in front of the light to see if it looks the way they want it to.
- Prompt learners to play with the direction of the light or the distance between their puppet and the light to explore other interesting effects.
- Help learners troubleshoot and find materials that will do what they had in mind, or brainstorm alternatives.
- See if multiple learners or groups might be able to use all of their characters to tell a story: *What would happen if your characters met? Can you use all of your characters to tell a story? What other props or backgrounds would you need?*
- Help learners take a video of their puppet show in action.

Indicators of Success

Engagement with the narrative

- Referencing the narrative: Learners look at or talk about the scenes or puppets that others have created.
- Elaborating on the narrative: Learners tell their own story or add to one of the scenes that they see.

Empathy indicators

- Emotional responses: Depending on the stories they create, learners may imagine characters' excitement, happiness, or other emotions.
- Cognitive perspective-taking: Learners imagine what their characters would want or need. They might also think about events in the story from their character's point of view, or act out how characters would respond to the imaginary situation.
- Prosocial behavior: Learners create scenes in which characters need help or protection, or in which characters work together or cooperate.

Engineering practices

- Ideation: Learners think about different ways to create puppets and set up the scenes (e.g., generating ideas for characters, adjusting lights to create shadows in different shapes or colors to convey the character or story).
- Problem scoping: Learners consider how they can use the properties of the materials to make their puppet resemble the character that they have in mind (e.g., how they might use what's available to depict legs, hair, wings, fins). They might also consider other effects they would like to produce (e.g., making moveable parts, using the distance of the light for effect, changing the mood of the scene with color or backgrounds).
- Testing: Learners try out different materials and positions of the lights to see what characters' shadows look like, or tell part of their story before deciding what to add next.
- Iteration: Learners change or add features to improve their designs, adjust the materials they used to build the characters or scenes, or add to their stories to create more characters, change the mood or scenery, or extend the plot.

FACILITATION CARDS

The facilitation cards below include sample prompts that facilitators can use to reinforce the narrative at multiple points throughout the activity. You can create facilitation cards for each activity that you develop, using the ones below as examples.

EMERGENCY STRUCTURES

Helping learners get started:

- Explain the challenge: "Build a structure that can protect everyone in your group in an earthquake!"

Supporting problem scoping and ideation:

- Remind learners of the narrative while building: "Will you be safe inside? Is there room for everyone?"

Encouraging testing and iteration:

- Help learners test their structures by shaking and tipping (with learners inside to make sure they fit!)
- Ask what they could change to make the structure safer for those inside.

HELP THE PETS

Helping learners get started:

- Introduce the challenge: "All of these pets need someone to take care of them. Can you build something that will help?"
- Have some examples set up to inspire creative ways of using materials.

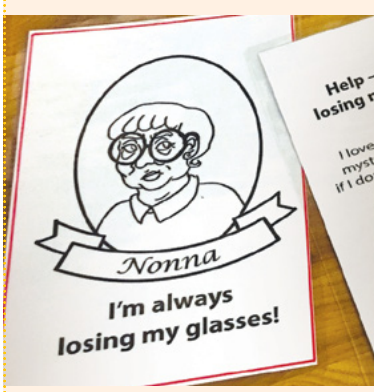
Supporting problem scoping:

- Ask learners what the pets might need or what would make them happy.
- Encourage learners to pick a name for their pet, or think about their own pets.

Encouraging testing and iteration:

- Help learners troubleshoot problems, or suggest further challenges that might help the pets: "What else would be fun for them? What else might they need?"

HELP GRANDMA



Helping learners get started:

Help learners pick someone to help: "Each of these people has a problem that they need help with. Can you design an invention to help them?"

Supporting problem scoping and ideation:

- Talk about the problem Grandma is facing and learners' own everyday experiences.
- Remind learners to read all the information on the card as they plan their designs.

Encouraging testing and iteration:

- Ask learners to tell you about their design and how Grandma will use it.
- Ask what else would make the design easier, safer, more useful, etc.

AROUND THE WORLD

Helping learners get started:

- Introduce the challenge: "Design a vehicle to help you travel around the world using only wind power."
- Ask learners: "Where do you want to travel to?" Show the testing stations.

Supporting problem scoping and ideation:

- Encourage learners to extend the story: "Where are you going? What will you do there? What will you need?

Encouraging testing and iteration:

- Ask learners if their vehicle worked the way they wanted it to, and how they could make their design better to travel in.
- Encourage learners to try their design in other landscapes.

SAFE LANDING

Helping learners get started:

- Introduce the challenge: "Our space friends need help landing safely on a planet!"
- Help learners choose a character to help and ask them to give it a name.

Supporting problem scoping and ideation:

- Attach the character to a smartphone with an accelerometer app.
- Ask learners about how their design will protect their character.

Encouraging testing and iteration:

- Help learners test their designs and check their results in the app.
- Ask what happened when their design fell, whether they think their character landed safely, and how they could make their design land more safely or slowly.

SHADOW STORIES

Helping learners get started:

- Invite learners to tell a story: "Design shadow puppets and scenery to tell a story with light and shadow."
- Show examples of puppets/scenes that other learners have created.

Supporting problem scoping and ideation:

- Ask learners what kinds of characters or stories they are interested in.
- Help learners explore materials to spark ideas, or encourage them to add to a scene that others started.

Encouraging testing and iteration:

- Encourage learners to test out their puppets often by placing them in the light.
- Prompt learners to experiment with the direction of the light to create effects that can help tell a story.

CONCLUSION

Throughout this guide, we have shared our process for developing narrative-based engineering activities, and the strategies we found to be most effective for inviting girls' into engineering and supporting their engagement in engineering practices. We hope that the activities we developed and the lessons we learned from this work inspire you to reimagine your engineering activities in ways that foster empathy for others as an integral part of the engineering design process. By experimenting with different ways of using narrative elements in your work, you can apply and build on these techniques to create more inclusive and engaging entry points into engineering for all learners.

For more information:
Articles and other resources related to this project will be shared at:
https://www.informalscience.org/understanding-how-narrative-elements-can-shape-girls-engagement-museum-based-engineering-design

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