Design Challenge Resource Collection

Module 1: Introduction to Design Challenges

This module is part of a Design Challenge Resource Collection, developed by a cross-functional team at the Oregon Museum of Science and Industry (OMSI) with decades of experience conceptualizing, developing and building museum exhibits. The collection is intended to support exhibit developers and designers as they work to create interactive design challenges.

These modules are designed for someone to read individually or facilitate with a team. There are great benefits derived from collaborating on the exhibit development process. Throughout the modules, activities for groups of individuals are called out in blue boxes.

Team Activity

Discussion prompts and other activities for groups are in blue boxes like this one.

Each module stands alone; there is no specific order to explore the modules, nor is there a need to read them all. However, in some cases, references are made between modules for opportunities to learn more. Finally, these resources are not meant to be prescriptive, but rather examples, tools and approaches the OMSI team has found valuable in the development of non-facilitated engineering design challenge exhibits for the museum floor that are accessible, relevant and engaging for visitors.

The entire set of resources can be found on the *Design Challenge Resource page*

1. Introduction to Design Challenges
2. Exploring Design Challenges
3. Approaches to Exhibit Accessibility
4. Testing a Design: Measures of Success.
5. Exhibit Design Sprints
6. Graphic Development for Design Challenges
7. Prototyping Design Challenge Exhibits
8. Participatory Co-development of a Bilingual Exhibit
9. Documenting Exhibits: The Exhibit Record Tool

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Introduction to Design Challenges

This module provides a brief overview of how design challenges are defined and used in both classrooms and informal settings. Examples of engineering design challenges from museums are provided to highlight different approaches to design challenges in informal settings. This is by no means an exhaustive look at all the design challenges out there; however, it will examine a few useful examples and give a brief history of design challenges at OMSI.

Before you begin, think about the characteristics of a design challenge you've interacted with. What makes a design challenge stand out to you?

Team Activity

As individuals, take two minutes to write down a few design challenge exhibits you have experienced, and your ideas about the characteristics of design challenges in general.

As each person shares their ideas and experiences, record them on chart paper or whiteboard. Discuss features of design challenges that are memorable as well as similarities and differences in characteristics mentioned.

Characteristics of an Engineering Design Challenge

What exactly is a design challenge?

People don't agree about the definition of a design challenge; there are, however, commonly-cited characteristics. Typically speaking, design challenges:

- Involve a clear problem or goal (distinguishes design challenges from tinkering, making, or craft design)
- Present an open-ended problem—one that has many acceptable (though not optimal) solutions
- Present an ill-structured problem, that is, one that cannot be solved routinely by simply applying mathematical formulae in a structured way
- Result in a solution that is a human artifact or procedure
- Encourage use of engineering design practices
- Have multiple entry points, and can be addressed by people of all abilities
- Uses science and/or math

For a deeper discussion on defining design challenges, take a look at Incorporating Engineering Design Challenges into STEM Courses (Householder and Hailey, 2012).

You should define the desired qualities of a design challenge for yourself—your definition might not look like this list, and that's okay. You just need to be deliberate about your reasoning. For example, with OMSI's Creatividad silvestre | Wild Creativity exhibit, the goal was to engage visitors in engineering practices as defined by the C-PIECE Framework (*https://omsi.edu/wp-content/uploads/2023/02/C-PIECE-Framework-A-graphic-research-summary.pdf*). Throughout the development process, the team prioritized challenges that would foster engagement in these practices.

Design Challenges in Formal Settings

Design challenges in the classroom are necessarily going to look different than those at an unfacilitated exhibit; however, it's useful to touch on design challenges in the classroom because that's where problem-based learning/design-based learning starts. Classrooms are where much of the research has focused. Also, it's useful to start in classrooms, move to facilitated programs and exhibits, then move to unfacilitated exhibits, because the difficulty of designing successful activities progressively ratchets up.

Design challenges change the way work in the classroom is traditionally done: they create personalized, open-ended group work aimed at an ill-structured problem (this doesn't mean the problem isn't clear, but simply that there are implicit constraints and many possible paths toward a solution). They move away from a competitive atmosphere, in which each student is working individually on an identical set of problems designed to allow for only one correct answer, and create an atmosphere of collaboration, in which group participants are working together toward a shared purpose. They also require more social work from the teacher: social dynamics within groups can make or break the experience, and students often need help navigating the emotions associated with "productive failure," which is a hallmark of successful design challenges.

Because of all this, teachers can struggle when implementing design challenges: they require social work and mediation, they take a lot of time, and they can feel chaotic or like there isn't "teaching" happening around science and math subject matter.

Why use a design challenge?

Research shows* that design challenges and problem-based learning:

- Heighten conceptual understanding
- Support long-term retention of science and math skills
- Promote abstract or systems thinking
- Lead to success in science class

- Decrease the achievement gap between some demographic groups
- Increase interest and self-efficacy in engineering
- Promote desire to learn
- Teach the design process
- Raise awareness about what engineers do
- Help students learn to communicate and express themselves
- Build confidence, self-esteem, and leadership skills

The impacts listed here are largely due to what researchers call "productive failure." Students who experience frustration during an engineering design challenge gain more competence in applying the science and math skills they were using than students who don't (Householder and Hailey, 2012). As a result, successful design challenges intentionally push students to the point of frustration (but not so far as to make them give up). You can imagine that this is a much easier balance to navigate when a teacher or facilitator is there in person. Research also shows that design challenges do these things, but a single design challenge doesn't need to (or even can, arguably) do all these things at once.

Design Challenges in Informal Settings

Many museums have facilitated drop-in spaces for 'tinkering', 'making' or completing design challenges. Some examples include:

- Museum of Science, Boston's rotating Design Challenges (*https://www.mos.org/drop-in-activities/design-challenges*)
- Ingenuity Challenges at LawrenceHall of Science (*https://www.lawrencehallofscience.org/visit/exhibits/design_build_test/ingenuity_lab*)
- Exploratorium's Tinkering Studio (*https://www.exploratorium.edu/tinkering/about*)

* See citations at the end of the module

The following examples present a closer look at some design challenge experiences in museums.

Science Museum of Minnesota "Tapered Wind Tube"

At the "Tapered Wind Tube", visitors are challenged to make and test a 'wind rider' that will travel up and out a tall wind tube and land upright as it comes back to ground.

This activity has many of the characteristics of an engineering design challenge: it is open-ended and ill-structured, it requires practicing engineering processes, and there is a clear goal. Without that goal, it would still be a popular and compelling experience, but by definition, would be a maker, tinkering, or inquiry activity.

Science Museum of Minnesota “Pneumatic Ball Run”

The “Pneumatic Ball Run” challenges visitors to devise a system that will move a ball horizontally from a set starting point to a set finish. This exhibit really focuses on the characteristic of applying science or math to complete the challenge—the task can’t be accomplished without the application of pneumatic principles.

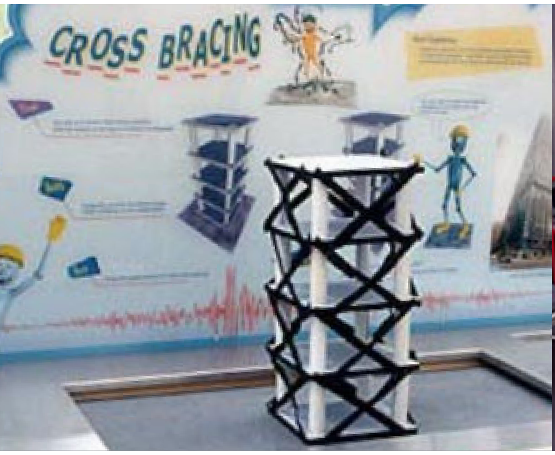
Museum of Science, Boston “Solar Cars”

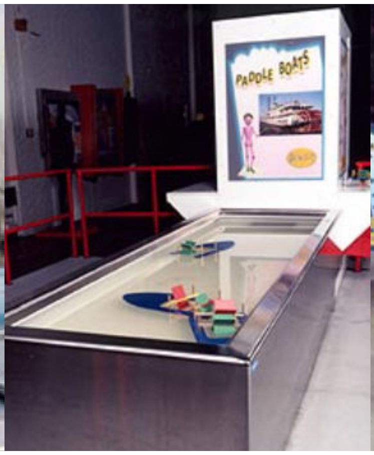
“Solar Cars” is a facilitated, constructivist activity where visitors practice science thinking skills as they come up with their own questions to investigate and test the answers to these questions with the solar cars. This activity was not originally designed to be an engineering activity; however, it has many characteristics of one: designs are created, tested and refined by the visitor. In order to change “Solar Cars” into an engineering activity, educators at MOS picked one goal and asked the visitors to try to achieve it.

A central challenge faced by developers and designers who create unfacilitated design challenges is how to set up the exhibit to provide support traditionally provided by a facilitator. Remember, the shift to design challenges in classrooms required teachers to support and facilitate a far more complex set of social dynamics and emotional work. When we commit to an unfacilitated design challenge, we are banking on the aspiration that our exhibits can provide all of this social scaffolding in the place of a human being.

OMSI *Engineer It!*

Engineer It! was OMSI’s first NSF-funded foray into engineering design challenges. The intention of Engineer It! was to invite everyone, but particularly children, to explore engineering in a practical sense and to have opportunities to test, observe, invent and enjoy. Many of the challenges were more directive than our museum is trending toward now—for several, there was a “right” answer.





OMSI *Design Zone*

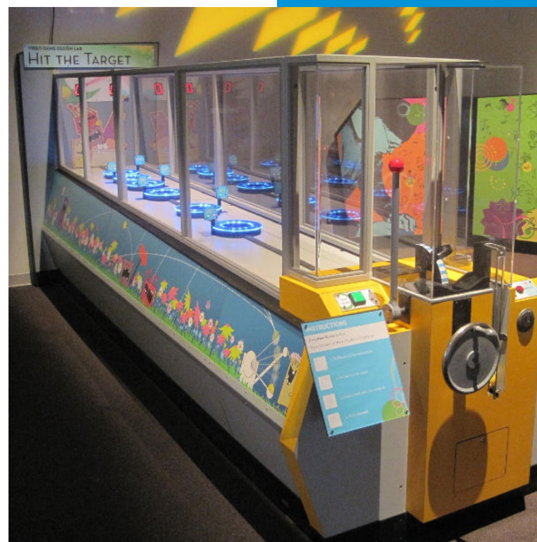
Design Zone's primary objective is to engage visitors in algebraic thinking.

Not all design challenges are "about" engineering or the design process. Design Zone uses design challenges to engage visitors in algebraic thinking.

Design Zone focuses on helping caretakers serve as facilitators by providing panels specifically designed to help them understand the activity so that they can explain it to their children.

From summative evaluation:

Design Zone sought to engage caretakers as facilitators, and this strategy was effective: When parents were engaged, 50% of students engaged in algebraic thinking; when they were not, only 31% engaged.



For more details on the uses of and approaches to graphic panels in design challenges, see Module 6: Graphic Development for Design Challenges in OMSI's Design Challenge Resource Collection: https://omsi.edu/for-museum-professionals/designing-our-tomorrow/design-challenge-resource-collection/

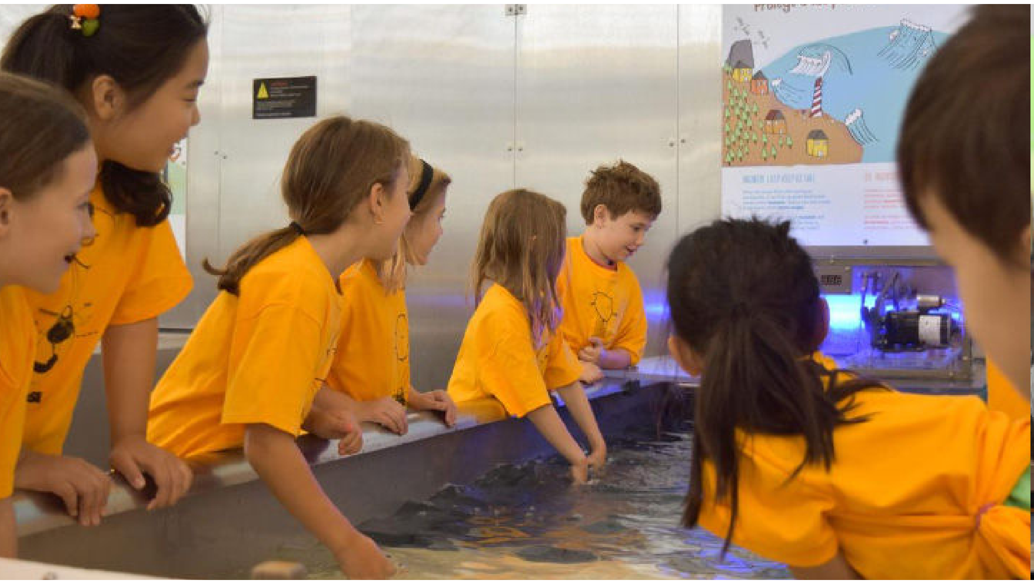
OMSI *Human Plus*

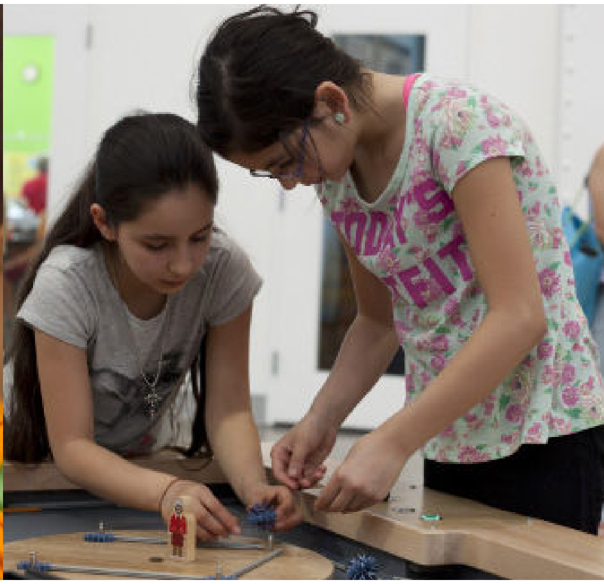
In Human Plus, visitors experience a creative, dynamic engineering process that considers the end user every step of the way. Featuring real-life people, the challenges they face, and how they overcome them has the potential to foster visitors' empathy in the exhibit experience, adding another layer of motivation to their problem solving.

Human Plus offers a range of design challenges created to involve visitors in user-centered engineering processes. It presents personal stories of users and engineers to emphasize that engineering is about people and requires empathy. Its design and content also highlights the design process.

The personal stories in Human Plus were more or less successful depending on how integrated into the activity they were. For example, the component pictured above challenges visitors to create a reacher-grabber to help a wheelchair user care for their pet.

As we can see, the personal story is very obvious both in the copy and the graphics; nevertheless, it's possible for visitors to understand the challenge (create a reacher-grabber) without using the story, so it's often ignored. The design challenge itself is, in a way, so intuitively successful that it undermines the storytelling goals of the larger exhibition.



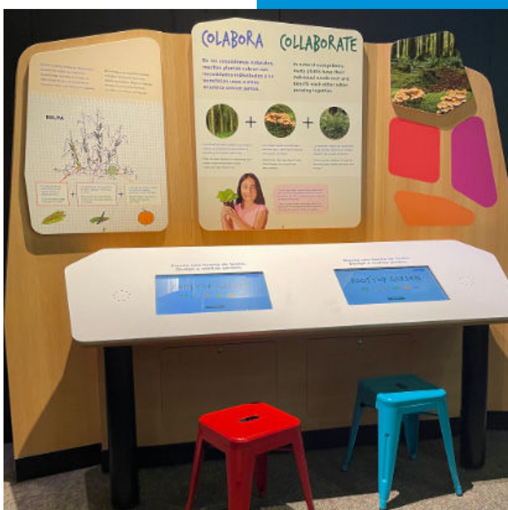


OMSI Designing Our World

Designing Our World is a project that relied most heavily on facilitated design challenges with after-school programs, but it also updated Engineer It! challenges to be more open-ended and bilingual (Spanish/English). Both the facilitated programs and the unfacilitated exhibition focused on the message that engineering is altruistic, personally relevant, and social.

OMSI *Creatividad silvestre* | *Wild Creativity*

Creatividad silvestre | *Wild Creativity* is a bilingual Spanish/English traveling exhibition that engages visitors in biomimicry, an approach to engineering that draws inspiration from nature's ingenuity to design solutions for the challenges we face in our own communities and around the world.The exhibit built on research and experiences with Designing Our Tomorrow to frame engineering and design challenges in ways that appeal to the target audience, girls ages 9 to 14 and their families. These include experiences that are collaborative - can do them with their friends or family, altruistic - can be used to help people, and relevant - can be used to solve problems that they recognise in their communities and around the world. The exhibit features three community challenges designed to engage visitors in engineering practices from the C-PIECE framework (Collaborative Practices at Interactive Engineering Challenge Exhibits: *https://omsi.edu/wp-content/uploads/2023/02/C-PIECE-Framework-A-graphic-research-summary.pdf*). Each community-based challenge was introduced by a fictional character to help audiences relate.

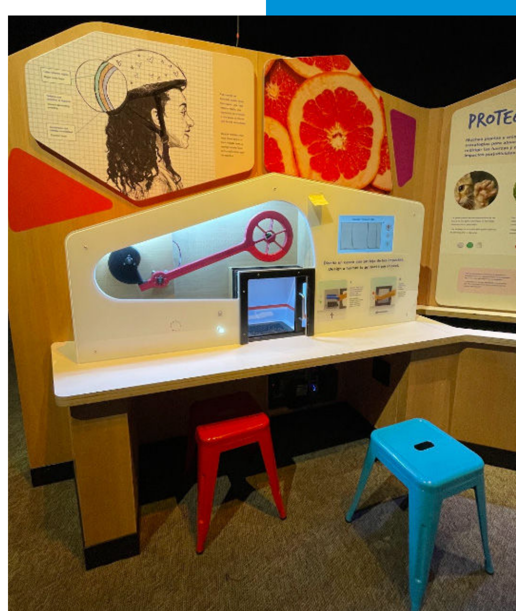


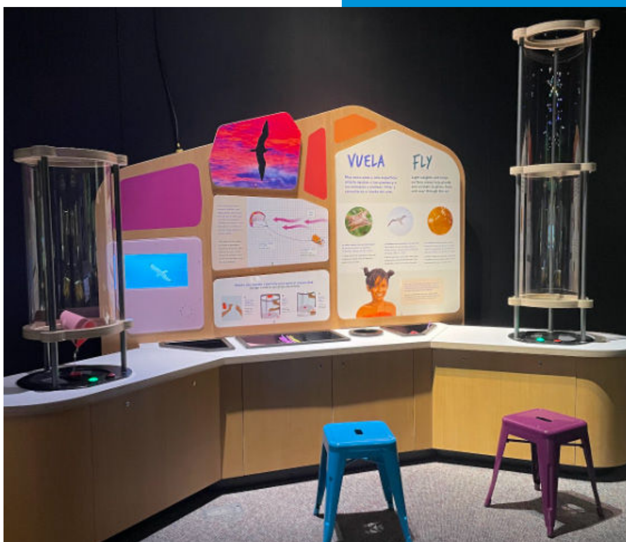
"Colabora | Collaborate"

At this iterative game, visitors are invited to use a touchscreen interface to design a garden that produces the most yield, which can be improved by mimicking natural ecosystems where certain plants are benefitted by growing near one another. Visitors are prompted to place crops in different squares on the digital garden, then improve their design to grow fresh produce with an urban family. After filling the garden with crops of their choice, on-screen feedback offers a yield score encouraging visitors to try again for a higher yield by utilizing biomimetic systems strategy.

"Protege | Protect"

Visitors select and stack inserts modeled after hedgehog quills, cat paw pads, and pomelo rinds into a cabinet to design a helmet cushion that will protect a bicycle rider. After closing the door, visitors see a hammer fall, putting impact, or force, on their design. The measure of force under the design is displayed as on-screen feedback. Visitors continue to iterate to improve their design and create the safest possible cushion for a bike helmet.





“Vuela | Fly”

Mimicking natural strategies like flying squirrels, dandelion seeds, and gliding birds, visitors design, build, and test kite models that could be connected to a turbine to generate electricity to charge a cell phone. Bins provide a variety of materials for visitors to construct a kite that floats in a wind tube. Once visitors connect their design to a test station and push the button, the lift of the kite pulls on a measurement device and on-screen feedback displays a real-time measure of the turbine’s energy generated by their kite, encouraging visitors to iterate its design.

Summary of Design Challenge Overview

After years of experience creating exhibits, OMSI developers have come to realize that unfacilitated design challenges are extremely complex exhibits to develop, but seem simple when they’re done well. The content and design must integrate seamlessly to guide visitors through a social, creative, and ideally frustrating (but only mildly frustrating) process. The exhibit must do all this while supporting all ability levels and being cognitively, linguistically, culturally, and physically accessible. This isn’t something that an exhibit team—even an experienced exhibit team—is likely to nail without iterative prototyping. Sometimes visitors show up and do surprising, delightfully creative things that completely evade your exhibit’s intent. Sometimes a simple task becomes a stumbling block. We teach visitors that engineers test and improve their designs. That’s exactly what successful design challenges require.

All this to say: teams should expect design challenges to be relatively expensive and time-consuming components to create. Anything they can do to plan for iterative testing will reap rewards in the final product. Read about OMSI’s prototyping processes in the Exhibit Prototyping Resource in OMSI’s Design Challenge Resource Collection: *https://omsi.edu/for-museum-professionals/designing-our-tomorrow/design-challenge-resource-collection/*

Citations

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