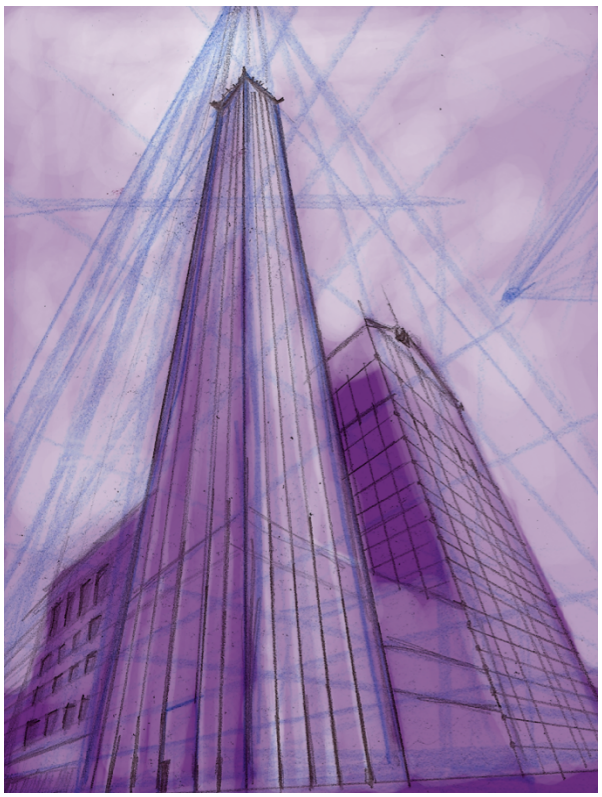
BUILT TO LEARN!

REDESIGNING SHELTER

An Integrated Design Thinking and STEM Curriculum



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The d.loft STEM Learning Project

The *BUILT TO LEARN! Redesigning Shelter* curriculum is a collaboration between the d.loft STEM Learning Project of Stanford Graduate School of Education's REDLab (Research in Education & Design), Stanford University students in the Winter 2014 and Spring 2014 offering of the course, *Educating Young STEM Thinkers*, teachers and students from the East Palo Alto Phoenix Academy in East Palo Alto, CA and the Stanford STEP-Sunnyvale Summer School in Sunnyvale, CA.

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Preface

According to the U.S. Department of Education, only 16 percent of American high school seniors are proficient in mathematics and interested in a STEM career.[1] In 2009, the Obama administration committed to prioritizing science, technology, engineering, and mathematics (STEM) education by launching the "Educate to Innovate" campaign to improve the participation and performance of America's students in STEM fields. This campaign includes efforts not only from the Federal Government but also from leading companies, philanthropic foundations, non-profit organizations, and science and engineering societies to work with young people across America to excel in science and math. Initiatives such as US2020, California STEM Learning Network, Citizen Schools, Code.org, NASA "Summer of Innovation", PBS Innovator Educators Challenge, and 100Kin10 have mobilized to address this issue**.** At this pivotal time, there is a nation-wide effort to increase students entering STEM fields, especially those from underrepresented groups. It is critical that students develop the 21st century skills and tools to participate actively in a society in which problems are increasingly complex and nuanced understandings are vital. The Partnership for 21st Century Skills has stated that developing competency in the areas of innovation, creativity, critical thinking, problem solving, communication and collaboration are essential to preparing students for the uncertain future, both in the job market and in their personal lives[2].

In addition to the economic imperative for STEM education, there is an anthropocentric and ecological imperative. As growing human populations around the world continue to face escalating systemic challenges around health, education, energy, environment, climate, food security, human rights, and poverty, young STEM thinkers and doers will increasingly be a part of the solution. In both in-school and out-of-school contexts, students begin learning the STEM foundations for developing viable solutions to difficult local, national, and global problems. Design thinking – an innovative, human-centered approach to defining and solving complex problems – is a dynamic process that can complement STEM learning in real-world settings. In the design thinking process, students begin by conducting interviews and observations, thus developing empathy for a user. Data synthesis provides the opportunity to uncover deep user needs and insights. Generative brainstorming techniques will give student tools to create innovative solutions using STEM knowledge and 21st century skills. In teams, they will build prototypes, test them, and incorporate user feedback. Students will leave this learning experience with the creative confidence to become active problem solvers in innovative, human-centered ways that will help them confront the challenges and possibilities that surround us in the 21st century. The d.loft STEM project goal is to introduce students to the design thinking process through hands-on, interactive learning activities that foster deep content knowledge in STEM fields and those engaged in STEM careers. This curriculum is a natural extension of that project goal. Through fostering these 21st century skills through STEM and design thinking, we hope that students will feel empowered to be change agents in their communities and beyond.

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[1] "Science, Technology, Engineering, and Math: Education for Global Leadership." U.S. Department of Education. <http://www.ed.gov/stem>

[2] "Framework for 21st Century Learning." Partnership for 21st Century Skills. <http://www.p21.org/our-work/p21-framework>

Introduction: A Teacher Guide

BUILT TO LEARN! Redesigning Shelter: An Integrated Design Thinking/STEM Curriculum provides an overview of the project goals, background information on design thinking, a teacher guide with teaching tips, a curriculum calendar overview, descriptions of materials, lesson plans, and material lists and resources.

Purpose

BUILT TO LEARN! Redesigning Shelter: An Integrated Design Thinking/STEM Curriculum provides an integrated approach to building STEM knowledge and skills while engaging students in both identifying and solving real-world problems using a design thinking approach. The focus of this year's curriculum is redesigning shelter. In this four-week program, students explore shelter-based design thinking challenges and STEM activities related to shelter. The curriculum focuses on the intersection between design thinking, STEM, and shelter.

The foundation of the curriculum is an enduring understanding: *students will develop the creative confidence to fail forward by building successful shelters using both STEM concepts and the empathy-driven design thinking process*. David Kelley, the founder of IDEO and Stanford's Hasso Plattner Institute of Design (d.school) describes creative confidence as "having the courage to take creative risks (and fail) and the knowledge that all of the ideas you create have value."[3] Likewise, a "fail forward" mentality refers to "the never-give-up attitude of being willing to fail early and often in order to learn as much as possible to produce the best possible solution through real experience."[4]

Scope and Sequence

This curriculum was designed for use at a Sunnyvale, California summer camp program for science teachers and student teachers from the Stanford Teacher Education Program (STEP), a teacher preparation program offered through Stanford's Graduation School of Education. The camp is designed for students in grades six through eight. The curriculum is modular and may be used in a variety of summer camp, after-school program, and workshop settings.

The curriculum builds its foundation on *design thinking*, an innovative, human-centered process taught at Stanford's d.school. The design thinking method and mindset are highlighted in the section below. The curriculum is divided into three major design thinking challenge modules, ranging between five to eight one-hour periods, along with additional standalone STEM activities. If your camp is shorter than the Sunnyvale summer camp, you could eliminate the second or third module; if it's longer, you could include some of the additional activities throughout the camp. In essence, the last two design thinking challenge modules function as

[3] "Defining Creative Confidence." OpenIDEO. <https://openideo.com/challenge/creative-confidence/inspiration/defining-creative-confidence>
[4] Poole, Lance (2013) "Product Matters!" Society of Actuaries. <http://www.soa.org/library/newsletters/product-development-news/2013/february/pro-2013-iss85-poole.aspx.>

both capstone experiences that tie together students' learning of the STEM concepts in the curriculum.

The first module, *The Personal Shelter Design Challenge,* begins with an introductory design challenge. This challenge gives students a brief overview of the process. Subsequent activities dive deeper into the design process by providing students with the opportunity to learn and practice the nuances of the design thinking process.

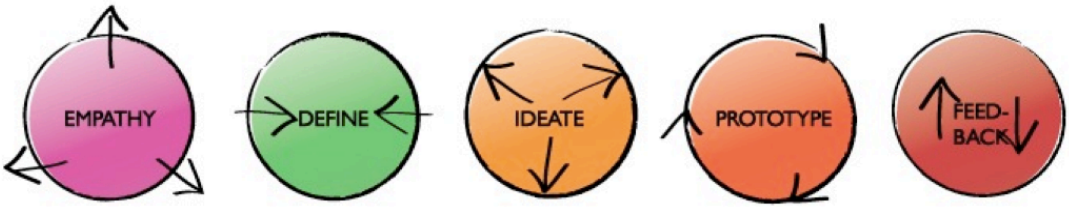
The second module, *The Global Shelter Design Challenge: Redesigning the Shelter Experience for Refugees in the Developing World*, has students empathize with children of roughly their age, who live in refugee camps in the developing world and do not have access to the same learning and play spaces, ranging from schools to playgrounds. They will put to practice the knowledge and skills they gained from the first module as well as some of the STEM concepts in the preceding units. They will move through the stages of the design process, from empathy to prototyping, eventually creating a prototype to address the needs of these children.

The third and final module, *The Local Shelter Design Challenge: Redesigning the School Shelter Space,* brings the curriculum closer to home as students apply their skills to working on a project to benefit their own community and school. They use design thinking and their STEM knowledge and skills gained throughout the curriculum to design a school shelter for a specific user. Their final products will be presented on the final EXPO day.

In addition to the three design challenge modules, there are 7 STEM-based units focused around different shelter topics: building principles, architecture, sustainability, structure and building materials, global shelter, biodiversity, and STEM careers. These units complement the design challenges by providing the background STEM knowledge and skills needed to create the best design solutions for a variety of users. These 7 content areas were chosen because they captured the variety of different considerations that engineers, architects, ecologists, and designers have to consider when thinking about shelter.

The curriculum is designed around the framework provided by these 3 design challenge modules and 7 STEM-based units, together forming 10 units for the entire curriculum. The units have been sequenced to build upon each other, and the recommended sequence of the units is detailed below in the Curriculum Overview section of the Introduction. We realize that in order to be adaptive to student needs, facilitators and teachers may want to sequence lessons or units differently. While STEM-based units and lessons can be moved around, we highly recommend that coaches complete the lessons within design thinking challenge modules in sequence as these lessons more specifically build upon each other. In addition, while many of the activities can stand on their own, teachers and facilitators should ensure that students have the relevant background knowledge in order to fully engage with the materials.

The Design Thinking Process



There are many different strategies that enhance learning. Design thinking is an orientation toward learning that encompasses active problem-solving and believing in one's ability to create impactful change. It engenders a sense of creative confidence that is both resilient and highly optimistic. David Kelley, founder of design consultancy IDEO and Stanford's Hasso Plattner Institute of Design, says, "My contribution is to teach as many people as I can to use both sides of their brain, so that for every problem, every decision in their lives, they consider creative as well as analytical solutions."[5][6] This model, which has energized business innovation, is being applied to K-12 education with considerable impact.[7] With its central emphasis on human needs, it refocuses curriculum and assessment and forefronts solving real-world problems.

EMPATHIZE

Design thinking is a process of human-centered innovation, and empathy is its foundation. To empathize, you observe; you view users and their behavior in the context of their lives. You engage; you interact with and interview users through both scheduled and short encounters. You immerse; you put yourself into someone else's shoes and experience what they experience.

As a human-centered designer you need to understand the people for whom you are designing. The problems you are trying to solve are rarely your own – they are those of particular users; in order to design for your users, you must build empathy for who they are and what is important to them.

DEFINE

During the define phase of the design thinking process, you develop a Point of View statement, a guiding statement that focuses on specific users, insights, and needs that you uncovered during the empathy mode. The Point of View statement is a clear and concise sentence that is referred back to as you move through a design challenge.

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[5] "IDEO's David Kelley on 'Design Thinking.'" Fast Company. <http://www.fastcompany.com/magazine/132/a-designer-takes-on-his-biggest-challenge-ever.html>

[6] "New Designs for Learning: A Conversation with IDEO Founder David Kelley." Learning First Alliance. <http://www.publicschoolinsights.org/visionaries/DavidKelley>

[7] Carroll, M., Goldman, S., Britos, L., Koh, J., & Royalty, A. (2010). Destination, Imagination & The Fires Within: Design Thinking in a Middle School Classroom. International Journal of Art & Design Education. Vol 29 Issue 1 (February 2010)

IDEATE

Ideation is the process of idea generation. Mentally it represents a process of “going wide” in terms of concepts and outcomes. Ideation provides the fuel for building prototypes and driving innovative solutions.

You ideate in order to step beyond obvious solutions. You ideate to harness the collective perspectives and strengths of teams. You ideate to create fluency (volume) and flexibility (variety) in innovation options.

PROTOTYPE & TEST

Prototyping is getting ideas and explorations out of your head and into the physical world. A prototype can be anything that takes a physical form – be it a wall of post-it notes, a role-playing activity, a space, an object, an interface, or even a storyboard.

Testing is the chance to refine prototypes and make them better. You place your low-resolution prototypes into the hands of your user and observe.

Prototypes that fail in the testing mode are just as useful as prototypes that succeed, because they all contribute to the understanding of how to make a good final product. You build by the saying “fail early and often” – by creating a lot of rough prototypes which are just barely good enough to get the essence of your idea across, you’re able to get valuable feedback from users which can be used on another prototype. Going through a few rounds of the prototyping and testing process will give you an incredibly detailed and useful picture of what your final product needs to be.

For more in-depth information on the steps, mindsets, and methods of the design thinking process, please download or view the Stanford d.school Bootcamp Bootleg.[8]

Curriculum Overview

The curriculum is based on an enduring understanding that is critical for students to retain by the end of the learning experience. In addition to the enduring understandings, there are specific unit understandings in each themed unit or module. Finally, each lesson also has its own specific learning objectives. Activities targeting these enduring and unit understandings are woven throughout each individual lesson. These lessons are also tied to specific Next Generation Science Standards (NGSS) for middle school students. A list of these standards can be found on the NGSS website.[9] A Curriculum Overview diagram depicting the Enduring Understanding, Unit Understandings, Next Generation Science Standards, and Learning Objectives can be viewed below.

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[8] Stanford University Hasso Plattner Institute of Design (d.school) Bootcamp Bootleg: http://dschool.stanford.edu/wp-content/uploads/2011/03/BootcampBootleg2010v2SLIM.pdf

[9] Next Generation Science Standards: http://www.nextgenscience.org/search-standards-dci

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Enduring Understanding	Week	Unit/Module	Unit Understanding	NGSS	Lesson	Learning Objectives
Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and the empathy-driven design thinking process.	WEEK 1	Design Thinking	Students will understand the basic steps of design thinking and how they can applied to designing a shelter	MS-ETS1-1	1 Hour Design Challenge: A Taste of Design Thinking	Engage in a design challenge; learn the steps of the design thinking process
				MS-ETS1-1, MS-ETS1-4	The Castle Design Challeng	Practice the design thinking process by designing a castle for a princess in need
				MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Design Challenge 1.0: Redesigning the Personal Shelter Experience	Explore the design thinking process in depth by designing a shelter for a fellow student or teacher
		Building Principles	Students will understand a basic few physics principles and how they apply to building a prototype	MS-ETS1-3, MS-ETS1-4	The Marshmallow Challenge	Learn about structural building principles and teamwork through prototyping
				MS-ETS1-3, MS-ETS1-4	Egg Shelter Drop	Learn about impact force, potential energy, and kinetic energy through prototyping
				MS-ETS1-3, MS-ETS1-4	Floating Egg Shelter	Learn about balance and center of mass through prototyping
	WEEK 2	Architecture	Students will understand how architects use both artistic perspective and scientific concepts to design shelters	MS-ETS1-4	Architecture and Perspective Drawing	Learn and practice about building blueprint creation, perspective drawing, and architecture drafting using buildings in their school
				---	Architect Speaker & Bill Nye Architecture Video	Learn about what architects do and how they use science to build shelters
		Sustainability	Students will understand how different aspects of the energy and sustainability are important in building a green shelter	MS-ETS1-2, MS-PS3-1	Building with Green Materials	Learn about building using natural and recycled materials at school and home; differentiate between materials used in structures
				MS-PS3-3	Keep it Cool!	Learn about insulation and design a structure that minimizes thermal heat transfer in shelters
				MS-PS3-1, MS-PS3-3	Exploring Energy Sources	Learn about the scientific principles and applications behind solar, wind, and kinetic energy through mini-experiments
				MS-ETS1-1	Design a Sustainable Home	Apply the sustainability and energy concepts to designing a shelter for a user
		Structure and Building Materials	Students will understand how the properties of building materials, geometrical shapes, and structural form influence a shelter's function, design, and stability	MS-ETS1-2, MS-PS1-2	Foundations: From Oobleck to Toothpaste!	Learn about building foundations and explore the properties of a variety of common materials in the context of engineering to determine which make for the safest foundations
				MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Building a Waterproof Roof	Design, build, and test a roof design made of different materials; learn about the form and function of roofs
				MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Geometrical Shapes and Composites	Learn about how composite materials, geometrical shapes and beam alignment contribute to the overall strength of the structure; design, build, and test a composite material design
				MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Earthquake-Stable Building	Design, build, and test a toothpick building meant to withstand an earthquake; learn about how simple geometrical shapes can form complex structures for stability

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Enduring Understanding	Week	Unit/Module	Unit Understanding	NGSS	Lesson	Learning Objectives
Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and the empathy-driven design thinking process.	WEEK 3	Global Shelter	Students will understand how the empathy-driven design thinking process can inform the successful design of shelters	MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Design Challenge 2.0: Redesigning the Global Shelter Experience for Refugees	Explore the design thinking process in depth by redesigning a learning space shelter for a young refugee in the developing world
				MS-ETS1-1	Crowded Shelter Challenge	Empathize with those in the developing world living in crowded spaces by building a shelter with space constraints
				MS-ETS1-1, MS-ETS1-2	Infrastructure: Marble Tracks	Design, build, and test "road" prototypes to connect villages in the developing world; learn about the role of infrastructure and engineering principles
				MS-ETS1-1, MS-ETS1-2, MS-LS2-1, MS-LS2-5.	Climate Zones Design Challenge	Learn about the Earth's different climate zones and design shelter prototypes based on the constraints of each geographical location
				MS-ETS1-1, MS-ETS1-2	Designing Healthier Kitchens for Nigerian Women	Empathize with Nigerian women and design healthier kitchens based on their needs; develop criteria for idea selection
		Biodiversity	Students will understand that shelter design also involves protecting biodiversity, including plants and animals	MS-ETS1-1, MS-LS2-5	Goldfish Shelter Design	Learn about the needs and environmental threats that are relevant to goldfish; design a shelter to protect goldfish and meet their needs
				MS-ETS1-1, MS-LS2-5	Building a Biodome for Plants	Design and build a self-sufficient biodome for plants that does not require watering
	WEEK 4	Structure and Building Materials	Students will understand how the properties of building materials, geometrical shapes, and structural form influence a shelter's function, design, and stability	MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Critical Load	Learn about concepts in structural engineering and how to measure the critical load, the weight at which a structure will fail.
				MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Geodesic Dome	Build a geodesic dome, test its strength, and learn about its unique structural principles
		Local Shelter	Students will understand how to apply STEM concepts and the design thinking process to a school-based redesign challenge in their own community	MS-ETS1-1, MS-ETS1-2, MS-ETS1-3	Design Challenge 3.0: Redesigning Shelter Spaces in the School	Explore the design thinking process in depth by redesigning shelter spaces at their school based on the needs of local teachers, students, and other school members; ideate, prototype, test, and present the final product on EXPO day
		STEM Careers	Students will understand how the engaging challenges and opportunities in these lessons tie to real-world STEM careers	---	STEM Career Fair & Speaker Panel	Explore the variety of STEM careers involved in designing, building, and engineering structures and shelters

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		STEM Careers	Students will understand how the engaging challenges and opportunities in these lessons tie to real-world STEM careers	---	STEM Career Fair & Speaker Panel	Explore the variety of STEM careers involved in designing, building, and engineering structures and shelters

Curriculum Lesson Calendar

To complement the curriculum overview, the curriculum lesson calendar below maps out how the lesson plans fit into a 4-week structure for a summer camp or afterschool program. The colors of each lesson align with the unit colors in the overview above.

Week	Hour	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1	Hour A	**A Taste of Design Thinking**	**DESIGN CHALLENGE 1.0 (Personal Shelter): Empathize**	**DESIGN CHALLENGE 1.0: Define**	**DESIGN CHALLENGE 1.0: Ideate**	**DESIGN CHALLENGE 1.0: Prototype & Test**
	Hour B	**The Castle Design Challenge**	**DESIGN CHALLENGE 1.0: Empathize & Define**	**Building Principles: The Marshmallow Challenge**	**Building Principles: Egg Shelter Drop**	**Building Principles: Floating Egg Shelter**
Week 2	Hour A	**Architecture: Perspective Drawing**	**Sustainability: Building with Green Materials**	**Sustainability: Exploring Energy Sources**	**Structure and Building Materials: Foundations - From Oobleck to Toothpaste!**	**Structure and Building Materials: Geometrical Shapes and Composites**
	Hour B	**Architecture: Speaker and Bill Nye Video**	**Sustainability: Keep it Cool!**	**Sustainability: Design a Sustainable Home**	**Structure and Building Materials: Building a Waterproof Roof**	**Structure and Building Materials: Earthquake Stable Building**
Week 3	Hour A	**DESIGN CHALLENGE 2.0 (Global Shelter): Empathize**	**DESIGN CHALLENGE 2.0: Define & Ideate**	**DESIGN CHALLENGE 2.0: Prototype & Test**	**Global Shelter: Climate Zones Design Challenge**	**Biodiversity: Goldfish Shelter Design**
	Hour B	**Global Shelter: The Crowded Shelter Challenge**	**DESIGN CHALLENGE 2.0: Ideate**	**Global Shelter: Infrastructure: Marble Tracks**	**Global Shelter: Designing Healthier Kitchens for Nigerian Women**	**Biodiversity: Building a Biodome for Plants**
Week 4	Hour A	**Structure and Building Materials: Critical Load**	**DESIGN CHALLENGE 3.0 (School Shelter): Empathize**	**DESIGN CHALLENGE 3.0: Prototype & Test**	**Preparation for EXPO DAY**	**EXPO DAY**
	Hour B	**Structure and Building Materials: Geodesic Dome**	**DESIGN CHALLENGE 3.0: Define & Ideate**	**STEM Career Fair & Speaker Panel**	**Preparation for EXPO DAY**	**EXPO DAY**

LESSON PLANS

WEEK 1

UNIT 1: DESIGN THINKING

DAY 1A: A Taste of Design Thinking
DAY 1B: The Castle Design Challenge
DAY 2A: Design Challenge 1.0: Developing Empathy
DAY 2B: Design Challenge 1.0: Empathy Practice
DAY 3A: Design Challenge 1.0: Point of View Statements
DAY 4A: Design Challenge 1.0: Brainstorming Solutions and Idea Selection
DAY 5A: Design Challenge 1.0: Prototyping and Testing

Hour	Day 1	Day 2	Day 3	Day 4	Day 5
A	**A Taste of Design Thinking**	**DESIGN CHALLENGE 1.0 (Personal Shelter): Empathize**	**DESIGN CHALLENGE 1.0: Define**	**DESIGN CHALLENGE 1.0: Ideate**	**DESIGN CHALLENGE 1.0: Prototype & Test**
B	**The Castle Design Challenge**	**DESIGN CHALLENGE 1.0: Empathize & Define**	**Building Principles: The Marshmallow Challenge**	**Building Principles: Egg Shelter Drop**	**Building Principles: Floating Egg Shelter**

Unit Understanding

Students will understand the basic steps of design thinking and how they can be applied to designing a shelter.

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Lesson Plan: A Taste of Design Thinking

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view. Display PPT Slide 1 before they enter the room.
✓ Arrange for students to have wall space on which to place Post-it notes.

Materials

- Prototyping materials (assorted)
- Paper (8 sheets per student
- Post-it notes (1 pad per student)
- Markers (1 per student)

Lesson Overview

In this lesson, students are introduced to the design thinking process. They build empathy and need-finding skills, brainstorm solutions, and build and test prototypes – the key components of the design thinking process applied to a small-scale challenge.

Learning Objectives

Students will:

- engage in a design challenge
- develop empathy
- conduct an interview
- synthesize information
- brainstorm ideas
- build prototypes
- test prototypes
- share information
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Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Design Challenge Introduction *60 minutes*

1. Present PPT Slide 3. Tell the class that they are going to get a taste of the design thinking process. Introduce the challenge: Redesigning the Before School Experience.
2. Present PPT Slide 4. Tell student to design the ideal before school experience. Give students 3-4 minutes to jot down or sketch their ideas. When they are done, present PPT Slide 5. Tell students that they just used a problem-solving approach to the challenge, and that now they will be learning a design-thinking approach.
3. Present PPT Slide 6. Introduce the idea of design thinking. Tell students that design thinking is a human-centered approach to innovation that has both process steps and mindsets.
4. Present PPT Slide 7. Tell students that design thinking is about solving a problem for someone else. Divide the class into pairs. Explain that they are going to redesign the before school experience, not for themselves, but for their partner, and that they will begin by interviewing their partners.
5. Review the interview questions presented on PPT Slide 7. Tell the students to begin with these questions first, and if they have time they can ask additional questions based on their partners' responses.
6. Tell each pair to choose who will be the first interviewer and interviewee, and that you will prompt them to switch roles after 5 minutes.
7. Have the interviewer takes notes as they ask the interviewee questions about their before school experience.
8. Ask students to read over their notes and think about what their partner said during the interview. Give students 2 minutes to write down a list of insights they captured. Ask them to consider the following:
    - What did you find out about your partners' experiences?
    - What stood out to you?
    - What are you curious about?
    - What surprised you?
9. Present PPT Slide 8. Tell the class that the next step in solving their design challenge is to write a "Point of View Statement." Ask them to start by thinking about their partners' needs. Ask the students to consider the following:
    - What does he/she like about getting ready for school?
    - What problems does he/she face?
    - What does he/she dislike about experience?
    - What does he/she need to make getting ready for school better?
10. Tell the students that the need must be a verb, and the insight is something that stood out to them as something that was important to their partners with respect to the cafeteria experience. This part of the process can be difficult. Encourage students to try to capture a need – it doesn't have to be complex. Start with the following example:

    - Henry needs a way to wake himself up promptly in the morning because he starts his day in a bad mood when his whole family complains about having to listen to his alarm go off repeatedly.
11. Present PPT Slide 9. Once your students have written a Needs Statement, have them brainstorm possible solutions to meet this need. Give them 4-5 minutes to come up with 25 or more ideas, using the following guidelines:
    - Say your idea.
    - Write your idea on a sticky note.
    - Stick it on a wall.
12. Present PPT Slide 10. Ask the students to choose one of their ideas that they are most excited about and explain that they are going to build prototypes for their partners. Tell the class that a prototype is not a model, but is a way to make an experience tangible. Explain that if they were going to build a new bed, instead of drawing a sketch, they might use the desks in the room. Remind them to think about creating something their partners can interact with.
13. Give students a variety of prototyping materials and tell them that they have 8 minutes to build their prototypes.
14. Present PPT Slide 11. Tell the students that they are going to test their prototypes with their partners. Give the 5 minutes to test each prototype. As they test their prototypes, ask students to record the interactions/responses of their user.
15. Use PPT Slide 12 to debrief the activity with the students. Explain that they just experienced the five steps of the design thinking process.

Lesson Plan: The Castle Design Challenge

Preparation

✓ Choose an adult volunteer to role-play the part of the princess. Tell the person that he/she will be interviewed by the students
✓ Gather materials and print copies of the “Needs/Wants and Solutions” tables for students
✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.

Materials

- Tiara, crown, or some kind of indicator of royalty
- Cardboard: 15+ sq. feet
- Scissors (1 pair)
- Duct tape (1 roll)
- Paper (3 sheets)
- Pens (3)
- Colored markers, pencils or crayons
- “Needs/Wants and Solutions” table in this lesson’s **Resources** section

Lesson Overview

In this lesson, students build empathy and needfinding skills, brainstorm solutions, and build and test prototypes--the key components of the design thinking process. The students interview a user, a princess, and incorporate her needs into the design and construction of a castle.

Learning Objectives

Students will:

- conduct an interview
- analyze interview data
- make inferences
- brainstorm solutions
- build prototypes
- test prototypes

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity I - Designing a Castle *35 minutes*

1. Present PPT Slide 13. Introduce the volunteer as the princess, and explain to the students that they need to design a castle for the person to live in.
2. Give the students the attached chart and pens, and have them interview the volunteer to find out what they need to include in the castle to make the prince/princess happy. Tell the students they have 10 minutes to interview the "princess." Remind the students to ask the princess questions to find out what she needs in her castle. Encourage them to keep asking the princess questions about her likes or hobbies to find out things the likes.
3. Tell the students that they have 10 minutes to compare their interview notes and determine the princess' needs.
4. Tell the students that they have 5 minutes to brainstorm possible solutions to meet the princess' needs.
5. Tell the students to use the prototyping materials to design their castles. Tell them that they have 10 minutes to build their prototypes.

Activity II - Testing the Design **10 minutes**

1. Ask the princess to step into the castle that the students have designed.
2. Tell the princess to ask questions and comment on the different design features she/he notices.
3. Tell the students that they can point out features in their design that they think the princess might like.
4. Ask the princess what she liked and disliked about the castle design and what she might change in future prototypes.
5. Ask the students to discuss the princess' reactions to their design.
6. Ask the students what they might change in a subsequent prototype.

Assessment *10 minutes*

1. Ask the students the following questions to assess their understanding of the activity and the extent to which they embodied the design thinking methodology.

- What was it like to interview the princess?
- How did you create your design?
- Is the princess happy with your design?
- What might you do differently based on the princess' feedback?
- If you were designing this castle for someone else how might it be different?
- What different materials might you have to design the castle?
- If you could pick one material to use, what would you pick? Why?
- How is making a castle different from making a house?
- How is a castle similar to the houses we live in today?

- What was your favorite part about today? Why?

Resources

For instructor/volunteer:
Royalty Requirements describes the role that the princess/should assume. The instructor who assumes the role of royalty should describe their wishes without suggesting a solution for the students conducting the interviews. For example, he or she might say, “I like to live with a lot of light,” instead of “I need a window.” This open-endedness allows students to generate different possible solutions to meet the princess’ needs.

Royal Requirements Table

The princess needs/wants:	**Example of a design/solution that reflects this need**
room so she doesn’t feel cramped	standing space in the courtyard
Sunlight	windows or open spaces
to see all of her surrounding land	a tall tower
to feel safe (protected from the evil army) the army has battering rams, arrows, and catapults	tall /thick walls, moat, drawbridge
a beautiful place to live	garden, decorations

For students:
Needs/Solutions Table (1 per student)

Needs/Solutions Table

Needs:	**Solutions:**

Lesson Plan: Design Challenge 1.0: Developing Empathy

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Preview or download the following videos:

- The Shelter Effect: http://www.youtube.com/watch?v=Lf2z38u2djA
- Project H Playground, Belize: https://www.youtube.com/watch?v=Lyn4n7FOOU0
- Haiti Earthquake Survival: https://www.youtube.com/watch?v=HPX_Gwm8mB0
- House Construction with Plastic Bottles: https://www.youtube.com/watch?v=LPxXH7rCSHQ
- Whodunnit?: http://www.youtube.com/watch?v=ubNF9QNEQLA

Materials

- Paper (5 sheets per student)
- Markers (1 per student)

Lesson Overview

In this lesson, students are introduced to the first design challenge – Redesigning the Shelter Experience. In this design challenge, students take a deep dive and learn the empathy phase of the design thinking process.

Learning Objectives

Students will:

- learn about the role of empathy in the design thinking process
- review information on observation and interviewing
- learn how to construct an Empathy Map
- engage in role playing
- participate in small group and whole class discussion

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

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MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Design Thinking *5 minutes*

1. Use PPT Slides 15-22 to introduce the design thinking concept to students.
2. Present PP Slide 23 to introduce the concept of the "fail forward" mentality: "the never-give-up attitude of being willing to fail early and often in order to learn as much as possible to produce the best possible solution through real experience." See if students have any questions and encourage them to practice this mentality throughout this design challenge.
3. Present PPT Slide 24. Tell students that their design challenge is Redesigning the Shelter Experience.

Activity II - Learning About Shelter *10 minutes*

1. Use PPT Slides 25-28 to introduce the topic of shelter.
2. Present PPT Slide 29, which contains links to four videos relating to shelter. All four videos are linked to clicking the pictures on the PPT slide. View the videos with the students, and ask them to take notes.
    - The Shelter Effect: http://www.youtube.com/watch?v=Lf2z38u2djA
    - Project H Playground, Belize: https://www.youtube.com/watch?v=Lyn4n7FOOU0
    - Haiti Earthquake Survival: https://www.youtube.com/watch?v=HPX_Gwm8mB0
    - House Construction with Plastic Bottles: https://www.youtube.com/watch?v=LPxXH7rCSHQ

Activity III - Empathy Mini-Lesson *5 minutes*

1. Present PPT Slides 30-31. Tell students that in order to solve their shelter challenge, they need to have a user. Tell them that the user is the person that they are designing for. Ask the following questions: How do you think you might be able to learn about a user?
2. Present PPT Slide 32. Discuss the two ways that design thinkers gain information about their user: observation and interviewing.
3. Present PPT Slide 33. Tell the students that design thinkers observe and interview in order to gain empathy for their user, which is the first step of the design thinking process.
4. Present PPT Slides 34-41. You can read the content aloud, ask the students to read it silently, or ask the students to read it aloud. As you move through these slides, ask students if they have any questions or need clarification of the ideas that are presented.

Activity IV - Observation *10 minutes*

1. Remind students that to develop empathy, they need to observe and to interview users. Present PPT Slide 42, and tell students that they will begin with observation.

2. Present PPT Slide 43, and emphasize the importance of observing with “fresh eyes,” especially when you are observing a place that you are familiar with, such as school or at home.
3. View the video entitled “Whodunnit?” linked to from PPT Slide 44. Ask for reactions to the video. The video link is here: http://www.youtube.com/watch?v=ubNF9QNEQLA
4. Present PPT Slide 45. Tell students that they are going to practice using their observation skills. Present PPT Slides 46-53. Allow students 2-3 minutes to observe each picture and record their observations. Ask each student to find a partner, and work in pairs to go beyond their initial observations, and continue to try to come up with more fine-grained and nuanced observations. For example, you might ask them to imagine stories related to the pictures and use the details in the pictures to support their ideas.

Activity V - Interview Modeling *15 Minutes*

1. Present PPT Slide 53.Tell students that another way to gain empathy for your user is through interviewing. Present PPT Slide 54. Ask students what they think makes a good interview.
2. Present PPT Slide 55. Ask students to observe while you model two short interviews on vacations. If possible, ask an adult to volunteer to be interviewed, or you can ask a student to volunteer.
    - In the first interview, ask closed ended questions. A closed-ended question results in short or single word answers. For example, you might ask, “Where did you go on your last vacation?” or “What hotel do you prefer when you travel?”
    - In the second interview, use open-ended questions, which encourage a full, meaningful answer using the subject’s own knowledge or feelings. For example, you might say, “How do you feel when you leave on vacation?” or “Why do you like to travel with [name of someone]?” In this interview, use the answers to create more questions. For example, if the interviewee mentions feeling rushed getting ready for a vacation, say, “Tell me more about what happens when you are rushed.” Ask a lot of “Why?” questions.
3. Discuss the interviews with the students. Ask the following questions:
   What differences did you notice between the two interviews?
   Which interview helped you gather stories and emotions from your user?
   Did asking questions based on the interviewee’s answers help you gain empathy for your interviewee?

Activity VI - Empathy Map Modeling *15 minutes*

1. Present PPT Slide 56. Explain that interviewing your user provides you with lots of information; and that the next step is figuring out what to do with this information.
2. Present PPT Slide 57. Tell the class that they are going to learn how to create an Empathy Map, and that this is a way for them to analyze their interview data. Tell them that analyzing data is an important part of being a design thinker because it helps you begin to understand your user’s needs.
3. Present PPT Slide 58. Review the content for each column of the map.

There are two columns: “Say/Do and Think/Feel.”

Under “Say,” list things the interviewee actually said during the interview. Include direct quotes.

Under “Do,” list what the interviewee did during the interview, which includes things like looking away, tapping the feet, smiling, laughing, crying, or crossing the arms.

The “Think” and “Feel” portions of the Empathy Map are for inferences about what the interviewee thinks and feels based on what he or she said and did.

There are no wrong answers on an Empathy Map.

4. Present PPT Slide 59. Discuss the examples included on the map.
   - It is important to model how to create an Empathy Map for your students. Draw an Empathy Map on a large piece of chart paper. Fill in the segments of the map using the interview you conducted earlier. For example, the interviewee might have “said” that she doesn't like to travel alone. You might infer that she “thinks” vacations are a social event, or that she “feels” too lonely when she travels by herself. Or the interviewee might have winced when she told you about flying to Australia, and you might infer that she is worried about the long flight.

Lesson Plan: Design Challenge 1.0: Empathy Practice

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.

Materials

- Paper (5 sheets per student)
- Chart paper (2 sheets per group)
- Markers (1 per person)

Lesson Overview

In this lesson, students will interview group members and create an empathy map based on the information they gathered.

Learning Objectives

Students will:

- conduct interviews
- analyze and synthesize interview data
- create an Empathy Map

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

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MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Interviews *25 minutes*

1. Present PPT Slide 60. Tell students that it is their turn to do an interview. Group students in teams of 5-6. Discuss the roles of each member of the group. Allow students to decide who will perform each role within the group.
2. Present PPT Slide 61 and review the tips for interviewing.

3. Present PPT Slide 62, which has a list of interview questions. Tell the students that they should begin their interviews with these questions. As they ask these questions, they can build on what they have heard and ask additional questions.
4. Give the groups 15 minutes to conduct their interviews.

Activity II - Empathy Map Construction *35 minutes*

1. Present PPT Slide 63. Give each team a large piece of chart paper and ask them to draw an Empathy Map. Tell the students to complete the Empathy Map based on their interviews. Visit each team to clarify any questions the students might have.

Lesson Plan: Design Challenge 1.0: Point of View Statements

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.

Materials

- Chart paper (2 sheets per group)
- Markers (1 per student)

Lesson Overview

In this lesson, students learn about defining a problem and creating a Point of View statement to address it.

Learning Objectives

Students will:

- learn the define phase of the design thinking process
- create Point of View statements based on user needs
- participate in class discussion

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Point of View Statement Modeling *20 minutes*

1. Present PPT Slide 65. Explain to students that the next step in the design thinking process is to define the problem.
2. Present PPT Slide 66. Introduce the Point of View statement, explaining that it is a way to synthesize their interview data. They will use this statement to help solve the design challenge for their users.
3. Explain the following parts of a Point of View Statement, using the information from the interview you conducted earlier to fill in the blanks:
    - The user: Use an adjective to describe you user; e.g., Grumpy Henry…

- A Needs: Use a verb to describe your user's need; e.g. …needs a way to wake up as soon as the alarm rings…
- An Insight: Describe why this will meet your user's need; e.g. …because he doesn't like to start the day facing the complaints of his family.

4. Ask students to generate additional examples of Point of View statements.

Activity II - Point of View Statement Creation *40 minutes*

1. Have students work with their teams to create Point of View Statements for their users. Give each group a blank piece of chart paper and have them duplicate the Point of View Statement from PPT Slide 66.
2. Give the students 15 minutes and tell them to create 2-3 Point of View Statements. As the students work, go to each group and clarify any questions the students might have.
3. Ask each team to share their Point of View Statements with the class. Allow students to provide feedback on the statements using the following questions:

   Could we think of many solutions to meet the need that is described in the Point of View Statement?

   Is there a clear description of the user, the need, and the insight?

Lesson Plan: Design Challenge 1.0: Brainstorming Solutions and Idea Selection

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.

Materials

- Post-it notes (1 pad per person)
- Markers (1 per person)

Lesson Overview

In this lesson, students will brainstorm for solutions and select an idea for prototyping.

Learning Objectives

Students will:
- brainstorm for ideas
- group ideas by theme
- participate in a vote to choose 3 top ideas

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

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MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Brainstorm *25 minutes*

1. Present PPT Slide 72. Explain that brainstorming is built upon mindsets, and that mindsets are a “road map” for how things are done.
2. Present PPT slides 73 to 80 to review tips for how to brainstorm. Read each rule aloud.
3. Present PPT slide 81 which contains a list describing how to brainstorm in a group.
4. Demonstrate with 2 or 3 people, how to conduct a brainstorm. Use one the following topics for our brainstorm: “Where to Go on a Summer Vacation,” “Desserts,”

"Amusement Park Rides," "Ways to Use a Pipe Cleaner," "Ways to Use Paper Clips," or "Crazy Pet Names."

5. Give the students 15 minutes to brainstorm ideas. Visit each team to encourage them to follow the brainstorming tips presented in the slides.

Activity II - Idea Clustering and Selection *20 minutes*

1. Present PPT Slide 82 and tell students that they are going to cluster their ideas into themes. Have them do this by rearranging their post-it notes.
2. Present PPT Slide 83. Tell the students that they are going select their favorite ideas that they would like to build for their users. Discuss the different possible ways to choose a favorite. These might include an idea that is easy to build, a crazy idea, or an idea that they are really excited about building.
3. Tell the students that each person has 3 votes, and that they should choose their top 3 favorite ideas and vote by placing a check mark on the post-it containing that idea.
4. Give students 3 minutes to vote. Have each group tally its 3 top ideas based on the votes.
5. Ask each group to share its top 3 ideas.

Lesson Plan: Design Challenge 1.0: Prototyping and Testing

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Preview or download the Caine's Arcade video: http://vimeo.com/40000072

Materials

- Pipe cleaners
- Markers
- Popsicles
- Tape
- Paper
- Assortment of cardboard
- Other materials available

Lesson Overview

In this lesson, students build a prototype of their chosen idea and test their prototype and capture feedback from their user.

Learning Objectives

Students will:

- build a prototype of their best idea
- test their ideas with their user
- capture user feedback

Activity I - Prototype I *35 minutes*

1. Present PPT Slide 86. Tell the students that they are now in the prototyping phase of the design thinking process.
2. Explain to the class that design thinkers build prototypes that are not finished products and that the purpose of a prototype is to put something in the hands of their user quickly to see if the person likes the idea.
3. Present PPT Slide 87. Show the video of Caine's Arcade, linked to the photo on the PPT slide: http://vimeo.com/40000072
4. Present PPT Slide 88, which explains some of the features of a prototype. Review each point and clarify any questions the students may have.
5. Present PPT Slide 89. Give students 25 minutes to build their prototype.

Activity II - Testing *15 minutes*

1. Present PPT Slide 90. Tell students that once they have created their prototypes, they will be testing them on the user they interviewed. Testing the prototype allows them to see the reactions and interactions of the user, which provides important feedback for rethinking their designs and finding out if it meets their users' needs.
2. Present PPT Slide 91. Provide the following guidelines for the designers:

- Don't over-explain your prototype. Allow your user to interact with it without interruption.
- Observe your user closely. You may learn something new about what they need.
- Don't sell your prototype.
- Give a brief sentence about your prototype as an introduction, and then don't do any more talking.

3. Provide the following guidelines for the users:
   - When you receive your prototype, say what you think out loud.
   - Be direct and honest in your feedback. Your designer wants to make sure that the design meets your needs. Be specific about what you like and don't like.
4. Present PPT Slide 92 and 93. Tell students to test their prototypes on their users and capture feedback based on these guidelines. Suggest to students to ask the following questions:
   - What did you like?
   - What didn't you like?
   - What would you change?
   - What surprised you?

Activity III - Prototype II *10 minutes*

1. Present PPT Slide 94. Tell students to spend the next 10 minutes revising their prototype based on the feedback they received from their user.
2. Tell students to share out their second round of prototypes with their user.
3. Have students share out their second round of prototypes with one another.
4. Celebrate! Students have concluded their first full-length design challenge!
5. Present PPT Slide 95. Encourage students to reflect on and discuss their “fail forward” moments during this design challenge. Ask them:
   - When did you fail or make a mistake?
   - What did you learn from that?
   - How did you improve your design?

WEEK 1

UNIT 2: BUILDING PRINCIPLES

DAY 3B: The Marshmallow Challenge
DAY 4B: Egg Shelter Drop
DAY 5B: Floating Egg Shelter

Hour	Day 1	Day 2	Day 3	Day 4	Day 5
A	**A Taste of Design Thinking**	**DESIGN CHALLENGE 1.0 (Personal Shelter): Empathize**	**DESIGN CHALLENGE 1.0: Define**	**DESIGN CHALLENGE 1.0: Ideate**	**DESIGN CHALLENGE 1.0: Prototype & Test**
B	**The Castle Design Challenge**	**DESIGN CHALLENGE 1.0: Empathize & Define**	**Building Principles: The Marshmallow Challenge**	**Building Principles: Egg Shelter Drop**	**Building Principles: Floating Egg Shelter**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand a basic few physics principles and how they apply to building a prototype.

Lesson Plan: The Marshmallow Challenge

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Provide space for teams of students to build their structures.

Materials

- 20 sticks of spaghetti
- 1 yard of tape
- 1 yard of string
- 1 marshmallow

Lesson Overview

In this lesson, students participate in a prototyping challenge to build the tallest spaghetti tower that can hold a marshmallow up top.

Learning Objectives

Students will:
- build a prototype
- work collaboratively in teams
- participate in a whole class discussion

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Activity I - The Marshmallow Challenge *60 minutes*

1. Present PPT Slide 67. Tell the students they will participate in *The Marshmallow Challenge*.
2. Divide students into teams of 4-5. Present PPT Slides 68-70, which explain the Marshmallow Challenge. The goal is to building the tallest freestanding structure using only 20 sticks of spaghetti, 1 yard of tape, 1 yard of string, and a marshmallow. The rules are:
   - The entire marshmallow needs to be on top.
   - Use as much or as little of the supplies as you want.
   - You may break up the spaghetti, string or tape.
   - You have 18 minutes.
   - When time runs out, you cannot be touching or holding the structure.
3. Allow the teams 18 minutes to work on their structures, and then measure each group's structure. Congratulate the winners.
4. Ask students the following questions:

- How did your team assemble the structure?
- If you were to do the Marshmallow Challenge a second time, what would you do differently?

5. View the video “Marshmallow Challenge” linked to from PPT Slide 67.

Lesson Plan: Egg Shelter Drop

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Gather materials
✓ Scout out a place in the school or facilities where the egg drop can be conducted
✓ Find/create an appropriate and safe egg drop zone by laying out a plastic trash bag

Materials

- Paper (8 sheets per team)
- Straws (15 per team)
- Eggs (1 per team per round)
- Tape (2 meters per team)
- Markers (for beautifying/personalizing the eggs)
- Plastic trash bags/newspaper (to prevent a mess from the egg drop and to indicate a dropping zone)

Lesson Overview

In this lesson, students design a shelter to protect a raw egg from a one-story drop. Students design a prototype of an enclosure, test their design, and iterate.

Learning Objectives:

Students will:

- develop empathy
- build prototypes
- test prototypes
- iterate their designs

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity I - *Egg Empathy* *10 minutes*

1. Present PPT Slide 84 to introduce the Egg Shelter Drop activity.

2. Divide the class into groups of 3 students. Give each team one egg. Tell the students that their egg is termed their “baby.”
3. Have the students draw and design the egg’s façade.
4. Tell the students that their egg “baby” must not break when dropped off a second story.
5. Tell the students that they will first create their enclosure and test it with an egg that has no drawing on it, and on the second attempt their egg “baby” will have to survive the drop.

Activity II - *Egg Shelter Design and Drop* *40 minutes*

1. Tell the students that they must design an enclosure that will stop an egg from breaking when it’s dropped from ten feet.
2. Tell the students that they may only use the materials that are provided and that they have 10 minutes to build their enclosures. Encourage the students to think about how to best enclose the egg and how the materials might help the egg survive the fall.
3. Climb to the second story of a building at least, a location where you can safely drop an egg without risk to the students or the people below.
4. Have the students test their shelter by carefully dropping their design off the one-story-high location, using a blank (white) egg.
5. After each egg is dropped, examine it and ask the students to observe what happens. If the egg breaks, ask them the following prompts:
   - Describe how the egg broke (at the bottom, smashed on the side, etc.) Why do you think the egg broke that way?
   - If the egg did not break, why do you think it survived the drop?
   - What should you change for the next round?
6. Once everyone has completed their testing, evaluated what worked and what didn’t work, and thought about ways in which the design could be improved, ask the students to iterate on their design.
7. Have each team conduct the drop a second time using its personalized egg “baby.”
8. Have students observe what occurred.

Assessment *10 minutes*

1. Have the students gather in a circle.
2. Ask each group to share its experiences.
3. Ask the following questions:
   - What was different between the first and second drop?
   - What specifically did you change in your design?
   - What if you got a third try? Would it structurally stay the same? Would you add aesthetic appeal?
   - What went right/wrong about this second test?
   - What materials were most useful in your design?
   - What other materials might be a good choice in making an egg shelter?
   - Why did we build the egg shelters twice? (Why do we prototype?)

Lesson Plan: Floating Egg Shelter

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Gather materials
✓ Preview or download the Makoko Floating School video:
http://www.youtube.com/watch?v=cSnQfeIYMWI
✓ Fill a large plastic bin with water

Materials

- Balloons (4 per team)
- 2-3 Eggs (1 per each team of 3 students) They could be hardboiled, or, if not, keep the eggs in a plastic bag.
- Cardboard
- Pipe-cleaners
- Blue Painter's Tape
- Scissors
- Plastic wrap
- Large plastic bin to hold the water
- Computer (for video)
- Binder clips
- Popsicle sticks
- Straws
- Sharpies
- Paper
- String
- Zip Ties
- Post-it notes (1 pad per student)
- Access to a water fountain or sink to supply water

Lesson Overview

In this lesson, students build a structure that safely holds an egg while staying afloat in water.

Learning Objectives

Students will:

- identify and leverage physics principles such as balance and center of mass in how they approach designing a structure to hold an egg and float on water
- empathize with people in different parts of the world who live on water and need to build floating structures in order to survive
- gain experience working in small groups with peers
- brainstorm solutions
- build prototypes
- test prototypes

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity I - A Floating School *10 minutes*

1. Present PPT Slide 96.
2. Present PPT Slide 97. Have students view the following video entitled Makoko Floating School, linked to the photo on the slide: http://www.youtube.com/watch?v=cSnQfeIYMWI.
3. After viewing, ask the students the following questions:
   - What did you notice?
   - What do you think it would be like to live in that environment?
4. Tell the students that they will build a version of the floating school themselves and that they will use an egg to represent a student, and balloons to serve as floatation devices for their structure.

Activity II - Building the Structure *30 minutes*

1. Divide the class into teams of 3 students.
2. Tell the students that they will use the materials provided to create a structure that safely holds an egg while staying afloat in water.
3. Have the student teams brainstorm possible solutions to make their structures. Provide Post-it notes and markers. Have the students select two designs per team. Tell them that they will build prototypes of these ideas.
4. Encourage the students to use the varied materials to build their prototypes. As the students are building their structures, ask them questions about their ideas and how they think their structure will fare. Point them in the right direction, but try to allow them to generate ideas, answers, and hypotheses. Assist them if necessary in the building of the structures, but allow them to be the main drivers of the project.
5. Once the teams have built one of their prototypes, encourage them to test their structure in water, with the egg. **NOTE:** It can be helpful to have the egg in a zip-lock plastic bag so that in case it breaks, the yolk doesn't get everywhere.
6. Provide time for each team to test their prototypes. During each test, have all the teams observe. Based on these tests, tell the students to go back to their designs and refine/improve them.

Activity III - Testing the Structure *10 minutes*

1. Do a final testing round of each group's prototype.
2. When testing, ask the students the following questions to determine the success of the structure:
   - Does the structure stay afloat?
   - Is the egg unharmed?
   - Does the egg crack?
   - Does the egg sink?

3. Lead a brief discussion clarifying the concepts of balance and center of mass.

Assessment *10 minutes*

1. Have the students gather in a circle.
2. Ask each group to share its experiences.
3. Ask the following questions:
    - What did you like about the activity?
    - What do you wish the activity had more or less of?
    - What objects float in water? What objects do not?
    - How do you make a floating structure more stable in water?
    - What if the egg were a real person? How would you build the structure differently
    - What inspired you to build the structure the way you did?
    - What do you think made your structure successful or unsuccessful?
    - What are some ideas in physics that you think could be related to this activity?
    - What did you learn about yourself and others while working in groups?
    - If you carried the bin of water with the structure inside it, and walked around in order to create more turbulence and motion in the water what do you think might happen to the structure and to the egg?

WEEK 2

UNIT 3: ARCHITECTURE

DAY 6A: Perspective Drawing
DAY 6B: Speaker and Video

Hour	Day 6	Day 7	Day 8	Day 9	Day 10
A	**Architecture: Perspective Drawing**	**Sustainability: Building with Green Materials**	**Sustainability: Exploring Energy Sources**	**Structure and Building Materials: Foundations - From Oobleck to Toothpaste!**	**Structure and Building Materials: Geometrical Shapes and Composites**
B	**Architecture: Speaker and Bill Nye Video**	**Sustainability: Keep it Cool!**	**Sustainability: Design a Sustainable Home**	**Structure and Building Materials: Building a Waterproof Roof**	**Structure and Building Materials: Earthquake Stable Building**

Unit Understanding

Students will understand how architects use both artistic perspective and scientific concepts to design shelters.

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Lesson Plan: Perspective Drawing

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ Find a solid cube to bring to class as a reference object to teach perspective drawing.
- ✓ Preview any of these videos on perspective drawing to prepare for teaching it:
  https://www.youtube.com/watch?v=fvyQlOY8OAw
  https://www.youtube.com/watch?v=RpLJT_SHqpU
- ✓ Read about concepts of perspective and examples of perspective drawing in **Resources** section.

Materials

- 1 reference cube (per class or group of several students depending on class size)
- 1 black felt tip pen per student
- 6 colored pencils (assorted colors) per student
- 1 grey marker per student
- 1 ruler per student
- Print out 15 pieces of paper with a solid line going across it horizontally (landscape) 3 inches from the top.
- Bring a laptop charger.

Lesson Overview

Students learn the process of constructing ideas for buildings by looking at building blueprints. Then, students learn about perspective drawing and their use in architecture.

Learning Objectives

Students will:

- learn about building blueprints.
- learn about perspective drawing and architectural drafting
- practice 1-point and 2-point perspective drawing techniques.
- apply these perspective drawing skills to make architectural sketches, using buildings in their school.

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity I - Blueprint Introduction **10 minutes**

1. Present PPT Slide 99.
2. Introduce students to building blueprints by presenting examples of various building blueprints. You may add to the images in the resource section by choose blueprints of fairly simple buildings, so students can see the process of how to ideate.
3. Ask the students if they can guess what the drawings on the blue print correspond to (for example, what does a door look like on a blueprint?
4. Explain the significance of a blue print and why it is necessary ideate and spend time planning. Ask:
   - Have you ever attempted to build something out of Legos without thinking ahead? What did you end up making?
   - What would happen if a builder decided to start building without planning first?

Activity II - Introduction to Perspective Drawing **10 minutes**

1. Distribute rulers, pens, markers or pencils.
2. Instruct the students to draw a cube.
3. Reveal the reference cube and compare each student's drawing to the cube.
4. Introduce the students to perspective drawing by presenting the examples found in the Resources section.
5. To further explain the concept, bring the students to a nearby road and observe how the sidewalk lines meet at a vanishing point on the horizon. You may mention that perspective drawing is like a representation of a 3d object on a flat piece of paper. The farther the objects are in the real work, the smaller they need to appear on the piece of paper.

Activity III - Cube Drawing Exercises **15 minutes**

Exercise 1: Muscle Memory (5 minutes)

1. Instruct the students to spend 3 minutes drawing a perfect cube in two point perspective with their ruler on a sheet of 8.5''x11'' paper.
2. Now instruct the students to spend 90 seconds drawing a perfect cube that cannot be identical to their previous cube without a ruler on a separate sheet of 8.5''x11'' paper.
3. Afterward, instruct the students to draw a cube in 30 seconds without a ruler
4. Compare the three cubes and discuss how the tighter time constraints and lack of ruler may have allowed the students to draw more expressively or even more accurately.

Exercise 2: Combining Cubes (10 minutes)

1. Now instruct the students to use a combination of cubes and rectangles to create any building or object in two-point perspective. (on a sheet of 14''x17'' paper).
2. Instruct the students to first draw with the grey marker and finalize the drawing with the black pen.
3. Have the students discuss their creation with their peers
4. As the students are being led through the activity, make sure to remind them of the purpose of the activity (to introduce the art and creativity in creating buildings and structures). Ask:

- If you were an architect, what would you add to your building to make it look aesthetically pleasing?
- How do you think perspective drawing helps city planners and builders? What would happen if they didn't do this?

5. When the students are done with their perspective drawings, point out geometric shapes and explain why geometry is necessary in design and ideating. Ask what would happen if buildings were made of circles and spheres rather than straight lines.

Activity III - Perspective Drawing Applications **25 minutes**

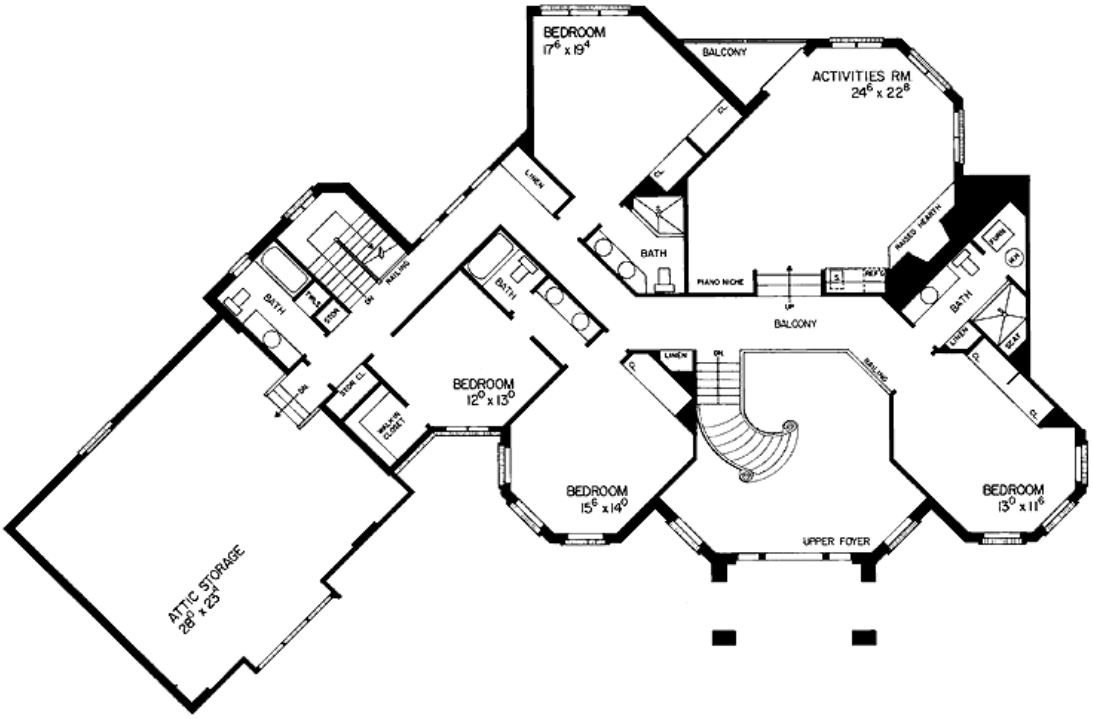
1. Lead the students around the school to the predetermined perspective drawing spot.
2. Tell the students that they have 20 minutes to make a drawing of the architecture based on their new perspective drawing skills. Encourage the students to each approach the building from a different angle so that their sketches are unique.
3. After the 20 minutes are up, have each of the students share their drawing to the class, and have them explain the perspective points they chose. Ask the students where the vanishing points are in their picture.

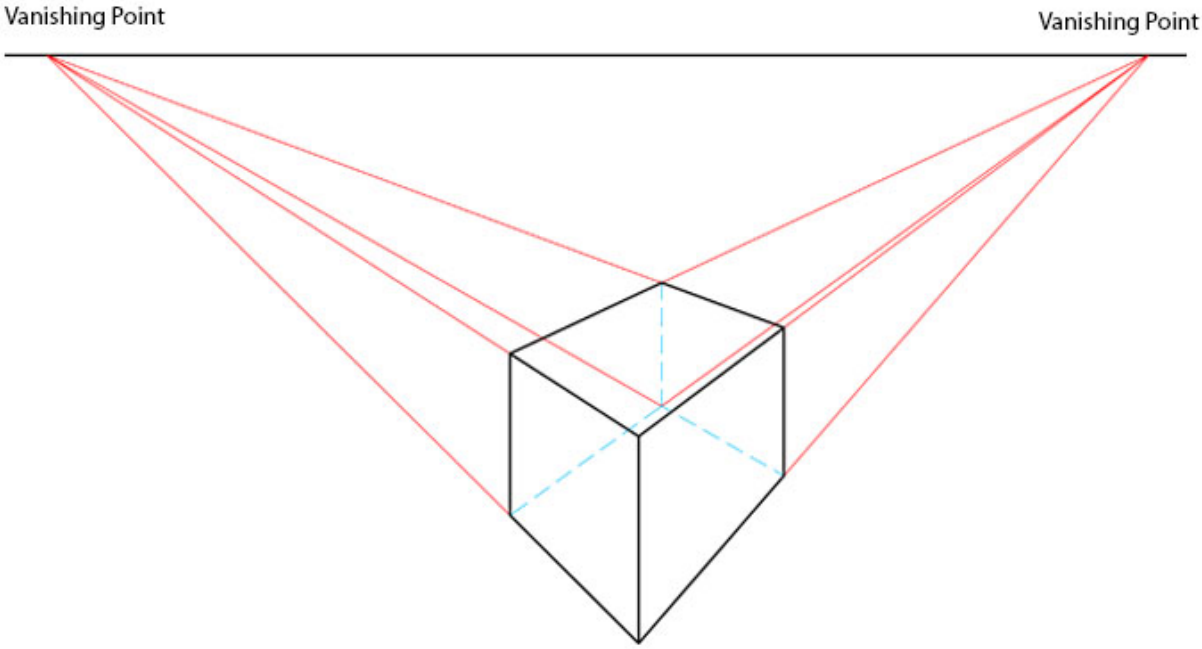
Assessment

1. Pose the following questions:
   - How do blueprints differ from perspective drawing? What purposes do they each serve?
   - Why is perspective drawing useful for making pictures realistic?
   - Why do you think architects learn how to do perspective drawing?
2. Throughout the lesson, instructors may assess students understanding of the following terminology:
   - blueprints
   - one-point perspective
   - two-point perspective
   - vanishing point
   - parallel

Resources


OUTBUILDING
KEY to SHADING, etc.
PANTRY
KITCHEN
HALL
DAIS
BUTTERY
ABOUT 1540
PORCH
GARDEN
WALL
SITE of CHAPEL
SCALE
FEET


BEDROOM
17⁶ x 19⁴
BALCONY
ACTIVITIES RM
24⁶ x 22⁸
LINEN
BATH
PIANO NICHE
BALCONY
BATH
BATH
BATH
BEDROOM
12⁰ x 13⁰
BEDROOM
15⁶ x 14⁰
UPPER FOYER
BEDROOM
13⁰ x 11⁶
ATTIC STORAGE
28⁰ x 23⁴


Vanishing Point
Vanishing Point

Perspective - What is Perspective?
By Helen South's Drawing/Sketching Glossary
Source: http://drawsketch.about.com/od/drawingglossary/g/perspective.htm

Definition: Perspective drawing is a system of representing the way that objects appear to get smaller and closer together, the further away they are.

What Does Perspective Look Like?

Imagine driving along a very straight open road on a grassy plain - the road, the fences and power-poles all diminishing towards a single spot far ahead of you. That's single-point perspective. Single- or one-point perspective is a simplest method of making objects look three-dimensional. It is often used for interior views or trompe l'oeil (trick-the-eye) effects. Objects must be placed to that the front sides are parallel to the picture plane, with the side edges receding to a single point. Take a look at Da Vinci's Study for Adoration of the Magi to see the effect. (notice how the building is placed so that it faces the viewer, with the stairs and side walls diminishing towards a single point in the center.)

Is that the same as Linear Perspective?

When we talk about perspective drawing, we usually mean linear perspective. Linear Perspective is a geometric method of representing the apparent diminishing of scale as the distance from object to viewer increases. Each set of horizontal lines has its own vanishing

point. For simplicity, artists usually focus on correctly rendering one, two or three vanishing points.
The invention of linear perspective in art is generally attributed to the Florentine architect Brunelleschi, and the ideas continued to be developed and used by Renaissance artists, notably Piero Della Francesca and Andrea Mantegna. The first book to include a treatise on Perspective, 'On Painting' was published by Leon Battista Alberti in 1436.

One Point Perspective

In one-point perspective, the horizontals and verticals which run across the field of view remain parallel, as their vanishing points are at 'infinity', with horizontals which are perpendicular to the viewer vanish towards a point near the center of the image.

Two Point Perspective

In two point perspective, the viewer is positioned such that objects (such as boxes or buildings) are viewed from one corner, so that two sets of horizontals diminish towards vanishing points at the outer edges of the picture plane, while only verticals remain perpendicular. It is slightly more complex, as both the front and back edges, and side edges, of an object must be diminished towards vanishing points. Two-point perspective is often used when drawing buildings in the landscape.

Three Point Perspective

In three point perspective the viewer is looking up or down so that the verticals also converge on a vanishing point at the top or bottom of the image.

Lesson Plan: Architect Speaker & Bill Nye Video

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ Contact your local chapter of the Architects Society to help identify a local speaker to talk about a career in architecture. You may find your local chapter here: http://www.asla.org/chapters.aspx
- ✓ Download or prepare the video on architecture by Bill Nye the Science Guy: https://www.youtube.com/watch?v=dfPGWgdLmBM

Materials

- Laptop

Lesson Overview

In this lesson, students learn about the field of architecture and how they use science to build shelters through a local speaker and a video.

Learning Objectives

Students will:

- learn about the main principles used by architects to build shelters
- learn to recognize the work of architects around them

Activity I - Local Speaker **30 minutes**

1. Present PPT Slide 100.
2. Introduce speaker to students and ask them to think about the following while listening to the speakers:
   - What do architects do?
   - How do architects contribute to building shelters?
   - What are some of the challenges that architectures face in their work?

Activity II - Bill Nye the Science Guy Video **23 minutes**

1. Present PPT Slide 101.
2. Tell students that they will be watching a video that also talks about architecture.
3. Play the Bill Nye the Science Guy video on architecture: https://www.youtube.com/watch?v=dfPGWgdLmBM
4. Give students time after the video to ask questions.

Assessment

1. Pose the following questions:
   - Identify one thing that you learnt about architecture today.
   - Explain what the role of architects compared to other engineers.
   - What part of architecture appeals to you? What does not? Why?

WEEK 2

UNIT 4: SUSTAINABILITY

DAY 7A: Building with Green Materials
DAY 7B: Keep It Cool!
DAY 8A: Exploring Energy Sources
DAY 8B: Design a Sustainable Home

Hour	Day 6	Day 7	Day 8	Day 9	Day 10
A	**Architecture: Perspective Drawing**	**Sustainability: Building with Green Materials**	**Sustainability: Exploring Energy Sources**	**Structure and Building Materials: Foundations - From Oobleck to Toothpaste!**	**Structure and Building Materials: Geometrical Shapes and Composites**
B	**Architecture: Speaker and Bill Nye Video**	**Sustainability: Keep it Cool!**	**Sustainability: Design a Sustainable Home**	**Structure and Building Materials: Building a Waterproof Roof**	**Structure and Building Materials: Earthquake Stable Building**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how different aspects of the energy and sustainability are important in building a green shelter.

Lesson Plan: Building with Green Materials

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Gather materials
✓ Find an outdoor location for this lesson

Materials

- Popsicle sticks
- Tape
- Rope
- Cardboard
- Paper
- Plastic bottles
- People Toys (one per group)
- Post-it Notes (3 packs)
- Markers (1 per person)
- Other recycled materials

Lesson Overview

In this lesson, students build shelters out of natural and recycled materials found around their school and home.

Learning Objectives

Students will:

- empathize with a user
- design and build using natural and recycled materials found in their school
- differentiate which materials are best used for different structural techniques

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design
Next Generation Science Standards MS-PS1: Middle School Matter

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Activity I - Identify a User *15 minutes*

1. Present PPT Slide 103.
2. Divide the class into groups of three.
3. Give each group a toy person that will function as each group's "user"
4. Ask each group to develop user characteristics for its toy person: These might include the following: name, sex, age, school, country of origin, family tree, aspirations
5. Have the students write their toy persons' characteristics on Post-it notes and place them on a space that is visible and easily accessed.

Activity II - Build Time 20 minutes

1. Tell the students that each group will build a structure where they imagine that their user would feel comfortable.
2. Tell the students that they can use an unlimited amount of materials of anything they can find in the area [i.e., grass, leaves, stones, sticks] or anything that they brought from home
3. While the students are building, ask the following questions:
   - Why are you building the structure you are building?
   - Why are you using those materials?
   - What would your ideal material for this house be?

Activity III - Build Time 2 15 minutes

1. Tell the groups of students to build a space where they imagine their user would be comfortable spending time.
2. Give each group a box of materials.
3. Tell the students that they can use the materials in the box as well as any materials they find in their surroundings.
4. While the students are building, ask the following questions:
   - Why did you decide to use these specific materials?
   - Is it easier to build with this material? Why?
   - How are the materials different from one another?

Assessment 10 minutes

1. Have the students gather in a circle.
2. Ask each group to share its experiences.
3. Ask the following questions:
   - What type of materials did they use? Why?
   - Was the first activity more difficult than the second? Why or why not?
   - Why did some things that were being build did not work?
   - Which version was less wasteful?
   - How are each of the materials created? Are all materials made from natural resources?

Lesson Plan: Keep it Cool!

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Gather materials and read through the **Resources** section information
✓ Put ice into a thermos or cooler
✓ Come prepared with extra ice that is well insulated so that you will have at least some whole ice cubes left during the testing period

Materials

- 5 pads of post-it notes
- 10 markers
- 20 ice Cubes
- Cooler and Ice
- 6 sheets of foam
- 10 sandwich bags
- 1 roll of Duct Tape
- 1 roll of scotch tape
- Hot Glue Gun
- 6 large sheets of cardboard
- 1 pack of Sculpey (clay)
- 1 roll of foil
- Saran wrap
- 30 sheets of paper
- 6 pairs of scissors
- 20 cotton circles

Lesson Overview

In this activity, students learn about heat transfer and material properties through the design thinking process, with a focus on prototyping. Students build a small structure that will stay dry while delaying the melting of a single ice cube.

Learning Objectives

Students will:

- collaborate in small teams
- prototype and ideate shelter designs given specific constraints
- be able to differentiate between waterproofing and insulating materials
- learn about heat transfer and how insulation works

Standards

Next Generation Science Standards MS-PS3: Middle School Energy

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Activity I - Keep It Cool **40 minutes**

1. Present PPT Slide 104.
2. Divide the class into teams of two students. Tell the students that they will make a structure that can keep an ice cube cool and solid for an extended time, and that the teams will compete against each other.
3. Define insulation:
4. Provide the students with a range of prototyping materials including cardboard, paper, foam, plastic bags, different kinds of tape, plastic sheets, aluminum foil, etc.
5. Tell the students to brainstorm ideas about possible issues that may arise while building. Give them the following prompts:
6. What will happen if you just make a cardboard structure? (can cardboard stay hard when water gets all over it?)
7. What material of all the things we have would be most waterproof?
8. Why would it be important to have a waterproof house?
9. Share real life examples of waterproofing and insulating. This includes examples such as adding a finish to wood or putting tarp over wood. Ask the students what types of insulation they may have seen.
10. Tell the students they are going to build prototypes of different structures and that they will test their structures out using ice cubes.
11. During the prototyping process, check in with the students and ask them to explain why they made different design choices. When a team is finished with a prototype, give them an ice cube and set a timer to see how long it will take for the ice cube to melt.

Activity II - Wrap Up **10 minutes**

1. After the teams have had a chance to prototype different types of structures for their ice cubes, come back together and do a mini design review for each structure. Ask the following questions:
   - What material seems to be the most or least waterproof?
   - What design worked best for keeping the ice cube cool?
2. Lead a discussion based on interesting and successful elements of each structure as far as insulation.
3. Describe how insulation works.

- Air is a poor conductor of heat, and when trapped in a hollow area is an excellent insulator.
- Discuss some of the points from the information provided in the Resources section.

4. Share with the students why it is important for structures to be insulating in terms of energy efficiency and general human safety.

Assessment

10 minutes

1. Have the students gather in a circle.
2. Ask each group to share its experiences.
3. Ask the following questions:
   - What good ideas did you take away from your peers during this project?
   - Can you think of materials that stay hot and cold easily? Why do you think that happens?
   - What would have happened if you had used a different material (such as cardboard, foam, etc.)?
   - What would you do differently if they you to create another prototype?

Resources

Keep it Cool

Student Resource:
Insulation, Heat Transfer, and Vacuums

◆ **Insulation and Vacuums**

Insulation is used for many purposes. Insulation is needed to protect fragile items from being damaged during shipping. It is used to keep cold air out of houses in the wintertime, it is used to separate electric wires, and it is used to keep cool items cool and hot items hot in a vacuum flask. Many materials are used as insulation from fabric to moss to plastic to fiberglass to animal skins. In the case of a vacuum flask, a vacuum serves as the insulation. A vacuum is created when a volume of space is essentially empty of matter; usually when air is pumped out. Light bulbs contain a partial vacuum, usually backfilled with argon, which protects the tungsten filament.

◆ **Heat Transfer**

Heat can transfer in three ways: conduction, convection, and radiation. Conduction is the transfer of heat by direct contact of particles of matter. Metals such as copper, platinum, gold, and iron are usually the best conductors of thermal energy. Convection is the transfer of thermal energy due to the movement of molecules within fluids. Radiation is the transfer of heat energy through empty space.

Source: http://www.tryengineering.org/sites/default/files/lessons/keepitcool.pdf

How Stuff Works: Insulation
Source: http://science.howstuffworks.com/dictionary/chemistry-terms/insulation-info.htm

Heat transfer: the transfer of thermal energy between substances due to a difference in their temperatures.

Conduction: the transfer of heat through a material by direct contact.

Convection: the transfer of heat in a fluid (gas or liquid) as a result of the movement of the fluid itself.

Radiation: the transfer of heat via electromagnetic waves through space.

Insulation to retard the flow of heat is important for the comfort and, in some cases, the survival, of humans and animals. Insulation also prevents damage to various articles by freezing or high temperatures, and lowers heating and cooling costs.

Contrary to popular belief, insulation is not used to keep cold from entering an area, but only to retard the flow of heat. All substances, whether solid, liquid, or gas, contain some heat, so the condition of cold is merely a condition of relatively less heat. Heat can flow in one direction only—from a warmer body to a less warm body—so insulation serves to retard this flow. In a refrigerator, for example, insulation slows the flow of heat from the room air to the interior of the refrigerator. In a building, insulation keeps heat in during winter and out during summer.

Air is a poor conductor of heat, and when trapped in a hollow area is an excellent insulator. Other insulating materials, some of which depend on air pockets for much of their insulating effect, include mineral wool, fiberglass, asbestos, wood, concrete, vegetable fiber, vermiculite, and foamed plastics such as polystyrene. These substances retard the conduction and convection of heat. Aluminum sheets and aluminum foil, on the other hand, prevent the radiation of heat, by reflecting it back toward its source.

Buildings can be insulated by using building materials that are themselves good insulators or by leaving spaces in walls and ceilings and filling the spaces with an insulating material. Such simple building materials as the snow blocks of Eskimo igloos, the straw of thatched roofs, and the sun-baked clay of houses in northern Africa, the Middle East, and Latin America provide good insulation.

Materials designed exclusively as building insulation commonly come as loose fills or in the form of batts backed with foil or paper. They are installed between the interior and exterior walls and in the floor or ceiling of the attic. Windows and doors are insulated by weather stripping around the frame and by creating a dead-air space through the use of storm windows and storm doors.

Lesson Plan: Exploring Different Energy Sources

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ Print and cut pinwheel cards (attached)
- ✓ Make ice cubes
- ✓ Make shoots
- ✓ Gather all other materials from the materials list
- ✓ Need area with sun
- ✓ Need an outlet if insufficient wind
- ✓ Make 1 pinwheel setup for demo

Materials

Energy Discussion

- Pictures / videos examples of solar, wind

Solar PV Activity

- PV panel
- Motor and/or low power light bulb

Wind Activity

- Motor (1 per setup)
- Alligator wires (2 per setup)
- Pinwheel card (1 per setup, attached)
- Furniture nail (1 per setup)
- Cork (1 per setup)
- LED (1 per setup)
- Hair dryer or other wind source

Solar Thermal Activity

- Small black bag
- Small white bag
- zip lock bags (2)
- Ice & cooler to insulate ice
- Kitchen scale

Kinetics Activity

- Shoots (can be made either with popsicle sticks or foam, see picture in activity description)
- Marbles (different sizes//masses)
- Sufficient area for rolling

Lesson Overview

In this lesson, students learn about different energy sources through a series of activities. They explore the use of solar energy, wind energy, and kinetic energy and learn about their applications.

Learning Objectives

Students will:

- Learn about solar thermal systems.
- Learn about solar electrical energy generators
- Learn about generating wind energy
- Learn about generating kinetic energy

Standards

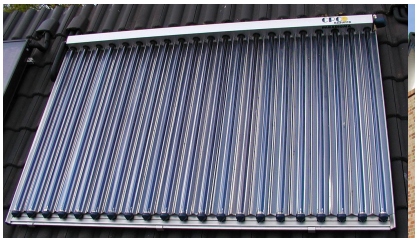
Next Generation Science Standards [MS-PS3: Middle School Energy]

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Activity I - Energy Examples **10 minutes**

1. Present PPT Slide 106.
2. Show the students videos and pictures of solar PV, solar thermal, and wind energy.
3. Ask students if they have seen these energy sources before and if they understand how they work.
4. Explain the basics of the technology to the students.



Activity II - Solar Thermal Energy **10 minutes**

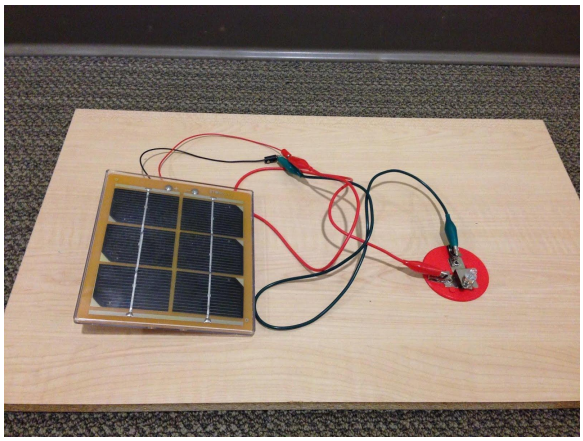
1. Show the students the black bag and the white bag and explain that you will be conducting an experiment to see which melts ice more quickly
2. Have the students use the kitchen scale to measure two equal masses of ice

3. Have the students place the ice in the ziploc bags, and each ziploc bag in either a white or black bag. **NOTE**: Be certain that the amount of ice is exactly equal in each bag, and that both bags are in the same amount of sunlight.
4. Place the bags in direct sunlight, making sure that the sun won't move such that one ends up in the shadows.
5. Have the students check back every five-ten minutes to see which bag has melted more.
6. Ask the following questions:
    - Which bag melted faster?
    - Why does the black bag melt faster? Does this happen only for ice?

Troubleshooting: If the ice in the white bag melts faster, be prepared to discuss reasons this might be so-- different amounts of ice, different amounts of sunlight, materials of bags were different, etc. Consider repeating the experiment again to ensure the expected result.

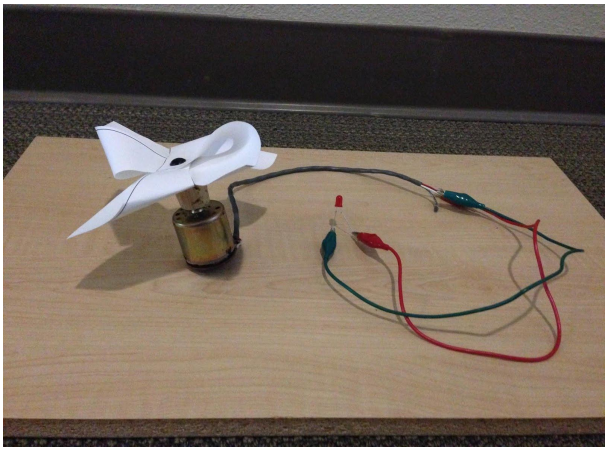
Activity III - Solar Electrical Energy **10 minutes**

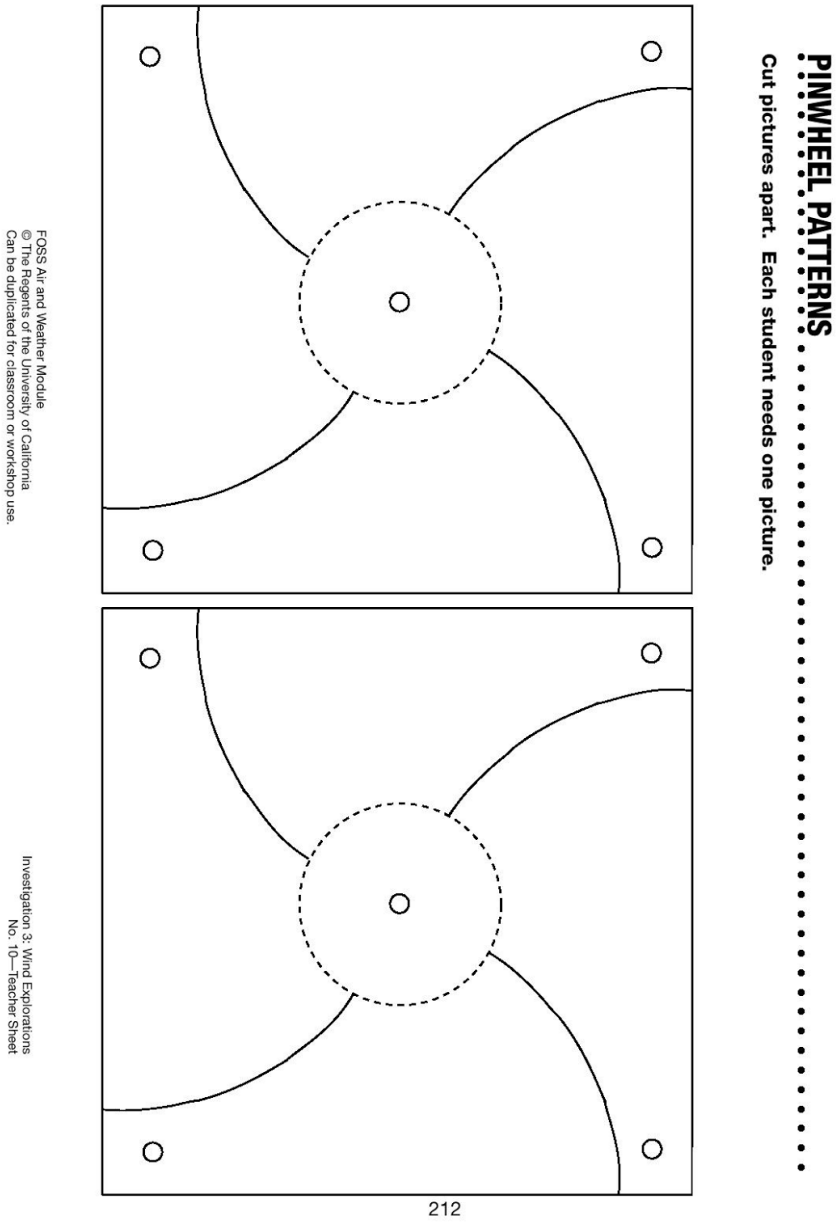
1. Show the students the solar panel, asking them if they have ever seen one before
2. Connect the panel to the lightbulb or motor, using alligator clips
3. Have the students take the panel setup into the sunlight
4. Ask them to see what factors influence the lightbulb. Ask the following:
    - What happens if you cover the panel? Partially, fully?
    - What do you think happens on a cloudy day?
    - How big would a panel have to be to light up a whole house?



Activity IV - Wind Energy **10 minutes**

1. Explain to students that they will be making their own windmills.
2. Give each student a tack, windmill drawing, and pair of scissors.
3. Have the students cut along the solid lines
4. Next, have the students fold over the corners to the center and secure it with the furniture nail to the cork
5. Once the windmill is secured via cork to the motor, connect the wires from the motor to the LED, ensuring that the positive lead from the motor is connected to the positive (longer) wire of the LED
    - You could also ask the students why they think it has to be connected in a certain way
6. Have the students place the pinwheel in the wind to spin. If the LED does not light up, you likely need more wind-- plug in the hairdryer and use it to blow stronger wind on the pinwheel.
7. Once the LED is lit, ask the students:
    - Do you think this would be easier to harder with a bigger pinwheel?
    - What do you think is happening?
    - The wind is driving the motor backwards, which sends electricity to the LED



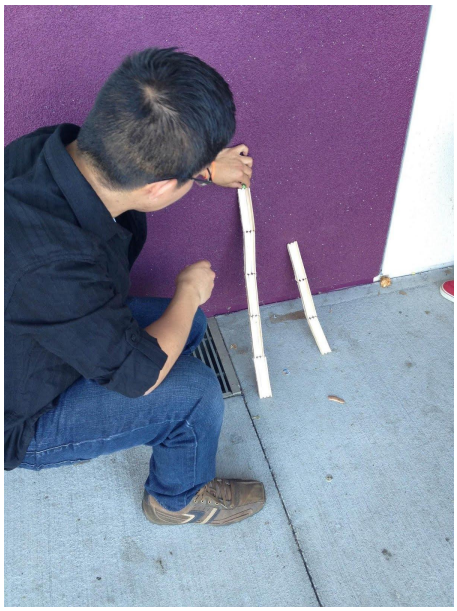


Activity V- Kinetic Energy

10 minutes

1. Have students set up the shoots of different sizes by leaning them against a wall.
2. Give students marbles of different sizes and masses.
3. Ask the students to drop the marbles into the shoots.
4. Have the students record how far the marbles travel.

5. Compare the distances, retesting to see what happens with different marbles but the same shoot and different shoots but the same marble
6. Discuss the activity and the conclusions, asking questions such as
   - Why are there more than one shoot and why are they different sizes?
     - Potential Energy depends on height
   - Why are the marbles different sizes and which marble do you think will go the most distance and why?
     - Potential energy depends on mass height and acceleration and Kinetic (movement-based) energy depends on mass, velocity and acceleration
   - Marbles were not moving at first how did they gain all that energy?
     - Conservation of energy, potential energy got transferred to kinetic energy



Assessment

1. Ask questions throughout the activity, some of which have been outlined above.
2. After the activity, instructors can bring the group together and ask culminating questions, such as:
   - What did all the activities have to do with one another?
   - How do you think our electricity gets into our walls?
   - Why do people think that solar and wind are better for the Earth?

Lesson Plan: Designing a Sustainable Home

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Gather prototyping materials.
✓ Preview or download the Stanford students design a zero energy home (Stanford Start.Home) video: https://www.youtube.com/watch?v=GP10W7BoCx0&list=PLpGHT1n4-mAsB4ncw5Iy3yRR9NwVbMmOx
✓ Gather information on sustainable features for homes
- Solar Panels
- Wind Mills
- Rain Water Collector
- Solar Water Heaters

Materials

- 1 set of note pads per group
- Butcher paper (2'x4' per group)
- 1 mid-sized cardboard box per group
- 10 sheets of paper per group
- 5 1'x1' felt
- 1 roll of tape per group
- 1 set of scissors per group
- 20 popsicle sticks per group
- 10 pipe cleaners per group

Lesson Overview

This lesson explores the various technologies and tradeoffs of energy efficiency in the household. Students will empathize, design, and prototype a home for a particular user who wants a green home.

Learning Objectives

Students will:
- understand the process and skills needed to interview a user
- understand the importance of generating ideas
- learn various technologies that are used in energy efficient houses
- consider the financial trade-offs present when investing in green technologies for the household
- communicate and pitch their ideas to a customer or stakeholder
- work in teams to plan and prototype a house

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Introduction to Energy Conservation **5 minutes**

1. Present PPT Slide 107. Play the Stanford students design a zero energy home (Stanford Start.Home) video, linked to the photo and the text on the PPT slide: https://www.youtube.com/watch?v=GP10W7BoCx0&list=PLpGHT1n4-mAsB4ncw5Iy3yRR9NwVbMmOx
2. Explain to students what a "green" home is.
3. Solicit a few suggestions for what features a sustainable home might have.
4. After a few students have responded, list some other technologies currently used to make a home sustainable, explaining the technology if necessary.
5. Tell them that they will be designing and building a model of a "green" home.
6. Present the students a user profile of Susie, who is building a green home and has certain needs.
7. Tell students to consider Susie's needs when designing her sustainable home.

Activity II - Ordering **10 minutes**

1. Ask students to get into teams.
2. Provide each team with the Order Form and ask them to select what technologies and materials will appear in their house. Remind them that they must stay under the $200 budget.
3. Once they have completed the Order Form, check their budget math. If they are vastly under budget, encourage them to purchase more energy efficient options.
4. Once they have approached the $300, give them the materials with which they can build a prototype of their house. You may want to assign certain materials to certain technologies (for instance, if they ordered the rainwater collector, you may want to give them an egg carton or if they ordered a solar panel, you may want to give them aluminum foil).

Activity III - Brainstorming **5 minutes**

1. Put the butcher paper on the wall
2. Give students each a stack of post-its
3. Have the students generate ideas for what should go into the home
4. If they have difficulty generating ideas, prompt them with ideas like the following:
   - What ideas would a seven-year-old be able to add?
   - What does Susie want and need?
   - What is the best feature you can include to save energy?

Activity III - Prototyping **25 minutes**

1. Give the students the prototyping and drawing materials

2. Tell them that after 25 minutes, they will pitch their home to their client and convince them to buy the home
3. Tell them that they may use different types of paper, glue, and tape to make their prototype.
4. Prompt them to build using sustainable resources
   - For instance, if using solar panels, ask them where their solar panel might be placed.
   - If they have a rainwater collector, ask what they may need to get the water to the house.
5. Also encourage them to be creative with their designs.

Activity IV - Presenting **10 minutes**

1. Have the teams present their designs to each other.
   - They should share how the house is sustainable.
   - They should explain how much their house costs.
   - They should also explain what are the sustainable features used and why.
   - Tell them what features meet the needs of the user.
   - Give them critiques about what features aren't addressed
2. Remind the students about features that were mentioned as desirable during the interview

Activity V - Debrief ***5 minutes***

1. Ask the students to reflect on their design.
2. Ask them to write down the pros and cons of their design.
3. Ask them a few questions to prompt their thinking:
   - If you could do it again, what would you do differently?

Assessment

1. An instructor will be able to see how many of the needs demonstrated in the interview came to fruition in their plans.
2. The instructor can also ask students if they would have added more features to their design if they had more materials or time.
3. Ask the students questions about their designs, such as how their prototypes could be designed better or what components of their designed seemed to work well.

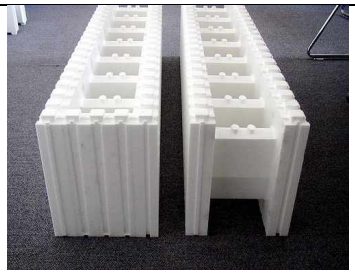
Resources

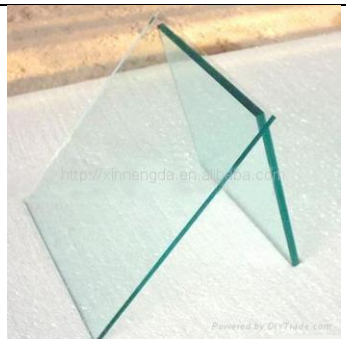
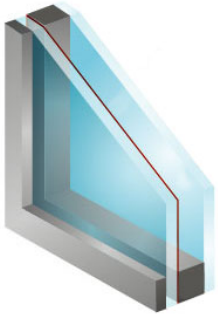
User Profile: Susie

Susie is building a new house in sunny California and she wants her house to be a sustainable, green home that is affordable to build. She has a budget of $300 and wants you as the house architect and engineer to consider the many different materials, technologies, and ways to conserve energy in her new house. Her ideal house is one that keeps her warm in the winters and cool during the summers. It also should be a comfortable house for her with the basic appliances she needs for cooking.

ORDER FORM

BUDGET = $300.00

Materials	Types	Pictures	Cost
Building Material	***Wood***		60
	Insulated concrete		80
Appliances	***Normal***		10
	Energy Efficient		30
Lights	***Incandescent***		5

	Energy Efficient (CFLs)		10
Windows	***Normal***		10
	Insulated		25
Water Heater	***Standard***		10
	Solar Powered		25

Additional Features	**Picture**	**Cost**

Solar Panels		25
Small Wind Turbines		35
Rainwater Collector		10
Recycled Water System		30

WEEK 2

UNIT 5: STRUCTURE AND BUILDING MATERIALS

DAY 9A: Foundations: From Oobleck to Toothpaste!
DAY 9B: Building a Waterproof Roof
DAY 10A: Geometrical Shapes and Composites
DAY 10B: Earthquake Stable Building

Hour	Day 6	Day 7	Day 8	Day 9	Day 10
A	**Architecture: Perspective Drawing**	**Sustainability: Building with Green Materials**	**Sustainability: Exploring Energy Sources**	**Structure and Building Materials: Foundations - From Oobleck to Toothpaste!**	**Structure and Building Materials: Geometrical Shapes and Composites**
B	**Architecture: Speaker and Bill Nye Video**	**Sustainability: Keep it Cool!**	**Sustainability: Design a Sustainable Home**	**Structure and Building Materials: Building a Waterproof Roof**	**Structure and Building Materials: Earthquake Stable Building**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how the properties of building materials, geometrical shapes, and structural form influence a shelter's function, design, and stability.

Lesson Plan: Foundations: From Oobleck to Toothpaste

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Collect physical materials
✓ Preview and download the following videos:
http://www.youtube.com/watch?v=PwvvYxSZ7PI (start at 0:50)

http://www.youtube.com/watch?v=p1TcQXSK_6k

http://www.youtube.com/watch?v=f2XQ97XHjVw

http://www.youtube.com/watch?v=536xSZ_XkSs

✓ Make/prepare containers/tray to hold the land/foundation materials

Materials

- 1 cup of “Mars Mud” or silly putty
- 1 cup of Playdoh
- Land/foundation material
- Sheet metal (flat metal), small to be hidden under paper plate
- 1 tube of tooth paste
- 1 cup of sand
- 2 cups of corn starch
- 2 cups of water
- 1 cup for mixing corn starch and water
- Spoon (for stirring oobleck)
- Ball bearings (or any small weight)
- 5 small trays
- 5 paper plates/napkins (for hiding contents of the trays). These should be numbered.

Lesson Overview

This lesson is designed to introduce students to the topic of building foundations and foundation stability with a series of hands-on activities. After viewing videos about building foundations, the students will explore the malleability and deformation capabilities of a variety of common materials in the context of engineering and determine which would be the safest foundation.

Learning Objectives

Students will:

- explore varied materials for building foundations
- learn about foundation stability
- make Oobleck
- test varied materials for building foundations

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Activity I - Introduction *10 minutes*

1. Present PPT Slide 109.
2. Play the following videos for the students:
   http://www.youtube.com/watch?v=PwvvYxSZ7PI (start at 0:50)
   http://www.youtube.com/watch?v=p1TcQXSK_6k
   http://www.youtube.com/watch?v=f2XQ97XHjVw
   http://www.youtube.com/watch?v=536xSZ_XkSs
3. Ask the students the following questions:
   - Would you live in a house on one of these sand islands? Why or why not?
   - The sand islands are being built in Dubai. Why might creating these islands be a bad idea in an area near an ocean or a bay?
   - What kind of land should you build a house on?

Activity II - Guess What's In The Bag? 10 minutes

1. Instruct the students to close their eyes.
2. Have the students reach over to the numbered plate to touch the hidden foundation materials.
3. Have the students guess what they are touching. Ask them to rank the unknown substances (1-5) based on which substance they would prefer to use to build a house foundation.

Activity III - Testing 10 minutes

1. Have the students place a cup/container with ball bearings on top of the foundations (clay, sillyputty, sand, toothpaste, etc). Tell them that this simulates the load a house would apply to the foundation.
2. Ask the students to observe which foundation deforms the most by seeing how far the ball bearings sink.
3. Ask the students to observe how the load and foundation respond to vibrations or shaking.
4. Ask the students to discuss their observations and findings.
5. Lead a discussion on material properties and the statics analysis such as viscosity, density, surface tension, shear stress, non-Newtonian fluids.

Activity IV - Make Oobleck 10 minutes

1. Tell the students that they are they are going to make Oobleck. Begin with the water in the container and start adding the cornstarch to it. As you get closer to adding the full amount, start adding it slowly and mix it with your hand. The goal is to get a consistency where the

Oobleck reaches a state that is liquid and also solid (non-Newtonian fluid), depending on how hard it is struck. Keep adding cornstarch or water until the desired consistency is reached. This would apply to the foundation.

2. Have the students play with the Oobleck.

Activity V - Test the Oobleck **10 minutes**

1. Have the students repeat the test procedure with the Oobleck. Ask them to place a cup/container with ball bearings on top of the Oobleck**.** Ask them to observe how the Oobleck is deformed by the bearings.

Assessment **10 minutes**

1. Ask the students the following questions:
   - What type of land would make you feel safest?
   - Why?
   - What did you learn in this lesson?

Lesson Plan: Building a Waterproof Roof

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Gather materials
✓ Conduct brief research on roof design techniques and material properties to discuss with the class

Materials

- Bin or small container that can hold water
- A cup or watering can for pouring water
- A measuring cup
- Plastic storage containers (one per student/group)
- 30 sticky notes per group
- 10 pieces of string per group
- 10 paper clips per group
- Cardboard: 5+ sq. feet
- 1 roll of tape per group
- 20 pipe cleaners per group
- 5 pieces of paper
- 3 rolls of newspapers per group
- 5 pieces of large non-water proof fabric per group (enough to cover the container)
- 10 wooden dowels (optional)
- Branches and leaves found around school site
- Any other materials that can be found at school site
- Information sheet in the **Resources** section

Lesson Overview

In this lesson, students learn about the form and function of roofs on shelters, especially shelters made from limited materials in the developing world. Students design and construct a roof with the goal of making it as water proof as possible. They then test their roofs in a “storm” – pouring water over it to see if it holds.

Learning Objectives

Students will:

- design and build a waterproof roof for a shelter
- test their roof design by pouring water on it
- iterate their design after testing
- identify which elements of their design make for successful waterproof roof construction
- learn about how structural engineers improve the designs of buildings

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I – Introductory Discussion Activity *10 minutes*

1. Present PPT Slide 110.
2. For 3 minutes, ask the students to think about the importance of roofs in their lives:
    - Why do we need roofs on our shelters?
    - What are some of the different functions of roofs?
    - What are some of the different shapes of roofs that you've seen before?
    - How do different shapes match the different functions of roofs?
    - What are some of the different materials that you've seen used for roofing?
    - How are the materials used different here in the USA compared to abroad in developing countries?
3. Encourage students to take notes on the sticky notes provided when they are brainstorming.
4. For 3 minutes, share out your experiences and responses to the questions about roofs (i.e. Raul shares his experience with a leaky roof caused by a flat root that couldn't fully support all the water weight).
5. For 4 minutes, hand out the *Waterproof that Roof!* Information sheet for students to read briefly. **NOTE:** If the students find this section too tedious or boring, frame the research as necessary for the competition and getting a head start to know what properties are better for their design. Another idea is to ask these questions and have students consider these ideas after they jump in and begin building. This may help some students visualize better.

Activity II – Brainstorming and Building the Roof *25 minutes*

1. Split the students up into groups of 3.
2. Tell the students that they have 5 minutes to brainstorm roof designs that use the materials presented, but they cannot touch their materials until the building phase
3. Hand each group a set of materials for roof design and building. Each group will get a container, which will function as their shelter. Explain to the students that their limited materials reflect the limited materials that exist in the developing world, where individuals have to build their roofs with whatever they can find or whatever they can afford.

4. Tell the students that they have 20 minutes to build a roof based on one of their brainstormed designs. Tell them to use the materials to build a roof over the container. Their goal is to build the most waterproof roof so that they have the least amount of water in their shelter (the container). **NOTE:** One possible challenge is that a student may not have a clear idea of where to start. In this case, ask guiding questions to help them think through what they might try:
   - Which material would be more effective in keeping water out, the cloth or these leaves?
   - What supports a roof?

Activity III – Testing, Iterating, and Reflecting 20 minutes

1. Have students bring their containers and roofs outside to an area where water can be poured over the roofs.
2. Hand the students a cup of water or the watering can to pour water over each roof. The same amount of water should be poured for each roof, one at a time.
3. After waiting 1 minute, remove the roofs and pour the water in the container into the measuring cup to be measured. The student group that ends up with the least amount of water collected in their container is the winner of the first round.
4. Ask students to consider what worked and what didn't work about their design
5. Tell the students that they have another 10 minutes to try improving their roof designs so that they can win the second round.
6. Test the roofs for a second round by pouring water on the roofs and measuring the water collected in the container. The student group that ends up with the least amount of water collected in their container is the winner of the second round round.

Activity IV – Letter Writing (optional, if time permits) 5 minutes

1. Ask the students to write a letter to someone who just moved to a developing country and has to build his or her own shelter.
2. Tell students to specify in the letter what they learned in their prototypes and to give directions to the individual to build a roof for their shelter given the limited materials in the developing world.

Assessment

1. Examine the results of the rain simulation between the first and second rounds. Consider: Did the students improve their designs?
2. Read the letters that the students
3. Ask the following questions to assess their understanding of the activity:
   - What made your design successful?
   - What would you do differently if you could do a third round?

Resources

Waterproof that Roof!

Student Resource: Roofing Materials

The primary job of a roof is to keep water out of a structure. These structures can range from something as simple as a bird house or mailbox to a sports stadium. Of course, roofs also protect against wind, cold, and heat, and also keep unwanted animals and pests out. The pitch (or angle) of a roof is usually proportional to the amount of precipitation the building anticipates. Houses where there is low rainfall may have flatter roofs than areas where large rain or snowfall levels are anticipate. In these areas, steeply pitched roofs with efficient gutter systems are prevalent.

◆ **History**

With the involvement of engineers, much of the innovations and changes in roofing have taken place in the last 200 years, but of course roofs have been important to society for much longer. The Greeks and Romans were believed to be the first to experiment with different roofing styles. The Romans introduced slating and tiling as early as 100 BC. Thatched roofs made of woven grasses were introduced around 735 AD, and have been used extensively in many parts of the world. Thatch is roofing made of plant stalks in overlapping layers. In most of Europe and the United Kingdom, thatch was the preferred roofing material in the countryside -- and also in some villages -- until the late 1800s. Wooden shingles and clay tiles became more popular and spread to mass-production of roofing materials. Concrete tiles are a more recent development. Now, a variety of engineered materials are used to improve water resistance and also increase the lifespan of a roof. Thatched roofs, for example, may require frequent maintenance, while some more recent materials can last up to thirty years without maintenance. But performance isn't the only attribute valued in a roof. Thatch roofs once looked in danger of dying out, and considered a symbol of poverty, but a thatching revival is under way as people look to these designs for their charm in spite of high maintenance.

◆ **Roofing Materials**

The materials used in a roof may be determined by a variety of factors including local laws, material availability, climate, cost, and frequency of required maintenance. Materials can be just about anything, from wheat straw, sea grass, banana leaves, laminated glass, aluminum sheeting, slate, ceramic tile, cedar panels, plastic or rubber sheets, asphalt and asbestos shingles, galvanized steel, and fiberglass sheets, to precast concrete. Newly engineered materials, and advances in solar panels and sun roofs have also had an impact on what roofs look like and how they perform over time.

For more information, please visit the source:
http://www.tryengineering.org/sites/default/files/lessons/roof.pdf

Lesson Plan: Geometrical Shapes and Composites

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
- ✓ Find a video of buildings or structures failing to demonstrate the problems that arise due to poor engineering design and poor material selection.
  - Tacoma Bridge Collapse: https://www.youtube.com/watch?v=XggxeuFDaDU
  - Building Collapse in the Philippines: https://www.youtube.com/watch?v=uKeENdyIluI
- ✓ Prepare construction paper, cardboard or printing paper cut to 8”x4” rectangles. Square beam mold made from lollipop sticks (glued together or taped)
- ✓ Prepare an example of a composite material made with paper and different geometrical shapes

Materials

- Videos of various structures failing
- A variety of 8” x 4” pieces of sheet materials (cardboard, construction paper, regular paper and foam)
- 1 roll of tape or glue bottle per group
- 1 pencil per group
- 1 ruler per group
- 1 square beam per group
- 1 prize for the winning student or group
- Books or other heavy objects to be used as weights

Lesson Overview

In this lesson, students design and prototype their own sheet of composite material made out of cardboard and paper to maximize its strength. Students learn about geometrical shapes and their effect on the strength of a structure.

Learning Objectives

Students will:

- understand the concept of a composite material
- understand the effects of geometrical shapes and beam/column alignment in the overall strength of their material
- prototype their own composite material
- test their composite designs with real world constraints
- identify which elements of their design prevent failure

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Failing Structures **5 minutes**

1. Present PPT Slide 112.
2. Show the students the prepared videos of different structures that collapse or fail unintentionally.
   - Tacoma Bridge Collapse: https://www.youtube.com/watch?v=XggxeuFDaDU
   - Building Collapse in the Philippines: https://www.youtube.com/watch?v=uKeENdyIluI
3. Ask them to reflect and think of reasons why these building structures could have failed.
   - Why do you think the building or structure collapsed?
   - Do you think the use of different materials could have made the structure stronger?
   - Do you think the use of different shapes could have made the structure stronger?
   - What would you have done to make the structure stronger?

Activity II - Geometrical Shapes & Composites **5 minutes**

1. Ask the students to brainstorm the geometrical shapes that they most often see used in building or structure design.
2. Ask them to draw as many shapes as possible and describe the places in a building where these geometrical shapes are used and why.
   - Why do the pillars in most structures have a circular or square cross-sectional area?
3. Ask students to think of ways in which organizing these shapes into layers with different beam/column alignments might make a stronger structure.
4. Explain to the students what a composite material is.
   - A composite material is a combination of two or more materials which still remain different from one another in property even after combining
   - Plywood is a composite material because gluing wood together at different angles gives the plywood better properties than natural wood
   - Concrete is a composite material made of cement, water, and additional chemicals
5. Show them an example of a prefabricated composite material. NOTE: You may use cardboard to show how the different layers add to its rigidity or make your own composite material (see photo below).
6. Show the students how the material's rigidity differs when you bend the material along its column/beam alignment vs. perpendicularly.

Activity III - Prototyping **20 minutes**

1. Depending on the student-materials ratio, either split the students into groups or have the students work individually.
2. Ask the students to prototype a composite material that will have an overall top dimension of 12” x 6”.
3. Tell the students that they may use different types of paper, glue, and tape to make their prototype. **NOTE:** Using tape might be a difficult choice for putting the composite material together as it takes much longer than using glue. Glue does take additional time to dry however.
4. Tell the students that they may also use pencils or the square beam to help them roll paper and create their composite material. **NOTE:** students may have trouble folding the paper. It might help to model how to roll paper with a pencil, ruler, or square beam.
5. Tell the students that their composite materials will be tested by placing their finished prototype between two desk and adding weights towards the center of the prototype to see how strong and resistant their design is compared to other students’ designs.
6. Tell the students that the composite material that holds the heaviest load will win a prize.

Activity IV - Testing of Prototypes **10 minutes**

1. Have the students test their prototypes.
2. Place the composite prototype between two desks.
3. Begin slowly placing weights on the prototype. You may tape the edges of the composite material to each desk to prevent the composite bridge from slipping when weights are added. To make sure testing is consistent, add the same weights in the same order.
4. Once the composite sheet collapses or breaks, count the number of weights placed on it. Keep track as each student or group tests their prototype.
5. Reward the winning team.

Activity V - Debrief **5 minutes**

1. Lead a discussion relating the failed structures to the videos shown at the beginning of the lesson. Clarify any questions the students may have.
2. Ask the students to consider how their composite material could have helped to make the failed structures safer and keep them from collapsing.

Assessment

1. Test the composite prototype to determine a certain threshold weight (to be decided by the instructor).
2. Ask the students to respond to the following questions:
   - What made your design strong and prevented it from failing earlier?
   - If you could do it again, what would you do differently?

Lesson Plan: Earthquake-Stable Building

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Preview or download this National Geographic video of earthquake footage:
https://www.youtube.com/watch?v=4Y-62Ti5_6s

Materials

- Cardboard (1 1'x1' square per team)
- Wood toothpicks (40/team)
- Plastic toothpicks (40/team)
- Licorice candy (20 ½" pieces/team)
- Marshmallow (20 pieces/team)
- Clay (1 can play-doh/team)
- 100g weight (1 per class)

Lesson Overview

In this activity, a toothpick structure will be constructed using various materials to join the toothpicks. The structure will undergo an earthquake shake to see how resistant the joints are in structure during the earthquake event.

Learning Objectives

The students will:

- learn how a structure's design can affect overall structural rigidity.
- have the ability to work in teams and communicate efficiently.
- learn how material type will affect the rigidity of a structure.

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Introduction **5 minutes**

1. Present PPT Slide 113.

2. Show the class the National Geographic earthquake footage: https://www.youtube.com/watch?v=4Y-62Ti5_6s
3. After the earthquake video, have a small earthquake experience discussion. Use the following questions to facilitate conversation with students:
   - Has anyone ever experience an earthquake? if so can you describe your experience.
   - From the video, what terrified you the most? (items falling from shelves, building collapsing, etc.)
   - Does anyone know what engineers do to keep new building stable during an earthquake?
4. Separate class into groups of 2 or 3 students

Activity II - Brainstorm and Prototype **25 minutes**

1. Tell students that they will build a 4 level structure made of toothpicks and joining material of their choice. A 100g weight will be hanged from the top level of the structure using a thread and paperclip. The structure will then be shaken to determine if the design successfully overcame the earthquake.
2. Tell students that they have the choice picking wood or plastic toothpicks (20 total per team). They can only one material for their joining medium (licorice, marshmallows, or clay).
3. Allow teams to brainstorm ideas to create their earthquake proof design. They should be able to decide what type of toothpicks and joining material they will be using.
4. Tell students to pick up their materials and prototype their design.

Activity III - Test and Reiterate **10 minutes**

1. Once each team is finished, attach 100g weight at 4th level of structure. (The weight will give the structure some mass that will determine the rigidity of the structure when the structure is set to the earthquake test)
2. Attach the structure to the weight.
3. Shake the cardboard (where structure is attached) back and forward slowly and then intensifying frequency slowly.
4. Repeat similar motion for all other teams.
5. Ask students to take notes as they observe how different materials/joining materials affect the rigidity/stability of the structure during the earthquake simulation.
6. Using observations/notes from Earthquake Tests, have students reiterate their design. They can choose new materials if desire.
7. Retest new prototypes as in step 2 and 3.
8. Allow students to make notes in how their own structure behaved during the second prototype

Activity IV - Debrief **5 minutes**

1. Ask the following questions to trigger a conclusion discussion:
   - Did the materials you choose for your first prototype behave as you expected?
   - How did the two types of toothpicks compare with each other?
   - How did the joining materials compare with each other?
   - Did the structure's design influence the stability of the structure?
   - If a reiteration was perform, How did the second prototype compare with the first?

Assessment

Students will be assessed during the conclusion session by analyzing their participation in the discussion of what did and did not work. If the students reiterated their prototype, their second prototype could be used to assess their learning when compared to their first prototype. Students should be able to select the best design and explain the best features of the prototype.

WEEK 3

UNIT 6: GLOBAL SHELTER

DAY 11A: Design Challenge 2.0: Developing Empathy
DAY 12A: Design Challenge 2.0: Point of View Statements and Brainstorming
DAY 12B: Design Challenge 2.0: Brainstorming Solutions and Prototyping
DAY 13A: Design Challenge 2.0: Prototyping and Testing
DAY 11B: The Crowded Shelter Challenge
DAY 13B: Infrastructure: Marble Tracks
DAY 14A: The Climate Zones Design Challenge
DAY 14B: Designing Healthier Kitchens for Nigerian Women

Hour	Day 11	Day 12	Day 13	Day 14	Day 15
Hour A	**DESIGN CHALLENGE 2.0 (Global Shelter): Empathize**	**DESIGN CHALLENGE 2.0: Define & Ideate**	**DESIGN CHALLENGE 2.0: Prototype & Test**	**Global Shelter: Climate Zones Design Challenge**	**Biodiversity: Goldfish Shelter Design**
Hour B	**Global Shelter: The Crowded Shelter Challenge**	**DESIGN CHALLENGE 2.0: Ideate**	**Global Shelter: Infrastructure: Marble Tracks**	**Global Shelter: Designing Healthier Kitchens for Nigerian Women**	**Biodiversity: Building a Biodome for Plants**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how the empathy-driven design thinking process can inform the successful design of shelters in the global context.

Lesson Plan: Design Challenge 2.0: Developing Empathy

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Set up the video of Hanadi's story (can also click on the picture in the PPT):
✓ https://www.youtube.com/watch?v=1q6MVtxiaMU

Materials

- Paper (5 sheets per student)
- Markers (1 per student)
- Written user profile of Hanadi in the **Resources** section

Lesson Overview

In this lesson, students are introduced to the second extended design challenge on Global Shelter: *Redesigning the Shelter Experience for Young Refugees in the Developing World*. Students engage in the empathy phase of the design thinking process by learning about the needs and challenges of young people in refugee camps in Northern Africa, especially in terms of learning spaces.

Learning Objectives

Students will:

- learn the design thinking process in more depth while exploring the empathy stage of the design process in more depth
- build empathy for the challenges that young people in refugee camps face in the developing world
- search for insights about the way that displaced individuals in developing regions live in refugee camps
- review information on observation and interviewing
- practice constructing an Empathy Map
- participate in small group and whole class discussion
-

Activity I - Empathy *25 minutes*

1. Inform the students that they will be participating in the first extended design challenge and that it will be a longer and more in-depth version of what they learned in the Introductory Design Challenge.
2. Present PPT 115, which introduces the challenge Redesigning the Shelter Experiences for Young Refugees in the Developing World.
3. Present PPT Slide 116 that shows the students the design thinking process, and remind them that they are going to begin today's activity with the empathize phase.
4. Present PPT Slide 117 to explain that students will be doing an observation of two videos and should be paying attention to the videos. Tell students that they are going to practice using their observation skills. Here are some additional pointers to tell the students:

- Observe carefully what you see
- Listen carefully to what the user is saying
- Try to put yourself in their shoes
- Listen carefully and take notes while you're watching

5. Present PPT Slides 118-120 that contain a background on the location of Jordan/Syria, Za'atari refugee camp and a video of the user, Hanadi, a 17-year-old Syrian refugee living in the camp.
6. After watching the video, ask the students the following question to quickly debrief the video:
   - What did you learn about Hanadi?
   - What surprised you about Hanadi?
   - If you could ask Hanadi a question, what would you ask her?

Activity II - Empathy Map Creation *25 minutes*

1. Present PPT Slides 121-122. Inform students that they are now participating in the Define phase. Tell students to begin an empathy map. Review the content for each column of the map.
   - There are two columns: "Say/Do and Think/Feel."
   - Under "Say," list things the interviewee actually said during the interview. Include direct quotes.
   - Under "Do," list what the interviewee did during the interview, which includes things like looking away, tapping the feet, smiling, laughing, crying, or crossing the arms.
   - The "Think" and "Feel" portions of the Empathy Map are for inferences about what the interviewee thinks and feels based on what he or she said and did.
   - There are no wrong answers on an Empathy Map.
2. Give each team a large piece of chart paper and ask them to draw an Empathy Map. Tell the students to complete the Empathy Map based on their interviews. Visit each team to clarify any questions the students might have.

Resources

WRITTEN USER PROFILE: Hanadi

Hanadi is a 17-year-old girl living in the Za'atari refugee camp in Jordan.

When the civil war in Syria began in July 2012, 17-year old Hanadi and her family fled their home in Damascus, Syria. For one year they moved across Syria to escape the violence. In February 2013, they finally crossed the border to safety in Jordan. With it

came an overwhelming sense of relief. But life in the Za'atari, like any refugee camp, is tough.

At Za’atari refugee camp, Hanadi has only made 2 friends, Rana and Isra. They spend most of their time going to school, hanging around in the heat, and doing homework. Hanadi wishes she could learn more subjects, like art, in school. They want to do more, but there are no spaces for young people to have fun in the camp. Hanadi sometimes feels unsafe and scared because she sees other young people fighting out of the frustration. These young people, like Hanadi, miss home and do not want to spend their time just hanging around this camp.

Hanadi really misses her home country, Syria. She misses her old friends, her house, the streets, the markets, her school, and her old life.

Lesson Plan: Design Challenge 2.0: Point of View Statements & Brainstorming

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT so that students can view it.

Materials

- Chart paper (2 sheets per group)
- Markers (1 per student)
- Post-it notes (1 pad per person)

Lesson Overview

In this lesson, students define the Hanadi's needs by creating a Point of View statement based on their notes and empathy map from the previous day. Students then begin brainstorming different ideas on how to address her needs.

Learning Objectives

Students will:

- create Point of View statements based on user needs
- brainstorm different ideas to address user needs

Activity I - Point of View Statement *10 minutes*

1. Present PPT Slide 125. Remind the students that they are going through the define phase of the design thinking process.
2. Present PPT Slide 126 and review the Point of View statement, explaining that it is a way to synthesize their interview data. Tell the students that they will use this statement to help solve the design challenge for their users.
3. Review the following parts of a Point of View Statement
4. The User: Use an adjective to describe you user
   A Need: Use a verb to describe your user's need
   An Insight: Describe why this will meet your user's need
5. Ask students to generate additional examples of Point of View statements before they begin crafting their own statements.

Activity II - Point of View Statement Creation *20 minutes*

1. Have students work with their teams to create Point of View Statements for their users. Give each group a blank piece of chart paper and have them duplicate the Point of View Statement from PPT Slide 126.
2. Give the students 15 minutes and tell them to create 2-3 Point of View Statements. As the students work, go to each group and clarify any questions the students might have.

3. Ask each team to share their Point of View Statements with the class. Allow students to provide feedback on the statements using the following questions:
4. Could we think of many solutions to meet the need that is described in the Point of View Statement?
5. Is there a clear description of the user, the need, and the insight?

Activity I - Brainstorm *25 minutes*

1. Present PPT Slide 128. Tell students that they are now going through the Ideate stage of the design thinking process.
2. Explain that brainstorming is built upon mindsets, and that mindsets are a “road map” for how things are done.
3. Present PPT Slide 129 to review tips for how to brainstorm. Read each rule aloud.
4. Present PPT Slide 130, which contains a list describing how to brainstorm in a group.
5. Before brainstorming, lead a quick 5-minute improvisation activity to get students warmed up for brainstorming in teams.
6. Give the students 15 minutes to brainstorm ideas. Visit each team to encourage them to follow the brainstorming tips presented in the slides.

Lesson Plan: Design Challenge 2.0: Brainstorming Solutions and Prototyping

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.

Materials

- Post-it notes (1 pad per person)
- Markers (1 per person)

Lesson Overview

In this lesson, students will select an idea for prototyping.

Learning Objectives

Students will:

- brainstorm ideas based on user needs
- group ideas by theme
- participate in a vote to choose 3 top ideas

Activity I - Brainstorming *15 minutes*

1. Before brainstorming, lead a quick 5-minute improvisation activity to get students warmed up for brainstorming in teams.
7. Give students 10 minutes to revisit their ideas from yesterday and brainstorm new ideas again to warm up before prototyping. Visit each team to encourage them to follow the brainstorming tips presented in the slides.

Activity II - Idea Clustering and Selection *20 minutes*

1. Present PPT Slide 130 and tell students that they are going to cluster their ideas into themes. Have them do this by rearranging their post-it notes.
2. Present PPT Slide 131. Tell the students that they are going select their favorite ideas that they would like to build for their users. Discuss the different possible ways to choose a favorite. These might include an idea that is easy to build, a crazy idea, or an idea that they are really excited about building.
3. Tell the students that each person has 3 votes, and that they should choose their top 3 favorite ideas and vote by placing a check mark on the post-it containing that idea.
4. Give students 3 minutes to vote. Have each group tally its 3 top ideas based on the votes.
5. Ask each group to share its top 3 ideas.

Activity III - Prototyping *25 minutes*

1. Present PPT Slide 132. Tell the students that they are now in the prototyping phase of the design thinking process.
2. Explain to the class that design thinkers build prototypes that are unfinished products and that the purpose of a prototype is to put something in the hands of their user quickly to see if the person likes the idea.
3. Present PPT Slide 133, which explains some of the features of a prototype. Review each point and clarify any questions the students may have.
4. Present PPT Slide 134. Give students 20 minutes to build their prototype.

Lesson Plan: Design Challenge 2.0: Prototyping and Testing

Preparation

✓ Set up the BUILT TO LEARN!: Redesigning Shelter Curriculum PPT

Materials

- Pipe cleaners
- Markers
- Popsicles
- Tape
- Paper
- Assortment of cardboard
- Other materials available

Lesson Overview

In this lesson, students will build a prototype of their chosen idea and test their prototype. Students will learn more about new design solutions for refugee needs in the developing world.

Learning Objectives

Students will:

- build a prototype of their best idea
- test their ideas with the user (in this case, the teacher)
- capture user feedback (in this case, the teacher)
- learn about new design solutions for refugee needs in the developing world

Activity I - Prototype I *15 minutes*

1. Present PPT Slide 136. Give students an additional 15 minutes to continue building their prototype from the previous day.

Activity II - Testing *15 minutes*

1. Present PPT Slide 137. Tell students that once they have created their prototypes, they normally would be testing them on the user they interviewed or observed. Testing the prototype allows them to see the reactions and interactions of the user, which provides important feedback for rethinking their designs and finding out if it meets their users' needs. However, since the user is Hanadi and she cannot be with the students, students will instead get feedback from the teacher(s).
2. Present PPT Slide 138. Provide the following guidelines for the designers:
   - Don't over-explain your prototype. Allow your user to interact with it without interruption.
   - Observe your user closely. You may learn something new about what they need.
   - Don't sell your prototype.

    - Give a brief sentence about your prototype as an introduction, and then don't do any more talking.
3. Provide the following guidelines for the users:
    - When you receive your prototype, say what you think out loud.
    - Be direct and honest in your feedback. Your designer wants to make sure that the design meets your needs. Be specific about what you like and don't like.
4. Present PPT Slide 139. Tell students to test their prototypes on their users and capture feedback based on these guidelines. Suggest to students to ask the following questions:
    - What did you like?
    - What didn't you like?
    - What would you change?
    - What surprised you?

Activity III - Prototype II *15 minutes*

1. Present PPT Slide 140. Tell students to spend the next 10 minutes revising their prototype based on the feedback they received from their user.
2. Present PPT Slide 141. Encourage students to reflect on and discuss their “fail forward” moments during this design challenge. Ask them:
    - When did you fail or make a mistake?
    - What did you learn from that?
    - How did you improve your design?

Activity IV - New Solutions *15 minutes*

1. Present PPT Slide 142. Tell students that there are new and promising solutions currently being developed to support refugees and their needs. Show the students the IKEA video of “Designing a Better Home for Refugee Children.”
2. Debrief the video and the experience of redesigning the learning space shelter experience for refugees, and particularly Hanadi.

Lesson Plan: The Crowded Shelter Challenge

Preparation:

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ Recall if possible, a personal story to share about living in a crowded living area
- ✓ Collect materials

Materials

- Assortment of cardboard, small, medium and large sized
- Tape, preferably duct tape
- Scissors
- Markers
- Paper

Lesson Overview

This lesson is intended to have students build shelters with limitations on space. Students will discuss what it means to live in a crowded space and will then build a makeshift shelter out of cardboard.

Lesson Objectives

Students will:

- learn about communities in living in crowded living spaces
- build a living space for crowded communities
- coordinate with other team members to build the living space

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity I - Discussion *20 minutes*

1. Ask students to examine the picture on PPT Slide 123. Ask students the following questions:
    - What do you see in the picture?
    - What different purposes does this room serve for the person in the picture?
2. Share out, if possible, a personal story on living in a crowded living space.
3. Pose the following question:

    - Have you seen someone live in a crowded living space with their other family members? What was it like?
4. Introduce students to the crowded shelter challenge. Tell them that they have 20 minutes to build a makeshift shelter out of cardboard that is designed to fit everyone inside the group (instructor(s) may or may not be included. The shelter should be constrained to a limited space, and the students need to find ways to fit everyone inside the constrained space.
5. Explain to students that the shelter needs to include the following:
    - Bedding/sleeping areas
    - Kitchen (refrigerator, stove, microwave)
    - Entertainment (TV, couch)
    - Bathroom (toilet, shower)
    - Doors
6. Encourage children to also consider the following questions:
    - How does the lighting work? (is there going to be one light for everyone? What if there are people that want to sleep while other people want to cook?)
    - How do people navigate the house most efficiently?
    - Is there anyone in the group that needs special accommodations? Do girls need to be separated from boys?
    - Is there a study area?

Activity II - Construction *30 minutes*

1. Spend the first five minutes helping and modeling to students how to set up the “walls” of the shelter.
2. Split the students into groups of two or three students. Ask them to choose one of the requirements above to design for, such as a sleeping area, kitchen, bathroom, etc…
3. Ask children to coordinate in using materials.
4. If there is more than an hour, instructor(s) are encouraged to spend more time on this section.

Activity III - Debrief *10 minutes*

1. Ask students to share out their experiences in building the shelter.
2. Pose the following questions:
    - What was your favorite part about the house?
    - Would you live here?
3. Students may share their own stories about their living situations in the debrief or in the preliminary discussion.

Assessment

1. In addition to the questions in the debrief, pose the following questions:
    - What were some of the constraints the constraints that you faced in your design? What determined these constraints?
    - What type of constraints were they?
    - How did you deal with them?

Lesson Plan: Infrastructure: Marble Tracks

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Gather materials
✓ Find an outdoor location for this lesson
✓ Come up with a real-life scenario in which a road connecting 3 towns would be needed (character use would be ideal)
✓ Collect cardboard from local recycling bins. Pre-cut some parts into smaller pieces to provide more options
✓ Prepare materials for teams. Set up courses for each team. Each group will have a course consisting of three separate towns. Find a 10 ft. space and place the three wooden blocks in descending height order, not in a straight line. The first town should be set up on a desk or table so the marble has momentum to move down the rest of the track. Try and make each course an even distance.

Materials

- Cardboard (1 large box per team)
- 1 pair of scissors per team
- 1 roll of tape per team
- 1 marble per team
- Paper
- Paper Towel rolls (or any other recycled cardboard materials)
- Paper clips (50)
- Rubber bands (25)
- Duct Tape (1 roll)
- Blocks (10)

Lesson Overview

In this activity students compete in a design challenge and prototype on a large scale. Working in small teams, students connect three “villages” with one “road”. The villages are blocks spaced across a 10-foot area on an incline, and the road is a cardboard structure for a marble to roll down.

Learning Objectives

Students will:

- learn principles of physics and structural engineering
- create large prototypes of roads that stand on their own
- participate in a design challenge based on a real life scenario

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Activity I - Introduction **10 minutes**

1. Present PPT Slide 143.
2. Ask the students the following questions:
   - Why are roads are important?
   - How do roads impact a society's efficiency?
   - How have roads have helped facilitate travel and trade?
   - You may wish to elaborate and share your thoughts and experiences with the students.
3. Ask the following questions to help connect the importance of roads to the students' local surroundings.
   - Do you travel to get to school?
   - How far is your doctor's office?
   - How do you get there?
4. Tell the class that 3 separate towns need to be connected.
   Provide the following users and contexts for the students:
   - A child in a rural village/area needs to get to the doctor's office. The area is mountainous, and a road must be built for the family to get help.
   - A family has five children who are hungry and need food. They must get to a grocery. A road must be built to help the family get their quickly.
   - A firefighter needs to get to another town. The firefighters need a direct road to the next town quickly in order to put out a fire at a burning house.

Activity II - Marble Tracks **30 minutes**

1. Divide the class into teams of three students.
2. Ask the students to discuss a strategy for 5 minutes. Have the students plan which materials and the structural design they will employ.
3. Inform students that they will be tested on being able to describe their design decisions, the execution of their design, speed, and design precision.
4. Tell the students to choose one team member to collect materials.
5. Tell the students to build and test their roads.
6. Encourage the students to test their roads with the marble during multiple points in their building process.
7. Every 5 minutes, remind students about how much time is left in the activity.

Activity III - Design Review **10 minutes**

1. Have each group test each of the roads they constructed. Ask the students explain their designs.
2. Do a final test with a marble, and record the time it takes for the marble to complete the track.
3. Lead a discussion using the following questions:
   - Why did you choose your particular materials and construction techniques?
   - What could you have done differently if you had another chance?
4. Lead a discussion on the societal impact of roads and where and why roads are built. Provide students with local examples.

Assessment

10 minutes

1. During the activity, listen to the communication between members of the teams to see if they are working together well and exploring multiple ideas.
2. As the students are working, ask them the following questions:
   - What is the plan for the rest of your track?
   - Why did you decide to use that shape for your track?”
3. After the activity has been completed, ask students the following questions:
   - What did you learn about building large prototypes?
   - What was challenging?
   - What would do differently the next time?

Lesson Plan: Climate Zones Design Challenge:

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Create building design challenge scenarios based on different climates/geographical areas and a specific structural need for that area
✓ Gather building supply materials outlined in the materials section

Materials

- Construction Paper (100 sheets)
- Lollipop sticks (100ct)
- Pipe cleaners (50ct different colors)
- Scissors (1/group)
- Tape/glue (a roll of tape/group)
- Cups (20ct)
- Cloth (12”x 12” 10ct)
- Cardboard
- Other prototyping materials
- See scenarios in **Resources** Section

Lesson Overview

The goal of this activity is to introduce the students to the variety of different climate zones and geographical locations. Students engage in the design thinking process as students define a need, design a prototype, reiterate a particular design for a given geographical zone with specified constraints and user needs, and communicate their design to an investor panel. In this activity, students understand the role of both geographical/climate constraints as well as imposed constraints in the design of a structure.

Learning Objectives

Students will:

- understand that each of Earth’s climate zones presents a variety of temperature, weather, and geographical differences that impact how real people in those regions live their lives
- understand how geographical and climate constraints play a role in designing a structure
- develop a shelter design based on empathy for users in the developing world
- communicate a design to other relevant stakeholders and parties (for example, an investor or government agency)

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design
Next Generation Science Standards MS-LS2: Middle School Ecosystems

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Activity I - Introduction **5 minutes**

1. Present PPT Slide 145.
2. Introduce students to the design process through a discussion. Pose the following questions:
   - Does it matter what kind of shelter is being designed (i.e. hospital vs school, etc)?
   - Is there a difference between designing a shelter in a jungle or a desert? If so, what would be different in each of these cases? (Same question can be posed about other climate zones: arctic, mountain, river's delta, etc.)
   - Are there any additional constraints in the design? What about money?
   - If you were the designer of a shelter, how do you think you could persuade an investor or government agency that your design is the best one?

Activity II - Design Challenge ***20 minutes***

1. Tell students that they will be working on a design challenge
2. Pair students up so that students are in groups of 2
3. Hand each group a description for a geographical area or climate zone (Appendix I)
4. Hand each group a list of shelter climate cards with design considerations for each climate zone (Appendix II)
5. Describe each environment/geographical area according to the descriptions & brief user profiles provided in the Appendix I or with added climate zones if desired
6. Relate some of these environmental conditions to something they have experienced (i.e. desert-hot summer day, humidity - hot after taking shower, etc.)
7. Show students pictures and design constraints of the geographical area they selected.
8. Ask students to define the problem/need each geographical area and user has to ensure they understand the problem they will work on.
9. For 5 minutes, ask students to brainstorm different ideas to address the design challenge scenario. You may ask them the following questions to get started:
   - What are the qualities of each climate zone?
   - Are you meeting geographical/climate restrictions with your design?
   - Are you meeting the constraints for each problem/need?
   - What shelter designs work best for each climate zone?
10. Allow students to gather prototyping materials as needed.

Activity III - Prototyping **20 minutes**

1. Ask students to begin prototyping a design solution. For this part of the activity, it might be helpful to have an instructor walk around and ask questions to the different teams to allow ideas to continue flowing. **NOTE:** To make the process more challenging you may price building materials and allot a specific amount of money to each group. They could use this

factor when they try to persuade the investor that their design works and is cost effective (teams with similar scenarios can compare design and costs associated with them).

Activity IV - Communicating Design **10 minutes**

1. Create an investor committee (made of other students not taking part in the challenge, or other instructors).
2. Allow each team to present their prototype to the committee and explain why they should invest in their design.
   - If applicable, students can test their prototype in front of the committee
   - Encourage students to communicate the best features of their design and address an potential pitfalls.
   - Encourage students to explain how their design meets the needs of the user in each climate zone and the constraints of each climate zone
3. Investor committee should determine if:
   - The design meets geographical/climate conditions
   - The design meets the climate zone's user need
   - The design meets all constraints imposed (i.e. jungle - resist flooding, desert - avoid heat)
   - The design is feasible to be built

Activity IV - Journaling ***5 minutes***

1. Ask students to write a journal entry using the following prompts:
   - What was the most important concept you learned in today's activity?
   - What did you like and dislike about today's activity?
   - Suggest one thing that would make today's activity more fun.

Assessment

The students will be assessed to determine if they understood the activity when they present their prototype to the committee of investors with the following criteria:

1. Did the team meet all the constraints set for their design challenge scenario?
2. Were the investors persuaded in investing in their project?
3. Use their journal entries as another form of assessment

Resources

Climate Zone Users and Constraints

Example of 5 different climate zones and geographical terrains, needs from users in each climate zone, and constraints of the design.

Different Scenarios (you may create different or additional scenarios from those listed):

1. **Desert** - Community in the Egyptian Saharan Desert

User Profile: Abdallah and Dalia, two Egyptian middle school students who want to play outside, need an outdoor play space that can keep them safe from the sun and heat

Design Constraints:

- Very hot environment (temperature can rise above 110 degrees Fahrenheit)
- Students allowed to be outside for only 15 min in the sunlight and dust
- Low cost materials necessary
- Water is scarce, so water is unlikely to be available for fountains or pools.

Pictures:

2. **Jungle** - Rural Village in the Bolivian Amazon Rainforest

User Profile: Sandro the doctor needs a way for his health clinic that serves a rural village in the jungle to be safe from the heavy monsoon rains and mosquitoes that carry disease.

Design Constraints:
- Very humid and wet environment (+90% humidity)
- Mosquitoes/bugs and other jungle animals
- Monsoon season brings lots of rain and the clinic needs to be prepared for heavy rains

Pictures:

3. **Arctic** – Alaskan Arctic Terrain

User Profile: Thomissa the Arctic scientist needs a way to keep her small vegetable garden growing by ensuring her produce receives the proper sunlight and nutrition during the Alaskan winter. She needs to feed her team of researchers during this time.

Design Constraints:

- Limited sunlight in winter
- Extremely cold weather in the winter (temperature drops below -40 degrees Fahrenheit)
- Money is not a problem

- Hunting animals (i.e. bears) might be attracted to the vegetable garden once they realize there's food there.
- Hint: build a greenhouse to keep the produce fresh and growing!

Pictures:

4. **Rivers** - Floating Community at the Mekong River Delta, Vietnam

User Profile: Anh the fisherwoman needs a way to stop her canoe in an area where canoes/boats are the only means of transportation on the delta

Design Constraints:

- Exposure to water by whoever is using the canoe should be limited as much as possible
- Temperatures in the area can be really hot, rest stop should provide some sort of cooling for the user
- Kids (who do not know how to swim) might also be users of the canoes so ensuring children safety is also needed

Pictures:

5. Mountains - Nepal

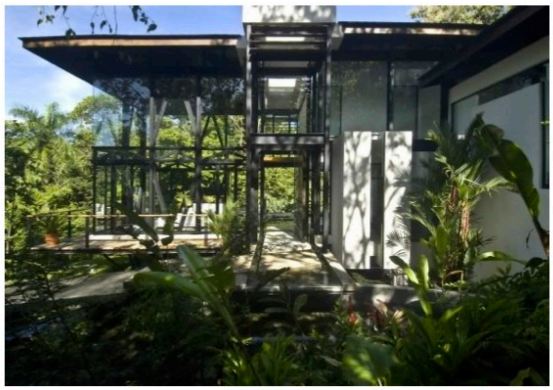
User Profile: Aditya the village leader needs a way to get water to many houses on the mountainside when it rains and snows in the high peaks.

Design Constraints:

- Transporting water by foot is limited by the treacherous road conditions and the cold weather during the winter
- Limited car access
- Money is not a problem
- Rain water collection is needed for an entire village (not just a single family)

Pictures:

Shelter Climate Cards

Cold Climate • Minimize area • Good insulation	
Temperate Climate • Daylight • Solar gains	
Hot Dry Climate • Light colors • Shady • Thick walls • Small windows	

Warm Humid Climate

- Lightweight
- Insulated roof
- No East/West windows
- Air movement

Lesson Plan: Designing Healthier Kitchens for Nigerian Women

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
✓ Gather materials
✓ Preview or download the following resources as needed:
- http://www.360nobs.com/2013/12/yet-another-silent-killer-who-says-98000-nigerian-women-die-yearly-from-cooking-with-firewood/
- http://www.cleancookstoves.org/countries/africa/nigeria.html
- http://www.cleancookstoves.org/our-work/the-issues/health-impacts.html
- Video: http://www.youtube.com/watch?v=IsgC-hKGx44 (0-1:55)
- Video: http://www.youtube.com/watch?v=aELeIVRqdDM (0:12-2:30)
- Fog machine video: http://www.youtube.com/watch?v=exKNbK7teQs

Materials

- 3 blank pages per group
- Prototyping materials are needed. The following are suggested:
- 1 cardboard box per group of students
- 1 pair of scissors
- 3 plastic cups
- 20 pipe cleaners
- 2 linear feet of aluminum foil
- 1 roll of tape
- 10 paper clips
- 15 sheets of construction paper
- 20 Popsicle sticks
- 1 pack of Post-it notes per student

Lesson Overview

In this lesson students explore issues that affect developing countries. Students gain empathy for the conditions under which Nigerian women must work to cook food and the effect that this has both on their health and the environment. They brainstorm solutions and build prototypes.

Learning Objectives:

Students will:
- develop empathy skills
- brainstorm solutions
- develop criteria for idea selection
- build prototypes
- test prototypes

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Activity I - Exploring the Issue **15 minutes**

1. Present PPT Slide 146.
2. Explain to the students that in many developing countries health issues arise from smoke inhalation during cooking - particularly for women and children. Share the following facts:
   - This is the fourth worst risk factor for disease in developing countries
   - Over 98,000 women died yearly from exposure to firewood smoke
   - If a woman cooks breakfast, lunch and dinner, it is equivalent to smoking between three and 20 packets of cigarette a day
   - It is the leading cause of blindness in developing countries
   - Cook stoves and fires release fine particles, carbon monoxide, and other pollutants at levels up to 100 times higher than the recommended limits
3. Show students the video entitled Impact of Smoke from Traditional Cooking Methods. Ask the following questions:
   - What did you think of this video?
   - How are the kitchens in the video and your kitchen different?
4. Explain the different ways in which this affects Nigerian women and children by sharing the facts below.
   - Smoke inhalation leads to diseases like cancer
   - Many women have back problems as a result of carrying wood
   - High % of income is spent by many families on wood
   - Smoke also results in blindness for many women and children
   - Nigeria has the highest rate of deforestation in the world
5. Introduce the design challenge to the students using the following user scenario:

   Onyinye is a woman living in Dadiya hills, Gombe State, Nigeria. She is mother to 5 children. She cooks everyday for her family using the firewood stove shown below. Her health is beginning to be affected by the smoke released by the fire.

5. Tell the students that they must redesign Onyinye's kitchen to improve effects it has on her health and so that a lower percentage of her family's income is spent on wood. Tell the students that the cost of their solutions should be very low (about 68% of population lives on < $1.25 US per day), they can only use a limited amount of resources, and that space is limited.

Activity II - Brainstorming & Prototyping **15 minutes**

1. Hand out one pad of Post-it notes to each student. Divide the class into teams of four students.
2. Tell the students that they have 5 minutes for their initial brainstorm session. Ask the students to write one idea on each Post-it note and place it on a wall. Remind the students to quickly generate ideas and not to spend any time explaining their ideas.
3. Ask each team to review the ideas they generated, and to choose 3 that they think seem most promising.
4. Ask each team to draw sketches of the 3 ideas they selected.
5. As a class, develop criteria for deciding which solution to move forward. Ask the students to think about what their idea would accomplish. (For example, reducing the amount of smoke, using alternative fuels, or reducing cooking time).
6. Tell students to use the class criteria that have been developed to select one idea of their top three ideas to move forward.
7. Give the students assorted materials and tell them that they have 10 minutes to build prototypes of their solutions.

Activity III - Testing **10 minutes**

1. Tell the students that they are going to test their prototypes. Tell the class that each group will role play by assuming the role of Onyinye and test the other group's prototype. Remind them to think about the class criteria as they test the prototypes.
2. Ask the students to collect written feedback as their prototypes are tested.

Assessment **10 minutes**

1. Have the students gather in a circle.
2. Ask each group to share its experiences.
3. Ask the following questions:
   - What did you like/dislike about this activity?
   - Was it difficult to empathize with the user?
   - What might you change about your prototype?
   - Why do we prototype?
   - Why is it important to gain empathy for your user?

WEEK 3

UNIT 7: BIODIVERSITY

DAY 15A: Goldfish Shelter Design
DAY 15B: Building a Biodome for Plants

Hour	Day 11	Day 12	Day 13	Day 14	Day 15
Hour A	**DESIGN CHALLENGE 2.0 (Global Shelter): Empathize**	**DESIGN CHALLENGE 2.0: Define & Ideate**	**DESIGN CHALLENGE 2.0: Prototype & Test**	**Global Shelter: Climate Zones Design Challenge**	**Biodiversity: Goldfish Shelter Design**
Hour B	**Global Shelter: The Crowded Shelter Challenge**	**DESIGN CHALLENGE 2.0: Ideate**	**Global Shelter: Infrastructure: Marble Tracks**	**Global Shelter: Designing Healthier Kitchens for Nigerian Women**	**Biodiversity: Building a Biodome for Plants**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand that shelter design also involves protecting biodiversity, including plants and animals.

Lesson Plan: Goldfish Shelter Design

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ A couple of goldfish in oxygenated water
- ✓ A deck of photos about pollutants from human behavior such as six-pack rings. Suggested photos in **Resources** section.

Materials

- Goldfish
- A transparent tank/tub
- Prototyping tools (e.g. color papers, pipe cleaners, plastic cups, water bottles, ice-scream sticks, small toys, etc.)
- Natural props (e.g. clean gravel, plants, seaweed, pebbles, etc..)
- Scissors
- Tape
- Small shark toy (optional)

Lesson Overview

This lesson is designed to introduce students to the concept of building shelters for animals and understanding biodiversity. Students explore the needs of a goldfish and understand the threats it may be faced with in the ocean. Students then design and create a physical prototype of the shelter and test the prototype with a real goldfish.

Lesson Objectives

Student will:

- develop empathy for goldfish and their needs
- build and test a goldfish shelter
- identify some of the man-made threats to the environment

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design
Next Generation Science Standards MS-LS2: Middle School Ecosystems

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solution

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services

Activity I - Needfinding **20 minutes**

1. Present PPT Slide 148.
2. Make sure the water is clean and has enough oxygen for the goldfish to live in.
3. Introduce the goldfish to the students. Have them observe the goldfish for a minute.

4. Ask the kids to brainstorm under the question “what do you think these goldfish need?”
5. After the students get a broad sense of the needs, ask the students “what do you think can hurt or make these goldfish unhappy?”
6. Ask the students to come up with at least five point-of-view/need statements. For example, “frightened goldfish need a way to protect themselves from invading sharks because they are much smaller and slower.”

Activity II - Designing and Prototyping **25 minutes**

1. Ask the students to brainstorm ideas of how the shelter for the goldfish should look like according to the need statements they have.
2. Tell students to build the components of the shelter in an empty transparent tub using the prototyping tools. Do not fill the water yet.
3. Ask students what they are building and why they are building it as they prototype.
4. When students are almost done, ask them to ensure that all the components in the tub will not float if water is poured in.

Activity III - Testing **5 minutes**

1. Fill the tub with fresh water.
2. Carefully put the goldfish into the tub. Let them swim around for half a minute or so.
3. Have the students simulate the scene when the goldfish are being chased by sharks using a shark toy or their own fingers and see whether the goldfish will behave according to their prediction or not (e.g. hiding in a cup with small opening).

Activity IV - Man-Made Pollutants **5 minutes**

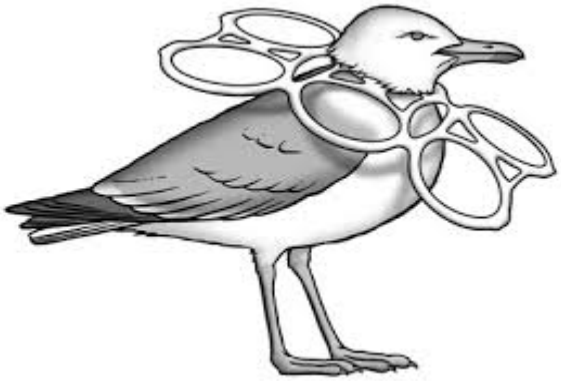
1. Show them the deck of photos of how human’s ignorance can harm the animals. On each photo, have them discuss how they can help prevent that from happening.

Assessment **5 minutes**

1. Have the students to gather in a circle.
2. Ask the students to share out their experiences.
3. Ask students about the factors that made their designs successful or unsuccessful.
4. Ask the students if their design helped them understand any additional needs of the goldfish.

Resources

Suggested images for man-made pollutants:



Lesson Plan: Building a Biodome

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Learn more about biodomes. For example, you can learn more about the biodome in the San Francisco Academy of Sciences. Read more in the **Resources** section.

Materials

- Pictures of various biodomes (included in the **Resources** section)
- 3 two-liter soda bottles (labels removed)
- 1 bottle cap
- 2 feet of thick cotton string
- Water to soak the string in
- 1 pair of scissors
- 1 thumb tack
- 1 small plant
- 1 roll of tape

Lesson Overview

In this lesson, students design and build a biodome made out of soda bottles and other various materials to make a shelter for a plant. Students learn about the way biodomes work, and how their biodome design influences the growth of the plants.

Learning Objectives

Students will:

- understand the concept of a biodome
- understand the needs of plants/animals/organisms to survive in a biodome
- understand the needs of their plant specifically to thrive and grow in their biodome
- prototype a biodome using the materials provided
- identify the features of their biodome design that will help the plants grow

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design
Next Generation Science Standards MS-LS2: Middle School Ecosystems

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solution

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services

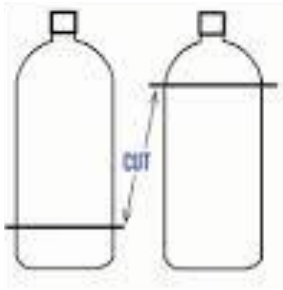
Activity I - Introduction to Biodomes **10 minutes**

1. Present PPT Slide 149.

2. Find out what the students already know about biodomes, and introduce the definition and purpose of biodomes to them (see appendix).
3. Show them pictures of biodomes (see appendix).
4. Discuss with them how and why different organisms, such as plants and animals, can thrive in the biodome. Pose the following questions:
   - What are the needs of plants, and how do those needs get met in a biodome?
   - What about for animals?
   - Why is it important for waste products produced by one species to be used by at least another species?

Activity II - Building Your Own Biodome **30 minutes**

1. Divide the students into groups.
2. Give each group their own plant, and tell the students that they will be designing a biodome for their plant.
3. Instruct students to cut the first bottle 2 to 3 centimeters above the top curve, and then cut off the bottom of the same bottle 2 to 3 centimeters below the bottom curve.
4. Have the students cut the second bottle by cutting the top off around 2 centimeters below the top curve.
5. Finally, have them cut the bottom off the third bottle 2 to 3 centimeters above the bottom curve.



(plastic bottles 2 and 3)

6. Have students poke a hole in one cap with a thumb tack and enlarge it with scissors to get the string through. Attach the cap to the bottle with the top.
7. Soak the strings in water, and then run the string through the hole in the cap. Explain to the students that the wick draws water into the soil.
8. Have each group insert the capped top, inverted, into the remaining bottom.

9. Slide the cylinder into it, and add the short top as a cover.
10. Instruct the students to fill the bottom part of each biodome with water until it touches the cap.
11. Add a little bit of soil into the capped section, always remaining mindful that the string runs up into the soil and is not stuck along the sides.

12. Carefully add the plant into the dirt, and pat it down so that it looks nice and settled in the dirt.
13. Add water to each plant until the soil is moist.
14. Put the cap on and tell the students that biodome is complete!

Activity III - Evaluating the Domes **5 minutes**

1. Ask the students questions to make sure they understand how the biodome works.
2. Discuss with them how the soil provides nutrients for the plants, the bottle contains the air, and the water for the plant gets soaked up through the string. The sun is necessary for the photosynthesis of the plant.
3. Discuss ways in which the design of the biodome could be improved in different ways.
   - What would you choose to improve it and why?
   - What about for different types of plants? What would you do differently? What if you wanted to make a biodome that included animals?

Assessment

1. Examine if they completed the biodome successfully.
2. Use the questions from the evaluation of the biodome to see if they understand the ways that different biodomes can be applied to different organisms.

Resources

Biodome Pictures:

SF Academy of Sciences Biodome

Montreal Biodome

Information on Biodomes

Source: http://www.wisegeek.com/what-is-a-biodome.htm#didyouknowout

A biodome is a scientific facility which creates a replica of an ecosystem in a controlled environment indoors. Many of these structures are designed inside geodesic spheres, because these structures create large amounts of room which can be useful in creating a credible replica of a real ecosystem. One of the most famous biodomes is the Montreal Biodome, built in 1992, and the Biosphere 2 project in Arizona is another example of a biodome.

There are a number of reasons to build a biodome. Many of these structures are used for research and science education, and they can also be used for experimentation. Biodomes can be built anywhere in the world, including in dense urban areas, and their interiors can be precisely controlled, allowing people to visit sub-Arctic climates, rainforests, deserts, temperate forests, and other types of ecosystems. Some biodomes include several climate zones which visitors can travel through. Research facilities such as labs are often attached directly to the facility to make scientific study easier.

From an education perspective, a biodome can be a powerful tool, as it exposes visitors to ecosystems they might not be able to see without taking an expensive and grueling trip. The space can be filled with plants, animals, and natural features which can all be used as starting

points to discuss the environment and the importance of environmental preservation. Many people visit biodomes as a form of recreation and they absorb interesting scientific information along the way.

These spaces are also very useful for scientific research. The ability to control the environment can allow scientists to play with environmental variables to see how they impact the ecosystem, and researchers can also study things like the spread of non-native plants, the role that introduced animals can play in an ecosystem, and the impact of pollution on the environment. Researchers can also test environmental remediation programs on a small scale in a biodome to determine whether or not they will be effective before being tried in the real world.

Areas with biodomes open to the public tend to advertise their facilities and make them easy to find. In some cities, visitors can purchase all access passes which will allow them to visit several attractions which may include things like biodomes along with science museums, art museums, and other institutions. If one has an opportunity to see a biodome, it is definitely worth a visit, as it can provide a fascinating glimpse into an ecosystem which might be otherwise inaccessible.

WEEK 4

UNIT 8: STRUCTURE AND BUILDING MATERIALS

DAY 16A: Critical Load
DAY 16B: Geodesic Dome

Hour	Day 16	Day 17	Day 18	Day 19	Day 20
Hour A	**Structure and Building Materials: Critical Load**	**DESIGN CHALLENGE 3.0 (School Shelter): Empathize**	**DESIGN CHALLENGE 3.0: Prototype & Test**	**Preparation for EXPO DAY**	**EXPO DAY**
Hour B	**Structure and Building Materials: Geodesic Dome**	**DESIGN CHALLENGE 3.0: Define & Ideate**	**STEM Career Fair & Speaker Panel**	**Preparation for EXPO DAY**	**EXPO DAY**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how the properties of building materials, geometrical shapes, and structural form influence a shelter's function, design, and stability.

Lesson Plan: Critical Load

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Get materials (provided below).
✓ Make sure to view and read the links in each activity with detail. Print worksheets for activity 2.
✓ Build structures and test to make sure activities are feasible.

Materials

- Small paper drinking cups
- Cardboard squares 24” x 24”
- Student resource sheets and worksheets
- 12 unused playing cards per group
- 1 roll of scotch tape per group
- 4 coins per group
- Base of an empty square based two quart cardboard juice/milk container per group
- Objects to build weight of based from 4-10 pounds (like coin, marbles, or sand) for each group

Lesson Overview

In this lesson, students will explore concepts of structural engineering and how to measure the critical load, or maximum weight a structure can bear. Students will learn about basic structures, how to reinforce, how to properly select materials for building. This lesson will reemphasize the ideas of designing and building a prototype as a team, which will be used to hold increasingly greater weights.

Learning Objectives

Students will:

- learn about concepts in structural engineering.
- learn how to measure the critical load, the weight at which a structure will fall.

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - Paper Cup Walk *15 minutes*

1. Present PPT Slide 151.
2. Introduce the idea of critical load by introducing the paper cup walk activity.
3. The idea of the activity is to see how many cups (and what arrangement of cups) is necessary to hold a person's weight. The student will start by placing a 24 x 24 inch cardboard square on the ground. They will then stack and arrange paper cups on top of the piece of cardboard. Once they are finished, they will place another cardboard square at the top. With another student to spot them, the student will sit on top of the platform.
4. After the activity is over, explain to the students why their structure did or did not work. Refer to this link for additional information: http://pbskids.org/zoom/activities/sci/papercupwalk.html
5. Allot 3 minutes to explaining the activity, 7 minutes for building the structures, and 5 minutes for debriefing the activity.

Activity II - Does it hold? Part 1 **30 minutes**

1. Prior to executing this activity, read information about civil engineering in this link to make debriefing more fruitful: http://www.tryengineering.org/sites/default/files/lessons/criticalload.pdf
2. Go over the reference sheet with the students. These may be read in class or provided as reading material for the prior night's homework.
3. Provide each student team with materials and ask them to devise a structure that will hold the most weight. They are to plan out their structure, and build a prototype for testing. Allow 20 minutes for planning and execution.

Activity III - Does it hold? Part 2 **15 minutes**

1. Place weights on each team's prototype increasing the weight until the structure fails. Students chart the maximum load each prototype successfully held (the amount just prior to failure). Allow 8 minutes for testing.
2. Each student group presents their vision for their design, and explains why they think their design did well or failed. Ask students how would they adjust the design if they could do it again? Allow 7 minutes for debriefing.

Assessment

There are assessments provided throughout the lesson. This type of lesson (and learned concept) allows for constant formative assessment.

Lesson Plan: Geodesic Dome

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Collect lesson materials.
✓ Read over why triangles are the strongest shape here: http://www.mathsinthecity.com/sites/most-stable-shape-triangle
✓ Read about how geodesic domes work: http://science.howstuffworks.com/engineering/structural/geodesic-dome2.htm

Materials

- 130 sheets of printer paper for each group
- 1 roll of masking tape for each group
- 20 books of various weights

Lesson Overview

In this lesson, students design and prototype gumdrop structures that must be able to carry the weight of books. After the first round, they will redesign their structure using triangles to carry the weight of books again.

Learning Objectives

Students will:

- Be able to describe how different shapes have different weight bearing capacities
- Build and test a geodesic dome's strength
- Run through multiple iterations to prototype a structure

Standards

Next Generation Science Standards MS-ETS1: Middle School Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Activity I - First Iteration **25 minutes**

1. Present PPT Slide 152.

2. Before beginning the activity, remember that the students learned about geometric shapes & composites two weeks ago. Building on that activity (without reminding them that they learned this—this will happen after they've built the first iteration), tell the students that they will be building a dome.
   - You want to see if they remember that triangles are the strongest shape without you explicitly reminding them.
3. Tell the students that this will be a competition to see whose group can hold the most books.
4. Give the students 130 sheets of paper for this first iteration.
5. For 5 minutes, tell the students to roll 2 papers together hot-dog style (so that the paper is rolled up long-ways, with the thickness of 2 sheets).
6. For 5 minutes, let the students brainstorm ways to create the dome.
7. Give the students 15 minutes to prototype the dome.
   - Remind them that even though the dome might be rounded at the top, their structure should be stable enough for the books to stay balanced. Their top still needs to be rounded though!
   - Tell the students not to bend the rolled up papers (as they will use them in the second round).
   - Tell them they can use the tape to connect the tubes.
   - Do not explicitly tell them that triangles are the most stable shape—instead, let them come up with ideas on their own.
   - Let students test their domes with books if they wish.
8. In the last couple of minutes, test each group and see how many books each dome can hold without collapsing.

Activity II - Debrief **5 minutes**

1. After the first activity is done, bring up what the students learned two weeks ago about geometric shapes and composites by asking: When you watched the videos of the collapsed bridges and buildings,
   - Why do you think the building or structure collapsed?
   - Do you think the use of different shapes could have made the structure stronger?
   - What would you have done to make the structure stronger?
   - For your own dome, what shapes did you use? Was your dome able to carry as many books as you thought? What could you have done to make the dome stronger?

Activity III - Second Iteration **20 minutes**

1. Tell the students that they will make a second dome with the same materials.
   - Tell them to carefully disconnect the dome (without unrolling the papers).
   - If the students used triangles in the previous iteration, tell the students to try a different shape to see how the load weight capacity is different.
   - If the students used a different shape in the previous iteration, encourage them to use triangles.
   - Tell the students to brainstorm their strategies again before building.
2. During the last five minutes, test the dome again with the books.
   - Also keep in mind that the material might not be as strong as the first time anyway, but this saves an enormous amount of paper.

Activity IV - Debrief **10 minutes**

1. Ask the students to reflect on their design failed or succeeded.

2. Ask:
   - Which shape could hold the most books?
   - Why do you think that shape could bear the most weight?
4. Discuss the benefits of triangles:
   - Cost efficiency of the triangles (less material than rectangles)
   - The triangle “does not easily deform and is able to balance the stretching and compressive forces inside the structure” (from mathsinthecity.com).
   - Use information from this website: http://science.howstuffworks.com/engineering/structural/geodesic-dome2.htm to discuss how geodesic domes work.

Assessment

1. Ask them if they remembered the Geometric Shapes and Composites activity from 2 weeks ago and how that knowledge helped them.
2. Ask the students questions about their designs, such as how their prototypes could be designed better or what components of their designed seemed to work well.
3. Ask what factors they think contributed to the success and failure of both prototypes, and what the difference was in the results.

WEEK 4

UNIT 8: LOCAL SHELTER

DAY 17A: Design Challenge 3.0: Developing Empathy
DAY 17B: Design Challenge 3.0: Point of View Statements and Brainstorming
DAY 18A: Design Challenge 3.0: Prototyping and Testing

Hour	Day 16	Day 17	Day 18	Day 19	Day 20
Hour A	**Structure and Building Materials: Critical Load**	**DESIGN CHALLENGE 3.0 (School Shelter): Empathize**	**DESIGN CHALLENGE 3.0: Prototype & Test**	**Preparation for EXPO DAY**	**EXPO DAY**
Hour B	**Structure and Building Materials: Geodesic Dome**	**DESIGN CHALLENGE 3.0: Define & Ideate**	**STEM Career Fair & Speaker Panel**	**Preparation for EXPO DAY**	**EXPO DAY**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how to apply STEM concepts and the design thinking process to a school-based redesign challenge in their own community.

Lesson Plan: Design Challenge 3.0: Developing Empathy

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view.
✓ Preview or download the X-Space Library Design Video:
https://d2pq0u4uni88oo.cloudfront.net/projects/863560/video-349448-h264_high.mp4

Materials

- Paper (5 sheets per student)
- Chart paper (2 sheets per group)
- Markers (1 per person)

Lesson Overview

In this lesson, students will be introduced to the third and final design challenge – Redesigning Shelter Spaces in Schools. Students will then interview group members and create an empathy map based on the information they gathered.

Learning Objectives

Students will:

- conduct interviews
- analyze and synthesize interview data
- create an Empathy Map

Activity I - Introduction and Interviews *35 minutes*

1. Present PPT Slide 154 as you introduce the challenge *Redesigning Shelters Spaces in the School*. Tell the class that in this challenge, they will be thinking about a variety of shelters in a school setting.
2. Present PPT Slides 155-160 that contain examples of shelters in school settings. Ask the students to generate additional examples based on their specific school setting.
3. Present PPT Slides 161-162 to ask students to consider what their schools need and to give them specific design considerations and constraints for their challenge. Encourage students to use what they've learned over the past several units on architecture, sustainability, structure and building material, biodiversity, etc.
4. Present PPT Slide 163 that shows the students the design thinking process, and remind them that they are going to begin today's activity with the empathize phase. Tell the students that they are going to engage in a design challenge based on shelter.
5. Present PPT Slides 164-167. Tell students that they are going to conduct interviews. Group students in teams of 4-6. Discuss the roles of each member of the group. Allow students to decide who will perform each role within the group.
6. Ask the students to share tips for good interviewing based on their experiences in the previous design challenges.

7. Present PPT Slide 168, which has a list of interview questions. Tell the students that they should begin their interviews with these questions. As they ask these questions, they can build on what they have heard and ask additional questions.
8. Give the groups 15 minutes to conduct their interviews.

Activity II - Empathy Map Construction *25 minutes*

1. Present PPT Slide 169. Tell the students that they are going to be in the define phase of the design thinking process.
2. Present PPT Slide 170. Give each team a large piece of chart paper and ask them to draw an Empathy Map. Tell the students to complete the Empathy Map based on their interviews. Visit each team to clarify any questions the students might have.

Lesson Plan: Design Challenge 2.0: Point of View Statements & Brainstorming

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT so that students can view it.

Materials

- Chart paper (2 sheets per group)
- Markers (1 per student)
- Post-it notes (1 pad per person)

Lesson Overview

In this lesson, students define their specific user's needs by creating a Point of View statement based on their notes and empathy map from the previous day. Students then brainstorm different ideas on how to address his or her needs for the school space redesign.

Learning Objectives

Students will:

- create Point of View statements based on user needs
- brainstorm different ideas to address user needs
- group ideas by theme
- participate in a vote to choose 3 top ideas

Activity I - Point of View Statement *5 minutes*

1. Present PPT Slide 171 and review the Point of View statement, explaining that it is a way to synthesize their interview data. Tell the students that they will use this statement to help solve the design challenge for their users.
2. Review the following parts of a Point of View Statement
3. The User: Use an adjective to describe you user
   A Need: Use a verb to describe your user's need
   An Insight: Describe why this will meet your user's need
4. Ask students to generate additional examples of Point of View statements before they begin crafting their own statements.

Activity II - Point of View Statement Creation *20 minutes*

1. Have students work with their teams to create Point of View Statements for their users. Give each group a blank piece of chart paper and have them duplicate the Point of View Statement from PPT Slide 171.

2. Give the students 15 minutes and tell them to create 2-3 Point of View Statements. As the students work, go to each group and clarify any questions the students might have.
3. Ask each team to share their Point of View Statements with the class. Allow students to provide feedback on the statements using the following questions:
4. Could we think of many solutions to meet the need that is described in the Point of View Statement?
5. Is there a clear description of the user, the need, and the insight?

Activity III - Brainstorm *25 minutes*

1. Present PPT Slide 172. Explain that brainstorming is built upon mindsets, and that mindsets are a “road map” for how things are done.
2. Present PPT Slide 173 to review tips for how to brainstorm. Read each rule aloud.
3. Present PPT Slide 174, which contains a list describing how to brainstorm in a group.
4. Before brainstorming, lead a quick 5-minute improvisation activity to get students warmed up for brainstorming in teams.
5. Give the students 15 minutes to brainstorm ideas. Visit each team to encourage them to follow the brainstorming tips presented in the slides.

Activity IV - Idea Clustering and Selection *10 minutes*

6. Present PPT Slide 175 and tell students that they are going to cluster their ideas into themes. Have them do this by rearranging their post-it notes.
7. Present PPT Slide 176. Tell the students that they are going select their favorite ideas that they would like to build for their users. Discuss the different possible ways to choose a favorite. These might include an idea that is easy to build, a crazy idea, or an idea that they are really excited about building.
8. Tell the students that each person has 3 votes, and that they should choose their top 3 favorite ideas and vote by placing a check mark on the post-it containing that idea.
9. Give students 3 minutes to vote. Have each group tally its 3 top ideas based on the votes.
10. Ask each group to share its top 3 ideas.

Lesson Plan: Design Challenge 3.0: Prototyping and Testing

Preparation

✓ Set up the BUILT TO LEARN! Redesigning Shelter Curriculum PPT for students to view.

Materials

- Pipe cleaners
- Markers
- Popsicles
- Tape
- Paper
- Assortment of cardboard
- Other materials available

Lesson Overview

In this lesson, students will build a prototype of their chosen idea and test their prototype. Students will learn more about new design solutions for local needs in their school space redesign.

Learning Objectives

Students will:

- build a prototype of their best idea
- test their ideas with the user (in this case, the teacher)
- capture user feedback (in this case, the teacher)
- learn about new design solutions for refugee needs in the developing world

Activity I - Prototype I *35 minutes*

1. Present PPT Slide 178. Tell the students that they are now in the prototyping phase of the design thinking process.
2. Explain to the class that design thinkers build prototypes that are unfinished products and that the purpose of a prototype is to put something in the hands of their user quickly to see if the person likes the idea.
3. Present PPT Slide 179, which explains some of the features of a prototype. Review each point and clarify any questions the students may have.
4. Present PPT Slide 180. Give students 25 minutes to build their prototype.

Activity II - Testing *15 minutes*

1. Present PPT Slide 181. Tell students that once they have created their prototypes, they will be testing them on the user they interviewed. Testing the prototype allows them to see the reactions and interactions of the user, which provides important feedback for rethinking their designs and finding out if it meets their users' needs.
2. Present PPT Slide 182. Provide the following guidelines for the designers:

- Don't over-explain your prototype. Allow your user to interact with it without interruption.
- Observe your user closely. You may learn something new about what they need.
- Don't sell your prototype.
- Give a brief sentence about your prototype as an introduction, and then don't do any more talking.

3. Provide the following guidelines for the users:
   - When you receive your prototype, say what you think out loud.
   - Be direct and honest in your feedback. Your designer wants to make sure that the design meets your needs. Be specific about what you like and don't like.
4. Present PPT Slide 183. Tell students to test their prototypes on their users and capture feedback based on these guidelines. Suggest to students to ask the following questions:
   - What did you like?
   - What didn't you like?
   - What would you change?
   - What surprised you?

Activity III - Prototype II *15 minutes*

1. Present PPT Slide 184**.** Tell students to spend the next 15 minutes revising their prototype based on the feedback they received from their user.
2. Present PPT Slide 185. Encourage students to reflect on and discuss their “fail forward” moments during this design challenge. Ask them:
   - When did you fail or make a mistake?
   - What did you learn from that?
   - How did you improve your design?

WEEK 4

UNIT 8: STEM CAREERS

DAY 18B: STEM Career Fair and Panel

Hour	Day 16	Day 17	Day 18	Day 19	Day 20
Hour A	**Structure and Building Materials: Critical Load**	**DESIGN CHALLENGE 3.0 (School Shelter): Empathize**	**DESIGN CHALLENGE 3.0: Prototype & Test**	**Preparation for EXPO DAY**	**EXPO DAY**
Hour B	**Structure and Building Materials: Geodesic Dome**	**DESIGN CHALLENGE 3.0: Define & Ideate**	**STEM Career Fair & Speaker Panel**	**Preparation for EXPO DAY**	**EXPO DAY**

Enduring Understanding

Students will develop the creative confidence to fail forward by building successful shelters using STEM concepts and empathy-based design thinking process.

Unit Understanding

Students will understand how the engaging challenges and opportunities in these lessons tie to real-world STEM careers.

Lesson Plan: STEM Career Fair and Panel

Preparation

- ✓ Set up the BUILT TO LEARN! Redesigning Shelter PPT for students to view
- ✓ Gather materials
- ✓ Decide how you want to partition students. Each student may work individually, or each team may be composed of no more than two students. This lesson is per student.
- ✓ Research the different STEM careers that are pertinent to the design and construction of shelters. Suggested videos:
  Materials Engineer: https://www.youtube.com/watch?v=DtosXFgP7C4
  Civil Engineer: https://www.youtube.com/watch?v=X6Kf_XTCt9Q
  Architecture: https://www.youtube.com/watch?v=vmHoGicPQQQ

Materials

- Various foundation materials:
  - Toothpaste (one 10 ounce+ tube should be enough for four students)
  - Sand (0.5 cup per student)
  - Dirt (0.5 cup per student)
  - Clay (one 4 ounce+ playdoh jar should be enough for each student)
- Construction materials:
  - Popsicle sticks (20 per student)
  - Cardboard (10 square inches per student)
  - Pipecleaners (5 pieces per student)
  - Scotch tape (one roll should be enough for four students)
- Decoration materials:
  - Markers (3 per student -- for decoration)
  - Colored construction paper (3 sheets per student)

Lesson Overview

In this lesson students learn about careers in various fields of STEM that are relevant to shelters--civil and structural engineering, material science, and design/architecture through a series of hands-on activities.

Learning Objectives

Students will:

- learn about materials science engineering by selecting the foundation for a house based on environmental factors.
- learn about civil engineering by designing and building the structure of a house.
- learn about design and architecture by making a house a home.

Activity I - Career Activities **30 minutes**

Materials science engineer (8 minutes)

1. Present PPT Slide 186. Hand each student a plate.
2. Assign a foundation to each student.
3. Have the students discuss the suspected advantages and disadvantages of their assigned foundation.
4. Explain the role of a materials engineer in designing and building shelters.

Architect/Designer (8 minutes)

1. Give each student a pencil and paper and ask them what they would like their home to have. A living room? Game room? Anything they want.
2. Allow 3 minutes for them to explore their ideas
3. Ask them to draw out a floor plan of their dream home.
4. Have the students examine the decoration materials and plan how they might beautify their shelter.
5. Explain the role of an architect in the design of shelters.

Civil/Structural engineer (8 minutes)

1. Hand each student the construction materials.
2. Have the students discuss the suspected advantages and disadvantages of the building materials they have selected.
3. Explain the role of civil and structural engineers in the design of shelters.
4. Ask students to finish their construction and allow extra time if needed.

Activity II - Debrief **15 minutes**

1. Present PPT Slides 187-190.
2. Relate each career to each previous lesson from the past few weeks.
    - Explain that the students have done activities that are related to each of the careers discussed in this lesson
    - Materials science – Foundations: From Oobleck to Toothpaste
    - Structural engineering - Geometrical Shapes and Composites, Earthquake Stable Building
    - Architecture/design - Perspective Drawing

Assessment

Pose the following questions to students during the debrief:

- What was your favorite part about building house? Picking and building on the foundation? Building the structure of the house? Deciding what components a house should have?
- Explain what the role of each type of engineer (materials engineer, civil/structural engineer, architect) does?
- Which of these parts of building the house do you think relates to which career?
- Which type of engineering/STEM career mentioned in this lesson appeals to you most? Why?