Vaccine Delivery

STEM Global Teacher Workshop
Pacific Science Center's Tinker Tank | pacificsciencecenter.org

LESSON OVERVIEW

Time: 1 50-minute class period with suggestions for extending the activity

Subject & Grade Level(s):

MS-HS engineering design: This engineering design challenge can be incorporated into science classes at the middle or high school level.

Brief Overview:

An authentic design problem is the delivery of vaccines to people living in remote villages around the world. Many remote areas struggle to receive necessary vaccines for various reasons, including rough terrain between medical facilities and villages and towns that is impassable to most vehicles. This activity engages students in the engineering design process as they design, build, and test a model of a vehicle capable of traveling rough terrain without damaging the vaccines it is transporting. In this simulated design task, students use K'nex and LEGO building materials to construct a vehicle that can travel along a LEGO track simulating rough terrain. This activity could be used to introduce students to the engineering design process. Suggestions are provided for increasing the complexity of the design challenge (e.g., carry more than one container, design a vehicle without wheels, etc.) as well as for incorporating an additional design challenge focused on the cold chain process of vaccine delivery.

STUDENT UNDERSTANDINGS

Anchoring Phenomenon/Design Problem:

Many international aid workers struggle to deliver necessary vaccines to remote areas for various reasons, including rough terrain between medical facilities and villages and towns. Your challenge is to design and make a model of a vehicle to transport these vaccines over rough terrain. You will use K'nex and other building materials to construct your model vehicle, which must be capable of safely carrying a container filled with "vaccines" from one end of a track to the other without spilling any contents. To simulate a vehicle driving between two destinations, your model will be pulled at a constant rate by a winch and attached to the winch by way of a small binder clip.

Driving Questions:

- How can a vehicle be designed so that it can travel rough terrain and safely deliver vaccine vials while meeting specific design criteria and constraints?

- How does an understanding of the engineering design process inform the design work, especially the concepts of tinkering and iteration?

Learning Objectives:

By the time participants complete this activity, they will be able to:

- Describe the merits and functionality of their design.
- Work with constraints on materials and time.
- Iterate through assorted designs using lessons learned via hands-on tinkering/discovery.

NEXT GENERATION SCIENCE STANDARDS

This lesson builds toward the following middle and high school level Performance Expectations (PEs). Hyperlinks direct to relevant sections of the Next Generation Science Standards and *A Framework for K-12 Science Education*.

<table>
<tr><th colspan="3">Performance Expectations</th></tr>
<tr><td colspan="3">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 (with lesson extensions focused on re-design and optimization).

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td></tr>
<tr><th>Disciplinary Core Idea(s)</th><th>Crosscutting Concepts (CCCs)</th><th>Science and Engineering Practices (SEPs)</th></tr>
<tr><td>ETS1.B: Developing Possible Solutions

ETS1.C: Optimizing the Design Solution</td><td></td><td>Developing and Using Models

Constructing Explanations and Designing Solutions</td></tr>
</table>

TEACHER PREPARATION

Materials:

Materials needed for building (20 students):

Building Material	Description/Source	Quantity
K'nex building supplies	Provide an assortment of K'nex building materials for each group to be able to construct a vehicle. Be sure to include K'nex wheels and tires if desired. LEGO or other construction materials could be substituted.	Assortment for each group
Other wheel options	Provide an assortment of alternative wheel options (e.g., masking tape roll, oat canister lid, plastic bottle top).	Assortment
String		~4' per group
Pipe cleaners		~40 total
Rubber bands	Assorted sizes	A few handfuls total
Stir straws		~40 total
Printer paper or cardstock		~20 sheets total
Binder clips	Assorted sizes	~20 total
Hole punch		~4 total
Scissors		~12 total

Materials needed for testing/operations:

Operations Material	Description/Source	Quantity
Computer and projector	To show Tinker Tank: Engineering Design Process slide deck. Alternatively, use the images in the *Appendix* to create a student handout.	1
Printer paper	For sketching designs	~1 sheet/student
Pencils		1/student
K'nex winch assemblies	1 K'nex Black Motor R2a; string; cardstock; K'nex building supplies; AA batteries. See *Appendix* for assembly information.	At least 2
Mini binder clips	Used to attach winch/string to vehicle for testing	1/winch
Spare AA batteries and screwdriver	For K'nex motors	As needed
LEGO baseplates and bricks	LEGO baseplates and bricks to form terrain (enough to create at least two 'tracks' for vehicles). Each track should be at least four baseplates long. See photos in *Procedure* for examples.	At least 2 tracks

Notes to Teacher for Preparing to Teach this Lesson:

- Decide how you will break students up into 4-6 design teams.

- Prepare materials
  - Gather materials listed in the "building materials" list and arrange in a central location in the classroom. See photo to the right which shows materials as displayed at an event able to accommodate approximately eight guests at a time.

- Arrange tables and chairs
  - Arrange 4-5 table pods with enough chairs at each to accommodate students.

- Adorn tables
  - Set one piece of paper and one pencil at each chair.
  - Set out at least one bin of K'nex with an assortment of K'nex wheels at each table pod.

- Prepare test station
  - Assemble at least two test tracks
    - Place at least four LEGO baseplates end-to-end flat on table (per track).
    - Attach LEGO bricks to baseplates to form terrain that becomes progressively "rougher". See photos below.

  - Build K'nex winch assembly. See instructions in *Appendix*.
  - Secure K'nex winch at the "roughest" end of each track. See photos below (see *Appendix* for more images).

- Provide students with any background desired (global health, vaccine delivery, engineering design process, etc.). See the *Resources* section.

Photos of a testing station with LEGO terrain and winch assembly at one end of track. Vehicle begins at far end of track and is pulled to near end by winch.

INSTRUCTIONAL PROCEDURE

Teacher Procedure:

Overview

Activity	Details
Introduce engineering design process **(6 minutes)**	- Use slides or make a handout from images in *Appendix*
Introduce design challenge **(3 minutes)**	- Introduce guidelines, expectations, and challenge
Sketching **(6 minutes)**	- Instruct students to sketch invention and write 'bill of materials' - Check sketches/plans and direct students to get materials on list
Build and test prototypes **(25-30 minutes)**	- Set students free to build and test their vehicle designs
Showcase inventions **(5 minutes; Optional)**	-Students share their vehicle designs
Cleanup and discussion **(5-10 minutes)**	-Reflect on the design process

Introduction to the Engineering Design Process (6 minutes)

1. Use slides or handouts created from images in *Appendix* to introduce students to the engineering design process.

2. Discuss: design process ‘definition’.
    a. Discuss things students used that morning that were designed by an engineer or specific type of designer.
        i. “We like to think of engineers as problem-solvers; what problem does X item address?” (*lead by asking students to share what they believe an engineer does*).

3. Design process graphic (*see Appendix*)
    a. Note the existence and validity of other representations of the engineering design process; *“This is how we choose to represent it in Tinker Tank at Pacific Science Center.”*
    b. Discuss each step, referring back to an example provided by students while talking about designed items used earlier in the morning when appropriate (e.g., item is a spoon):
        i. Identify the problem: *“Somebody or some people decided they wanted a better way to consume liquid foods.”*
        ii. Explore: *“They may have already had knives or something like forks, and likely just drank liquid foods from bowls.”*
    c. Allow students to think through process before revealing each step beyond ‘Devise a Plan;’ they will typically reason out that the next step is to create the product/process they designed, then test it, and so on.

Introduce Design Challenge (3 minutes)

4. Introduce challenge and kick off design phase (2 minutes)
    a. Challenge: Many international aid workers struggle to deliver necessary vaccines to remote areas for various reasons, including rough terrain between distribution facilities and villages and towns. Logistics and supply chain managers can only plan with the tools and technology available to them. This is where people such as mechanical engineers, vehicle operators, and automotive mechanics play a significant role. In this scenario, this is the expertise called upon to deliver critical healthcare. Your challenge is to design and make a model of a vehicle to transport these vaccines from this end of the track to the other without spilling any contents. The vehicle will be pulled at a constant rate and attached to the winch by way of a small binder clip.

5. Discuss guidelines and expectations (1 minute)
    a. Upon receiving the challenge, students will be tasked with sketching a design and writing a ‘bill of materials.’ They must talk with an instructor or chaperone about their plan to get checked off *before* collecting any construction materials.
    b. Students may test their vehicle as many times as time allows; early and frequent testing is encouraged.
    c. You may wish to facilitate a whole class discussion in which students define ‘success’ prior to designing the vehicle. How will they know if they had a successful test of their vehicle design?

6. Assign teams (2-4 students per team).

Sketch time (6 minutes)

7. Instruct students to sketch design and write 'bill of materials' on a piece of paper.

8. Check sketches/plans and direct students to gather materials on list. Prompt students with questions about their design and design process, such as:
    a. Tell me about your design!
    b. Why did you choose X type/amount of wheel/ski/sledge?
    c. How will your vehicle prevent the vials from spilling?

Create and test vehicles (25-30 minutes)

9. As students get their sketches approved, direct them to begin building and testing their vehicles.

10. Facilitator should demonstrate testing procedure to at least the first couple groups ready to test and check in when possible beyond that.

11. Testing procedure:
    a. Turn on motor in reverse and gently pull binder clip on string to the lower-terrain end of the test track. Turn off motor.
    b. Direct student to load half-full film canister (e.g., load with lentils, ¼" stir straw segments, beans) in their vehicle. Do not put the lid on the canister.
        i. You may wish to offer a 'dry run' without filling the canister first.
    c. Direct another student to attach a mini-binder clip to their vehicle in the place they believe will allow for the best performance and position their vehicle at the track.
    d. Direct another student to turn on the motor (forward) to pull the vehicle.
    e. Typically, a test is considered successful when the vehicle reaches the winch and the contents of the film canister have remained in the canister. What criteria did the students develop for determining a successful test?

12. Extend the design challenge as appropriate by issuing additional challenges. These may include modifying the vehicle to:
    a. Work without any wheels,
    b. Use X number of pieces/materials,
    c. Transport multiple canisters, or
    d. Traverse rougher terrain.

Showcase inventions (5 minutes, *optional*)

13. Teams volunteer to share their vehicles with the class, highlighting their design's key features and explaining any obstacles they encountered in the design process and how they iterated to solve those challenges.

Clean-up and discussion (5-10 minutes)

1. Employ your classroom discussion strategies to reflect on these discussions, in design teams and/or as a whole class. This may be done in-class, as an exit ticket, or as homework. Possible discussion questions include:
    a. What element of your vehicle design worked particularly well?

b. What were the weaknesses of your design? What would you change about your vehicle if you had more time or different materials?
c. Which criteria and constraints did you find most challenging?
d. Describe a challenge you encountered and how you iterated on your design to navigate the obstacle.
e. What sort of terrain or obstacles might one encounter when delivering vaccines to remote destinations?
f. What are some other ways vaccines could be delivered to remote villages?
g. Think about the people who might be involved in transporting vaccines or other medical supplies to remote destinations. What type of jobs might be involved in this work?

Student Assessment Opportunities

- During the design/build phase, teachers may observe the design teams to assess their teamwork and collaboration processes.
- One or more of the discussion questions may be assigned as an exit ticket, journal prompt, or homework assignment, providing students an opportunity to reflect on the activity and self-assess their learning processes and contributions to their design team.

Student Handouts & Teacher Resources

- Tinker Tank: Engineering Design Process slide deck

Suggested Lesson Extensions

- **Global Health Context – Background Readings & Videos:** Deepen students' engagement in the activity by having them read news articles or watch videos about how vaccines and medical supplies are delivered to remote destinations. These materials could be used when the design challenge is issued to help contextualize the problem and/or during the discussion to share one approach to solving the problem. See the *Teacher Resources* section.
- **Defining Criteria & Constraints:** As part of issuing the design challenge, have students identify and consider the criteria and constraints involved in the design problem, including time, materials, costs, scientific issues, users' needs, safety, cultural considerations, and environmental impacts (builds toward MS-ETS1-1, MS-ETS1-2, HS-ETS1-1 and HS-ETS1-3).
- **Cold Chain Design Challenge:** In a longer or multi-period session, students can be challenged to produce a more detailed model of the delivery container for the vaccines that would be on a transport vehicle. Provide a range of insulator options (e.g., foam, felt of various colors, bubble wrap) for students to use in their design. Place an ice cube in the model container and place the container under a stage light, heat lamp, or similar. Assess the success of designs based on the time it takes for the ice to melt. Students should define criteria and constraints if possible. Some may include:
    - Minimum melt time,

- Maximum container weight, or
- Minimum container capacity.

Notes on Adaptations and Inclusivity

- **Engineering Vocabulary:** If students are not yet familiar with the language of the engineering design process, they may need some support in understanding the terminology embedded in this lesson. This may be particularly true for middle school students and emerging bilingual students. The following list captures some of the engineering-specific terms used in the lesson materials.
  - Criterion(a)
  - Constraint
  - Design sketch
  - Iterate
  - Winch
- **Complexity of Design Challenge:** The complexity of the design challenge can be increased or decreased, depending on materials provided and additional design challenges you may choose to issue.
- **Inclusivity for All Learners:** Consider how the design challenge may need to be adapted to be accessible for all learners. For example, what building materials may work best for a student with a visual or mobility impairment? How might you elicit, build connections with, and leverage students' everyday expertise with engineering design, tinkering, and building? How might you group students with diverse expertise and learning needs into design teams so that they can support each other?

TEACHER RESOURCES

Background Information on Vaccine Delivery for Global Health

The Bill & Melinda Gates Foundation recognizes the delivery of vaccines as a high priority for increasing health—especially children's health—around the world. This is the challenge that they recognize:

> "Vaccines save millions of lives each year and are among the most cost-effective health interventions ever developed. Immunization has led to the eradication of smallpox, a 74 percent reduction in childhood deaths from measles over the past decade, and the near-eradication of polio.
>
> Despite these great strides, there remains an urgent need to reach all children with life-saving vaccines. One in five children worldwide are not fully protected with even the most basic vaccines. As a result, an estimated 1.5 million children die each year—one every 20 seconds—from vaccine-preventable diseases such as diarrhea and pneumonia. Tens of thousands of other children suffer from severe or permanently disabling illnesses.
>
> Vaccines are often expensive for the world's poorest countries, and supply shortages and a lack of trained health workers are challenges as well**. Unreliable transportation systems** and storage facilities also make it difficult to preserve high-quality vaccines that require refrigeration."
>
> *(Bill & Melinda Gates Foundation, Vaccine Delivery Strategy Overview)*

Videos on Vaccine Delivery via Motorcycles

Rx for Survival and Riders for Health: The Rx for Survival videos document global health challenges in the field and can be used to develop and ground the design challenge scenario. The episode "Delivering the Goods" (55:26 minutes) shows the difficulty in bringing life-saving technologies and pharmaceuticals to people in geographically challenging rural areas lacking transportation infrastructure. It features the organization Riders for Health that transforms a motorcycle sidecar into an ambulance, which makes for a relevant and inspiring engineering story. PBS Rx for Survival website is available here. (Video available on YouTube here).

- A clip of the video could be shown starting at 4:15 minutes and ending at 7:25 minutes.
- *Option:* continue viewing video through 12:04 minutes to include a feature on an infant/child field nurse.
- *Option:* continue viewing video through 14:04 minutes to show the motorcycle ambulance in action.

Nature video: The video, "Vaccine Delivery: The Last Mile" (4:58 minutes) features Riders for Health and their use of motorcycles to transport vaccines to rural areas. This video nicely sets up the barriers to vaccine delivery that present design/logistical challenges. Find the video here.

Career Connections

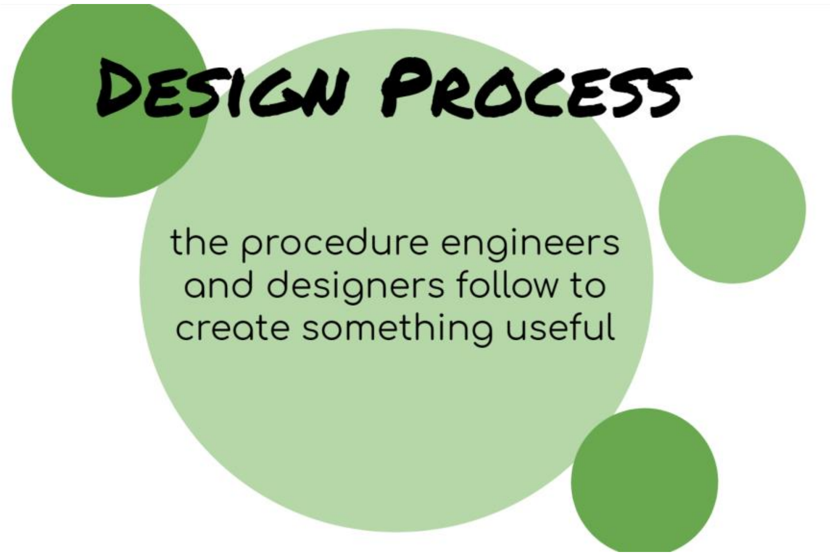
The following global health careers relate to this activity:

- **Logistics and supply chain manager:** https://www.bls.gov/ooh/business-and-financial/logisticians.htm
- **Mechanical engineer:** https://www.bls.gov/ooh/architecture-and-engineering/mechanical-engineers.htm
- **Automotive mechanic:** https://www.bls.gov/ooh/installation-maintenance-and-repair/automotive-service-technicians-and-mechanics.htm

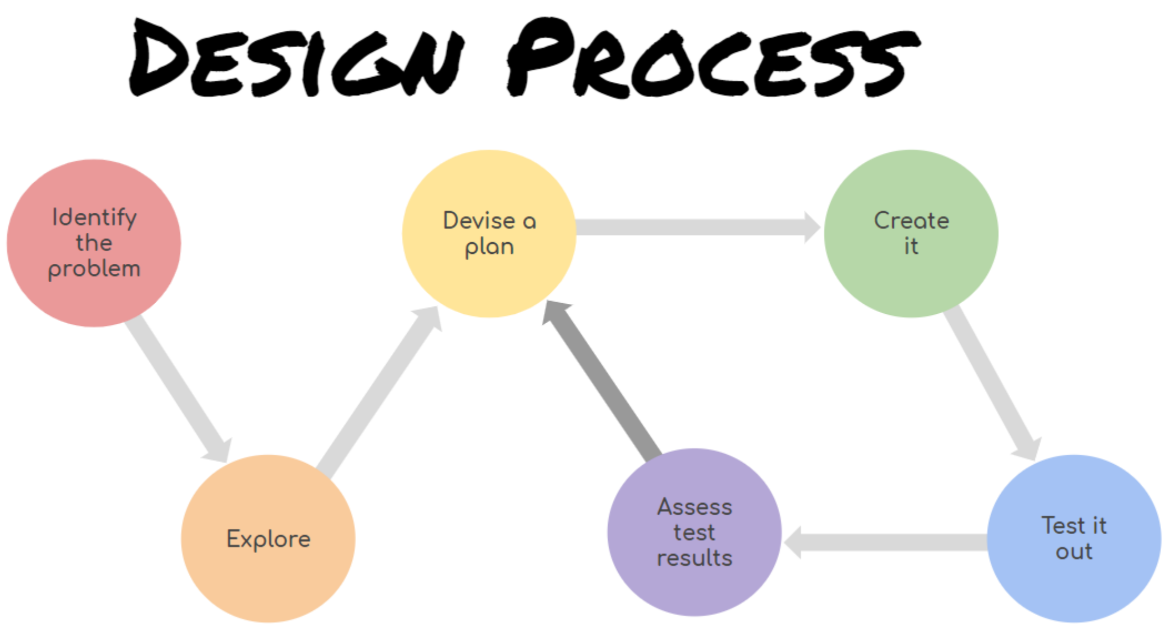
Credit: *This activity was originally developed by Pacific Science Center for use in their Tinker Tank program and adapted for a STEM Global Teacher Workshop in April 2019. Pacific Science Center is an independent, not-for-profit institution located in Seattle, WA that ignites curiosity and fuels a passion for discovery, experimentation, and critical thinking. This activity was authored by Brittany Strachota, PSC Tinker Tank Program Lead. Lesson plan adaptations supported by Kristen Bergsman of Laughing Crow Curriculum.*

Teacher Resource: Appendix

Design Process Definition



Engineering Design Process Graphic



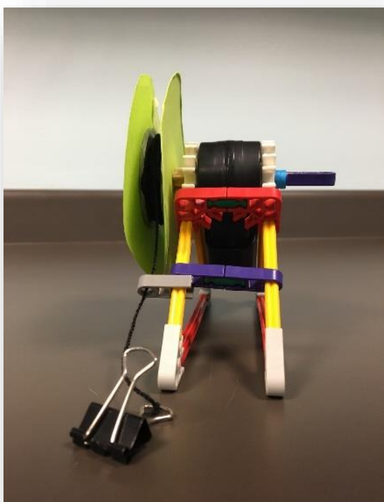
K’nex Winch Assembly

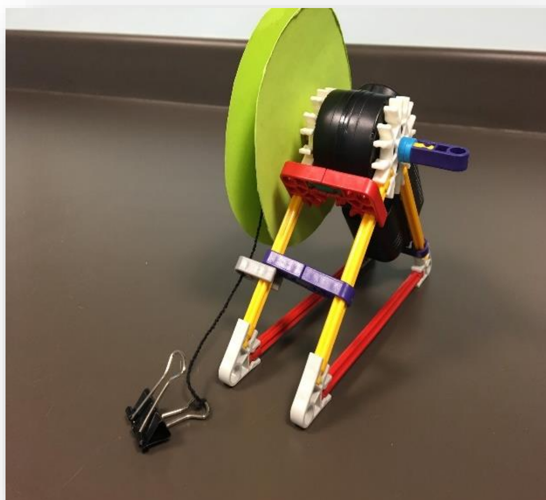
The winch shown here is made from K’nex, cardstock, string, and a small binder clip. You may use any means of pulling a load at a consistent rate that suits your needs and resources.

A triangular stand holds a K’nex motor in position. On one end of the axle, a cardstock circle (~5” diameter) is slid to the motor before a length of string (at least 1.5x the length of the test track) is tied in place; a congruent circle sandwiches the string. You may use a dab of hot glue to secure the end of the string and the discs to the axle.

Turn on the motor to wind the string around the axle and feed the end through a K’nex guide. Attach a small binder clip – or other material you plan to use to attach vehicles to the winch for testing.

This is a good baseline design; you will likely make some tweaks. Once you are confident in your design, you may wish to make more robust discs (e.g., using chipboard).





Example Vehicle Design

Six-wheeled vehicle prepared to carry canister of vaccine vials.