Drone Drop Challenge

STEM Global Teacher Workshop
PATH | path.org

LESSON OVERVIEW

Time: 90-120 minutes or 2-50 minute class periods

Subject & Grade Level(s):

MS-HS Science: This engineering design challenge can be incorporated into science classes at the middle or high school level. Lesson plan is written at the high school level, with suggestions for adaptations to middle school.

Brief Overview:

An authentic global health challenge is the delivery of critical medical supplies (e.g., vaccines, blood products, etc.) to remote communities accessible only by foot, bicycle, or motorbike. In this engineering design challenge that is a variation on the classic egg drop challenge, students work in teams to design, prototype, and test a vaccine container that will be delivered via drone technology. Students first explore commercially available delivery technologies and develop a list of requirements for the delivery technology. They then take on the role of a global health non-profit that has received a grant to develop delivery solutions based on drone technology. Students then work in teams to design, build, and test a vaccine container to integrate with the existing drone technology while considering project criteria and constraints. Before testing their prototype (egg drop), teams present a one-minute pitch for their design solution. This activity represents a partial design cycle, but could be extended to include re-design, re-test, and optimize phases.

STUDENT UNDERSTANDINGS

Design Challenge Scenario:

PATH, a global health organization, is working to streamline the "last mile" of cold chain supply systems. The vaccine cold chain is the equipment and systems that maintain vaccines at a safe temperature (usually 2°C to 8°C) from the moment the vaccines are made to the moment they are administered. Vaccine outreach visits to remote villages often require transportation by bike or by foot. After exploring the commercially available delivery technologies and developing a list of requirements for the delivery technology, you have received a grant to develop delivery solutions based on drone technology. Your partner, DropShip Inc, manufacturers drones for commercial shipping applications. Parcels are picked up by the drone and dropped off at the customer’s doorstep. To adapt this technology, you must design, build, and test a vaccine container to integrate with DropShip’s drones.

Anchoring Phenomenon/Design Problem:

A global health organization needs to design a vaccine container that can be used by existing drone technology to quickly and safely deliver vaccines to health care workers located in remote villages. The container needs to be: carried by a drone without decreasing its range below an acceptable level; able to carry a certain number of vaccine vials in a way that is quickly loadable; able to withstand drop/impact without damaging the container, vials, or other objects or people; and reusable for 1,000 delivery cycles.

Driving Questions:

- How can a container be designed for the safe delivery of vaccine vials by drone technology that meets the design criteria and constraints?
- How does an understanding of motion and forces help inform our design and testing of the vaccine container?

NEXT GENERATION SCIENCE STANDARDS

This lesson builds toward the following bundles of middle and high school level Performance Expectations (PEs). The lesson materials are written to support the high school level PEs; therefore adaptations should be made to the lesson to make it appropriate for middle school students (e.g., scientific/engineering vocabulary, complexity of provided materials, inclusion of re-design and optimize phase, etc.). Hyperlinks direct to relevant sections of the Next Generation Science Standards and *A Framework for K-12 Science Education*.

High School Bundle of Performance Expectations		
HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **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. **HS-PS2-3:** Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.		
Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Asking Questions and Defining Problems Constructing Explanations and Designing Solutions	ETS1.A: Defining and Delimiting Engineering Problems ETS1.C: Optimizing the Design Solution PS2.A: Forces and Motion	Influence of Science, Engineering, and Technology on Society and the Natural World Cause and Effect

Middle School Bundle of Performance Expectations		
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-ETS1-4:** 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). **MS-PS3-5:** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.		
Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Asking Questions and Defining Problems Engaging in Argument from Evidence Developing and Using Models Scientific Knowledge is based on Empirical Evidence	ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution PS3.B: Conservation of Energy and Energy Transfer	Influence of Science, Engineering, and Technology on Society and the Natural World Energy and Matter

TEACHER PREPARATION

Materials:

Material	Description/Source	Quantity
Material Kits	Assemble prototyping materials for kits, including **structural materials** (e.g., pipe cleaners, popsicle sticks, toothpicks, wire, binder clips, Legos, K'NEX, plastic sheet, cardboard, tape), **soft materials** (e.g., foam, sponge, bubble wrap, newspaper, fabric, plastic produce/grocery bags, balloons), and **miscellany** (e.g., rubber bands, springs, string)	1 kit per student team
Materials for Exchange *(optional)*	Assemble leftover extra materials from kits or small volumes of desirable materials not included in kits for Materials Exchange	
Payload	You may choose to use a raw egg, hard-boiled egg, acceleration sensor, or other items to represent the payload during the testing phase	1 per student team (disposable) or 1 total (reusable)
Universal Connector	Choose one material that will function as a universal connector that all teams will need to integrate into their design; their container includes the universal connector which the drone would then use as a handle for picking up/dropping the container	1 per student team
Testing Tools	Tools for teams to test their products against the specification such as a cardboard box of the correct dimensions, a scale for testing weight, and plastic eggs to fit in their compartments to test size (if performing an egg drop)	1 of each tool
Ladder or balcony	Ladder, balcony, or other high platform to use for testing the containers (egg drop style)	1
Piece of dense foam *(optional)*	A piece of dense foam may be used as a landing pad for the containers during testing	1
Student Handouts	*Team Instructions, Scoring Sheet*, and *Design Specification*	1 set of handouts per student team
Teacher Resource	*Scoring Rubric* (spreadsheet to use for assessment purposes)	1
Computer	Computer with internet access, speakers, and projector. For showing students a video about drone technology for delivery of medical supplies to remote communities	1
Reward *(optional)*	Small prize or award certificate for winning team	1

Notes to Teacher for Preparing to Teach this Lesson:

- This engineering design challenge could be integrated into a forces and motion unit, making connections to potential energy, kinetic energy, conservation of energy, energy transfer, and force.

- Determine if you will model this engineering design challenge after the classic egg drop experiment or use a different protocol. See the *Resources* section.

- Assemble the Materials Kits, one per team. Ensure that each kit includes the same type and amount of materials. Include structural materials, soft materials, and miscellany.

- Assemble desired tools for teams to test their products against the specification, such as a cardboard box of the correct dimensions, a scale, and plastic eggs to fit in their compartments (if performing an egg drop).

- Prepare and print student handouts, one set for each student team.
    - *Design Specification*
    - *Scoring Sheet*
    - *Team Instructions*

- Determine how and where you will set up a fair test of each team's designed container.

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

- Provide students with any background desired (global health, impact force, etc.). See the Resources section.

INSTRUCTIONAL PROCEDURE

Teacher Procedure:

Introduction to the Design Challenge (10 minutes)

1. Show students the Zipline in Rwanda video to introduce the design challenge and provide background information about the global health context and drone technology.

   Zipline in Rwanda video
   Zipline, 5/13/16, 3:32 minutes, captions available through YouTube
   https://www.youtube.com/watch?v=OnDpE8uSb7M

2. Introduce the design challenge and driving questions:

   Design Challenge: A global health organization is working to streamline the "last mile" of cold chain supply systems. The vaccine cold chain is the equipment and systems that maintain vaccines at a safe temperature (usually 2°C to 8°C) from the moment the vaccines are made to the moment they are administered. Vaccine outreach visits to remote villages often require transportation by bike or by foot, but drone technology could make this process easier and faster. Your challenge is to design a vaccine container that can be used by existing drone technology to quickly and safely deliver vaccines to health care workers located in remote villages. The container needs to be: carried by a drone without decreasing its range below an acceptable level; able to carry a certain number of vaccine vials in a way that is quickly loadable; able to withstand drop/impact without damaging the container, vials, or other objects or people; and reusable for 1,000 delivery cycles.

   Driving Questions:

   - How can a container be designed for the safe delivery of vaccine vials by drone technology that meets the design criteria and constraints?
   - How does an understanding of motion and forces help inform our design and testing of the vaccine container?

3. Discuss the flow of the design process:
   a. Teams will design and build a container for dropping from a drone.
   b. Students should begin by discussing and drawing a design for their container, and when they have an idea drawn the facilitator will come around and sign off.
   c. Once teams have received sign off, they can begin building.
   d. Teams should come up with a “brand” (team name, logo, etc.) .
   e. After building, all teams will present a 1-minute pitch of their design and brand, then the products will be tested (dropped).
   f. Teams will be assessed based on the provided score sheet.

4. Distribute materials to each team (material kits and handouts).

Design/Build Phase (60 minutes)

5. Design teams can get to work!
    a. Remind students to get sign-off on their design sketch before beginning to build.
    b. If necessary, remind students that their end product doesn't have to look like their sketch.

6. *(Optional)* Students may trade in some of their kit materials for others available at the Exchange with the permission of the Exchange manager (teacher/facilitator). Students negotiate the trade with the Exchange manager. The Exchange manager can decide whether to allow the trade and what materials from the kit are an acceptable swap for the desired materials from the Exchange. The Exchange presents an opportunity for teams to personalize their kits and represents the negotiations necessary between partners to achieve common goals.

7. At 15 minutes, remind students that they should be getting sign-off and moving into the build phase.

8. *(Optional)* At 20 minutes, remove an item from the Material Kits.

    a. For example, "The company we are working with has decided that in an effort to reduce their environmental impact, plastic bags will no longer be allowed on their drop containers."

9. *(Optional)* At 25-30 minutes, add an item into the Material Kits that must be incorporated into the final product
    a. For example, "The company we are working with has decided to standardize the drop container attachment. All containers must use this Universal Connector as a way to attach the container to the drone."

10. At 45 minutes, end the Design/Build phase by having students bring their creations to the front of the room (or test area).

Test Phase (15 minutes)

11. Bring teams up one at a time to give their 1-minute pitch/presentation of their design.
12. Perform a drop off each team's container from a ladder (or appropriate platform). Explain how you will be conducting a fair test of each container's performance.
13. Assess each container's drop performance (e.g., eggshell broken?). Score each team using the *Scoring Rubric* spreadsheet.
14. Announce the winning team! *(Optional)* Hand out a small reward or award certificate.

Discussion (10 minutes)

15. 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. Discussion questions:
    - What went well? What did your team struggle with?
    - Did people take on specific roles and divide up work, or did your team work together on all aspects?
    - Did your end product differ from your initial design?
        - How did your product transform throughout the Design/Build phase?
        - What were some of the major drivers of your iterations?
    - In what ways did you make trade-offs with your design?
    - What was the reasoning behind the design approach that your team took?
    - How did you decide which materials were appropriate to use for your team's design?

Student Assessment Opportunities:

- During the design/build phase, teachers may observe the design teams to assess their teamwork and collaboration processes.
- The *Scoring Rubric* can be used to assess each team's container design and its performance during testing.
- One or more of the discussion questions may be assigned as an Exit Ticket or homework, 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

- *Student Handout: Design Specification*
- *Student Handout: Scoring Sheet*
- *Student Handout: Team Instructions*
- *Teacher Resource: Scoring Rubric*

Suggested Lesson Extensions

- **Criteria & Constraints:** Rather than providing teams with the Design Specification handout, instead work together to develop a list of criteria and constraints for the design challenge.
- **Pugh Chart:** In the Design phase, encourage students to initially identify ideas for multiple design solutions. Then, ask each team to use a simple Pugh Chart to help them evaluate the different solutions based on the project's criteria and constraints. A Pugh Chart is an evaluation tool to aid in selection of a design solution. As the example below shows, list the criteria in the first column and the design solutions in the other columns. Score each solution for each criterion with -1, 1, or +1 points.

Criteria	Solution #1	Solution #2	Solution #3
Total Score			

- **Design Optimization:** Extend the activity by adding a re-design, re-test, and optimize phase. This allows students to consider the results of the first drop, and use that performance information to inform a re-design of their prototype. Conduct a second drop test. Then allow time for teams to consider the results of the second drop to optimize their final design solution.
- **Background Readings:** Deepen students' engagement in the activity by having them read news articles about how drone technology is being applied in global health contexts. See the *Resources* section.
- **Middle School:** Challenge students to develop a conceptual model that supports the claim that when the kinetic energy of an object changes, energy is transferred to or from the object, using the Drone Drop Challenge as the context for their model.
- **High School:** Challenge students to develop a conceptual model that explains how their design minimizes the force on the container during collision with the ground.

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.
    - Constraint
    - Criteria
    - Design requirements
    - Iterate
    - Payload
    - Prototype
    - Prototype/Design sketch
    - Solution
    - Tradeoffs
- **Complexity of Design Challenge:** The complexity of the design challenge can be increased or decreased, depending on what materials are provided in the Materials Kit and whether or not you decide to add and subtract materials or use the Exchange during the Build phase. You may also choose to adapt the criteria and constraints on the *Design Specification* handout. (If so, be sure to also revise the *Scoring Sheet* and *Scoring Rubric* to be in alignment with those changes).
- **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, or drone technology? How might you group students with diverse expertise and learning needs into design teams so that they can support each other?
  Video Captioning: Subtitles/closed captions can be chosen through YouTube for the Zipline in Rwanda video.
- **Article Resources:** Additional background readings are provided in the Teacher Resources section, however most of these have a high school or college reading level. To accommodate readers at different levels, employ your classroom reading strategies such as student grouping and jigsaw structures or create scaffolds or reading guides. In addition, the photographs from these articles could be shared with students to help them understand both the challenges and the innovation of vaccine delivery to remote regions of the world.

TEACHER RESOURCES

Egg Drop Experiments

The Egg Drop Experiment is a classic activity in physical science classrooms. The Drone Drop Challenge provides a real world context for the activity by situating it as a global health challenge, as well as focusing on the engineering design process. Adapt your favorite Egg Drop protocol or use this engineering-focused one for inspiration:

Bombs Away: Egg Drop Experiment

TeachEngineering, 2 hour egg drop design challenge
https://www.teachengineering.org/activities/view/duk_consenergy_rde_act

Background Information on Vaccine Delivery for Global Health

How Vaccines Reach the Most Remote Places on Earth

Unicef photo story, 4/24/17

https://www.unicef.org.au/blog/unicef-in-action/april-2017/photos-vaccines-reach-most-remote-places-earth

Outdated Supply Chains Limit Vaccine Availability

WHO, 3/30/17, Reading level: College

https://www.who.int/immunization/newsroom/press/global_immunization_impact_constrained/en/

Background Information on Drone Technology for Global Health

Sub-saharan Africa Leads the Way in Medical Drone Delivery

The Lancelet, Becky McCall, 1/5/19, Reading level: College

Available for free download with registration

https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(18)33253-7.pdf

Revolutionary Technology for Vaccine Delivery: Drones in Vanuatu

Unicef, 6/11/17, Reading level: High School

https://www.unicef.org/innovation/drones/technology-for-vaccine-delivery-vanuatu

I Launched a Blood-Delivering Drone: Rwanda uses Zipline Drones to Deliver Emergency Blood Supplies

Rachel Becker, The Verge, 4/13/18, Reading level: Middle to High School

https://www.theverge.com/2018/4/13/17206398/zipline-drones-delivery-blood-emergency-medical-supplies-startup-rwanda-tanzania

WakeMed Receives First UPS Drone Delivery of Medicine in U.S.

Richard Stradling, *The News & Observer*, 3/26/19, Reading level: High School

https://www.newsobserver.com/news/local/article228373214.html

Alaska Tests Drones for Delivery of Medical and Emergency Supplies

Folake Dosu, BuiltIn, 2/4/19, Reading level: College

https://builtin.com/robotics/deliver-emergency-medical-supplies-alaska-going-mushers-drones

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