THINKING AND ACTING LIKE A

SCIENTIST

TEACHER'S GUIDE

Save the City!

Design a device and transfer process to secure a toxic substance.

GRADES 6–8

Engineering Design

VAN ANDEL EDUCATION INSTITUTE

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INQUIRY-BASED SCIENCE

Save the City!

Engineering Design

Grade Level/Content	6–8/Engineering Design
Lesson Summary	Save the City! is an introductory engineering design lesson. Students focus on the process of designing, building, testing, and evaluating multiple solutions to move "toxic industrial chemicals" from one container to another within given criteria and constraints.
Estimated Time	2, 45-minute class periods
Materials	One full set for each student team testing ground consisting of: • 1 piece of large flip chart paper or a whiteboard • 1 marker • 2 containers • Approximately 100 pennies in a zip lock bag • 2, 6" pipe cleaners • 6–8 pieces of 7 1/2-foot rope • 4–6 large rubber bands • 1 hula-hoop 5′ diameter • Journals for each student One full set for the actual spill area consisting of: • 2 containers • popcorn kernels • 1 hula-hoop 5′ diameter
Secondary Resources	A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, Chapter 8. (page 204 focuses on Engineering Design)
NGSS Connection	**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.
Learning Objectives	• Students will design, build, and test multiple solutions to meet defined criteria for moving corn kernels from one container to another within given constraints. • Students will evaluate solutions to determine how to make improvements that result in an optimal design. • Students will develop an explanation (claim, evidence, reasoning) that identifies how their optimal design best meets the problem's criteria and constraints.

Design a device and transfer process to secure a toxic substance.

Industrial processes generate toxic and highly reactive substances that can negatively impact human health. Some of these substances require complex handling procedures due to their toxicity. In this lesson, students are introduced to a scenario that provides them with an opportunity to save their community from the imminent danger of a toxic chemical release that would negatively impact human health and the local ecosystem for years to come. Students start this learning experience by being introduced to a scenario and problem statement. As they proceed, they utilize an engineering design process to consider the role of criteria and constraints to quickly design, build, test, and evaluate possible solutions to save their town.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

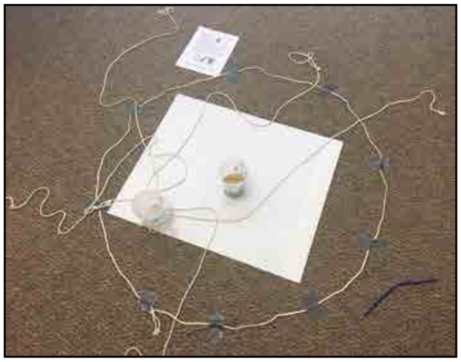
Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Establish a spill area for use by the whole class, as well as dedicated design and testing grounds for each team. To add intrigue and an element of competition to the experience, spread out testing grounds as much as possible to minimize the transfer of design ideas between teams.

- Identify a plan for assigning teams. This scenario works best with between 4 and 5 students per team.
- Prepare and set-up the following materials:
  - One full set of the following for each student team testing ground:
    - 1 piece of large flip chart paper or a whiteboard
    - 1 marker
    - 2 containers (plastic containers or beakers with lips work well)
    - Approximately 100 pennies in a zip lock bag (represents the toxic industrial chemicals)
    - 2, six inch pipe cleaners
    - 6–8 pieces of 7 1/2-foot rope (clothesline rope works well)
    - 4–6 large rubber bands (big enough to fit around all containers when stretched)
    - 1 hula-hoop 5′ diameter (other options: rope taped down or a circle cut from a table cloth)
    - Student journal for each student
  - One full set for the actual spill area consisting of:
    - 2 containers (similar in size but different from those provided in team testing grounds)
    - popcorn kernels (fill approximately 1/2 of the "shipping canister" in the middle of the spill area)
    - 1 hula-hoop 5′ diameter (other options: rope taped down or a circle cut from a paper table cloth)
- When set-up is complete, the practice and spill areas should resemble the pictured spill area as students begin working.



Spill Area

Part 2

INVESTIGATION FACILITATION

Problem *Introduce the scenario and problem statement along with its criteria and constraints.*

- Share the following details with student teams in written and oral form. As you do, answer clarification questions, but limit your guidance to the facts presented within the scenario.

  A shipping canister of highly toxic industrial chemicals has fallen off a transfer vehicle at the downtown railyard. The top of the canister has come off resulting in a dangerous situation for emergency response personnel. Additionally, chemical company representatives indicate that the canister is not strong enough to hold the chemicals for transit because of the fall. Due to its toxic nature, emergency response personnel cannot enter a contamination zone defined by a circle approximately 5 feet in diameter and extending to 15 feet in the air.

Continued

If the industrial chemicals are not transferred to a safe container for decontamination within 90 minutes (its estimated safe life under current temperature and humidity conditions) it will explode. If it explodes, toxic chemical residue will be spread across the city and into the neighboring drinking water reservoir. It is up to us to save the city and our drinking water source!

Problem Statement: Design a device and process to safely transfer the toxic industrial chemicals into a decontamination chamber before it explodes! Testing grounds have been set up for you to safely design, test, and improve upon possible design solutions until your design is ready for use.

- Have students write the problem statement in their journal.
- Continue by sharing the problem criteria and constraints. Ask students to also document these in their journal.

Criteria:

- Work as a team to build, test, and optimize a device and process to transfer all of the contaminated chemicals into a decontamination chamber without spilling.
- Successful solutions must be implemented within the allotted time and within the constraints listed below.

Constraints:

- Your team may only use the provided materials.
- No body parts can cross into the contamination zone.
- The damaged shipping container must stay in the middle of the circle.
- The decontamination container must be moved in and out of the contamination zone using your device.
- The industrial chemical must be transferred from the shipping canister to the decontamination container within 90 minutes or there will be a disaster! Note: 90 minutes presumes the use of 2, 45 minute class periods.
- You must not spill any of the unstable industrial chemicals or you will start a chain reaction causing the damaged shipping container to explode.

RICH LANGUAGE

If students are new to the engineering design process, review the concepts of *criteria* and *constraints* and how engineers need to account for both as they design solutions to problems.

Criteria: The requirements for a successful design solution. Criteria may include what the solution will do, how and in what way, durability, cost, and other considerations that are important to the end user. When possible, criteria should be quantifiable so the design's performance in meeting them can be measured.

Constraints: Constraints are limitations that must be taken into account when creating a possible solution. Constraints include details like materials, time, money, societal or environmental impacts, aesthetics, etc. Constraints must also include consideration of scientific principles and other relevant knowledge that can inform the design of a successful solution. They may be measurable quantities such as size, weight, cost, efficiency (in use of energy, for example), etc.

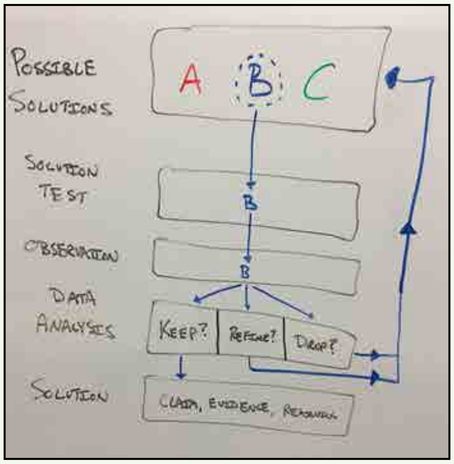
Personal Knowledge

Students capture what they already know about the problem as well as its criteria and constraints.

- Have students work with their team members to list ideas and questions related to the problem statement and its criteria and constraints. This list helps students think about key issues, applicable science, or similar solutions to consider as they move forward.
- Have a team member record these ideas on a large piece of paper or whiteboard. Ask students to document these ideas and questions, or have them take a picture for inclusion in their journal.

Possible Solutions

Students generate a range of possible solutions to test and refine based on the problem's criteria and constraints.



Process Diagram

- Provide an overview of how engineers move through design iterations that include a Possible Solution, Solution Test, Observation, and Data Analysis before choosing a solution that best meets the problem's criteria and constraints.
- Draw a diagram to show how this works. In the sample diagram, students have identified three possible solutions and moved ahead with option B to the point of analyzing data to determine how to proceed. Emphasize that their goal is to design and optimize a device and process to save the city in the available time.
- Student teams brainstorm and sketch between two and four ideas for possible solutions.
- Remind students that each solution includes two parts:
  1. a device, and
  2. a transfer process to move the industrial chemical to the decontamination container.
- Based on their personal knowledge and collective sense of how well each possible solution will work, teams will select one possible solution to test (in their assigned testing grounds), observe, and analyze for design improvements.

OPENNESS TO NEW IDEAS

Encourage students to think outside the box as they sketch a device and list a transfer process. Ideas will be shared quickly, so the challenge will be to capture several ideas that will allow them to make a good decision for moving forward with testing.

CREATIVITY AND CRITICAL THINKING

Encourage students to "mess about" with the materials provided. Have them make observations about the available materials to help them think creatively as they brainstorm possible solutions. Once they have identified between two and four possible solutions, teams will need to think critically about the criteria and constraints to select one to test and observe.

Solution Test

Students build and test a device and document their transfer process for their possible solution.

- Students will build their device in preparation for testing and observation.
- Students will likely want to rush to testing their design. Before moving into testing and observation, emphasize the need to clearly communicate their transfer process. Explain to them that a successful transfer process should be clear enough for a different team to read and execute with minimal confusion.
- Student teams test their possible design solution in their assigned testing ground within the constraints for the scenario.

Observation

Students record their observations.

- Remind students to record qualitative and quantitative observations in their journal.
- Students may be tempted to begin refining or developing a new device or transfer process in the middle of their observations. Encourage them to complete their Observation and Data Analysis to provide evidence to inform the choice (and possible redesign) of an improved design.

INTEGRITY

Encourage students to work within the problem's constraints. Although it may be tempting, they are to only use the materials they are provided.

Data Analysis

Students make sense of their data by comparing it to the problem's criteria and constraints in order to decide how to proceed.

- Have students **analyze** their data using the established criteria for success:
  - Work as a team to build a device and process that transfers all of the contaminated chemicals into a decontamination chamber without spilling.
  - Work within the constraints of the scenario.
- Have students **interpret** their results by deciding if the device and transfer process should be eliminated, refined, or selected as an optimal solution.
  1. If a device and/or transfer process should be eliminated, have teams identify what did not work. Have individual students record strengths and weaknesses from this solution test in their journals before returning to consider different possible solutions to design, build, and observe. Once identified, teams take their next possible solution through another round of Solution Test, Observation, and Data Analysis.
  2. If a device and/or transfer process can be refined to better meet the criteria, have student teams record strengths and weaknesses from this solution test that can be changed or added to future designs. Have individual students record these ideas in their journal before beginning another round of Solution Test, Observation, and Data Analysis for this improved design.
  3. If a device and transfer process meets the criteria and has been optimized based upon analyzed data from one or more previous designs teams can select it as their optimal solution for development of their claim, evidence, and reasoning prior to use in the spill area.

CRITICAL THINKING AND SELF-DIRECTION

Engineering design is an iterative process where students use the data they collect from tests of their designs to refine, eliminate, or select a solution. Highlight for students that the process of continuous refinement within the boundaries of criteria and constraints is how engineers design solutions to problems. As students refine or create a new possible solutions, they need to be self-directed, critical thinkers.

PERSEVERANCE

Challenge students to design another possible solution and repeat the process (Possible Solution, Solution Test, Observation, and Data Analysis) even if the students find a workable solution. Have them continue designing, building and testing improved solutions for the entire time they are given.

Part 3

DEVELOPMENT OF CLAIM

Solution

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from their analyzed data and subsequent improvements to document their optimized solution to the problem statement.
- Have them write their solution in their journal with the following parts:
  - Have students develop a **Claim** that solves the problem statement: Design a device and transfer process to secure a toxic substance.
  - Then, have them add **Evidence** (the analyzed data from each iteration of their design efforts) to support their claim.
  - Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as any science principles they have learned.

Claim

We claim our 3rd design is the best solution to transfer the toxic chemicals to the decontamination container. (See picture).

Evidence

We analyzed each device and process using the criteria. Our first possible solution did not successfully transfer the materials after three separate trials. Each of our second and third possible solutions were successful in transferring the practice materials, although the third possible solution included a much easier-to-understand process because it took less time to do. We tested all of our possible solutions under the same conditions prior to choosing the third design.

Reasoning

Investigation: We decided to stabilize control of the first possible solution. We did this by redesigning our ability to control the bottom of the shipping container while transferring the material to the decontamination container. After testing the second possible solution we saw that the process steps were difficult to understand so we changed them and retested the solution. We are very confident in our evidence because we did a fair test each time by following our process carefully. We collected and analyzed data for each design that helped us improve new solutions.

Science: We saw that the shift in weight when transferring the toxic chemicals from the shipping container required us to add a stabilizer to control the flow of the material. Adding this to our device allowed us to successfully pour the material into the decontamination container.

Evaluation

Students reflect on the investigation.

- Ask students what surprised them.
- Ask students how a consistent process of designing, building, testing, and evaluating multiple solutions allows engineers to develop high quality solutions to problems.
- Ask students what problem they would like to solve next.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Once identified, student teams test their optimized device and transfer process at the scene of the spill.

- Student teams will take their device and process to test their optimal solution in the spill area under strict controls for both the criteria and constraints.
- Students will attempt to solve the problem with their chosen solution while making qualitative and quantitative observations of both in their journals.

RISK-TAKING

This activity is exciting and fun for students. Encourage students to support each other as they succeed and are met with challenges. Applaud their efforts to take risks in the development of their designs instead of treating the lesson as a competition that results in winners or losers. Taking risks may result in a "failure" but this is critical to the development of great solutions.

Assessment

Have individual students explain how criteria and constraints are used to design optimal solutions to engineering design problems.

Determine how well individual students and teams:

- design, build, and test multiple solutions to meet defined criteria for moving corn kernels from one container to another within given constraints.
- evaluate solutions to determine how to make improvements that result in an optimal design.
- develop an explanation (**Claim, Evidence, Reasoning**) that identifies how their optimal design best meets the problem's criteria and constraints.