

Save the Hiker

Convert Between Forms of Energy to Save a Friend

The Tech Challenge 2018 Lesson 3: Science

Developed by The Tech Academies of Innovation

Lesson Overview and Standards

Advanced Prep and Set-up for Lesson

Lesson Guide

- A. Introduction
- B. First Design Challenge
- C. Content Learning
- D. Final Design Challenge
- E. Evaluation

Appendices

- A. Vocabulary
- B. Resources
- C. Background Information
- D. References
- E. Lesson Handouts

I. Lesson Overview

Can you build a device that will deliver life-saving treatment to someone in a hazardous situation?

Lesson Description:

During this lesson students will learn how energy is converted and transferred between objects. Working in groups and through the iteration process, teams will increase their knowledge of energy transfer by building a Non-Electric Emergency Delivery System (NEEDS) that will help a search-and-rescue team save lives.

Grade Levels: 4-8

Education Outcomes

Students will:

- Identify when energy is converted [4-5th] or transferred [6-8th] in a system.
- Use the engineering design process focusing on iteration and prototyping.
- Create diagrams with labelled energy transfer [4-5th] or conversion [6-8th] points.
- Explain how energy is transferred [4-5th] or converted [6-8th] in their device.

Education Standards Met: (Note: bolded parts of the standards are fully met by this lesson)

NGSS Disciplinary Core Ideas (DCI):

[4-5th] 4-PS3-4 Apply scientific ideas to **design, test, and refine a device** that **converts energy from one form to another**.

[6-8th] 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**.

NGSS Science and Engineering Practices (SEP):

Planning and Carrying out Investigations:

[4-5th] **Make observations** and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or **test a design solution**.

[6-8th] **Collect data about the performance of a proposed object, tool, process or system** under a range of conditions.

NGSS Crosscutting Concepts (CCC):

Energy and Matter:

[4-5th] **Energy can be transferred** in various ways and **between objects**.

[6-8th] The **transfer of energy can be tracked** as energy flows **through a designed** or natural **system**.

II. Advanced Prep & Set-up for Lesson

Materials (per approximately 30 students)

Note: Many of these materials are suggestions based on what students have found useful. This is not a limiting list – feel free to add other materials that you think may be useful to building the simple machines in this lesson. Think creatively and use materials you have on hand!

- Penny (or similar sized object to represent medicine)
- Table
- Landing area (21cm x 21cm) piece of fabric, paper, foam, etc.
- Ravine wall (shoebox top, plastic sheet, etc.) or room wall
- Masking tape (blue)
- Wood dowels
- Film canisters
- Small Playdough containers
- Assorted paperclips
- Binder clips
- Springs
- Rubber bands
- String
- Straw
- Dixie cups
- Small plastic container with lid
- Wooden sticks

- Corrugated plastic sheets (coroplast)
- Paper
- Plastic gears
- Pipe cleaners
- Coffee filters
- Scissors
- Balloons

Set-Up

1. Students will be introduced to the engineering design challenge. The following handouts will need to be distributed to the students (see Appendix E, Lesson Handouts):
 - KEWLE Handout
 - Journal Handout
 - Bubble Map
 - Energy Terms Organizer
 - Second Engineering Design Challenge Journal
 - Final Assessment

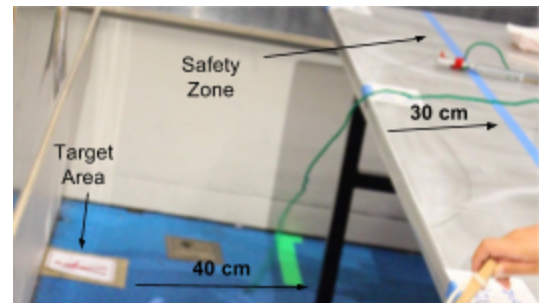
2. Materials:

- TESTING AREA materials (see picture)

The testing area needs the following materials:

- Table
- Optional: Wall (or board to represent ravine wall)
- Tape (blue or masking)
- 21cm x 21 cm target area
(The size can be changed depending on the degree of difficulty needed for the students.)

- Educator Note: This testing set-up makes it very difficult for the device operator to see the target area while in the “safety zone” and deliberately requires students to communicate during testing about how the device is functioning. The educator may ask students to consider the real-world constraints of this problem.
- Design and construction materials
Suggested materials are listed above. These are not required materials, but ideas based on materials students have had success with in the challenges we have run. An extension will be for students to suggest additional possible materials after their first iteration. You may choose to add materials during the challenge or just use the student suggestions as a way to emphasize real-world engineering.





3. Work areas

Three work areas are needed for this engineering design challenge:

- Materials table
 - One area for all the materials. Sort the materials into different containers for easy student access and clean up.
- Design and build table
 - Have an area for each group to design and build their prototype.
 - Students can design and build in groups of your preference (3-4 works well).
- Testing table
 - Designate one area for testing. See above for a list of testing materials and set-up. The testing area can be set up for multiple groups to test at the same time. Two groups can usually test simultaneously, one on each end of your testing table. A wall works as a great backing for the challenge. A piece of wood or similarly rigid material may also be used as a back if a wall is not available.
 - You may wish to test each group one at a time in front of the class.
 - Use tape (blue painter's tape works great) as your Safety Zone indicator. It should be placed 30 cm from the edge of the testing table. This safety zone is the area that your students cannot have their hands cross during the testing. Other parts of their device may cross (see picture).
 - Your medicine landing area (Target Area) is your 21cm x 21cm piece of fabric/carpet. This should be placed against the wall (see picture).
 - Your testing table should be 40 cm from the Target Area. This space represents the bottom of the ravine, like a river or stream, and the medicine must go over the ravine and land in the landing area without landing in the river (see picture).

Data Collection

Students will collect data as they perform their three iterations. (See Appendix E, Sample Data Collection.)

1. During the first design challenge this information will be recorded on a whiteboard or piece of poster paper.
2. During the second design challenge, teams will record this information on their Second Engineering Design Challenge Journal. (See Appendix E, Lesson Handouts.)

III. Save the Hiker

Guiding Question: Can you build a device that will deliver life-saving treatment to someone in a hazardous situation?

A. Introduction (20-30 minutes)

1. Show a video(s) to students to get them thinking about the challenges involved in the search and rescue of someone trapped on the side of a cliff:
 - Possible video options for educators to engage students may include:
 - “Lost hiker in dramatic cliff rescue.” This video shows a man stranded on the side of a cliff being rescued by a helicopter team. (<https://www.youtube.com/watch?v=Kpf8P7IRgDI>)
 - “Metro West rescuers bring trapped person to safety.” by Joel Hulsey at KSDK. This video is news coverage about two hikers that needed to be rescued. (<http://www.ksdk.com/news/local/metro-west-rescuers-bring-trapped-person-to-safety/423689435>)
2. Build empathy for the people (the rescuers and the people being rescued) in the situation through leading a discussion.
 - Record questions and answers in a shared space for the students (on a whiteboard, shared document, etc.).
 - Possible questions include:
 - *What is going on in this video?*
 - *What do these videos have in common?*
 - *What are some problems that the rescue team must solve?*
 - *What are some obstacles in this situation?*
 - *What types of materials might be helpful?*
 - *Have you ever experienced a situation where you or someone you know needed help?*
 - *Today we are going to do an engineering design challenge, where we are going to help someone stuck in a ravine. Keep in mind the ideas on the board as we design devices to help someone in a rescue situation.*
3. Introduce students to the scenario.

Imagine that you and your best friend, Justin Time, are hiking on a trail along an isolated hiking path. Justin ignores the caution signs and decides to take a selfie overlooking the ledge. Without warning the earth begins to shift and move under Justin's feet causing him to slip down the side of the mountain and land on a ledge inside the narrow ravine. Amazingly, Justin does not suffer any life-threatening injuries, but he does have to take insulin to manage diabetes.

You decide to build a device that will safely and accurately deliver this medication to your friend before it's too late. While the search-and-rescue team work out a strategic plan to save your friend, you return to your campsite to retrieve Justin's medicine and collect supplies to make a Non-Electrical Emergency Delivery System (NEEDS) to transport the medication to your friend.



4. Explain what a KEWLE Handout is and why students are going to be using it (What I know, Evidence of learning, What I wonder, What I learned, Evidence of learning).
 - *A KEWLE chart is a type of graphic organizer to help arrange what a person already knows about the topic, create questions to guide research, and finally to help identify what a person has learned throughout the process. We are going to use a KEWLE chart to analyze the problem presented in the scenario.*
 - Distribute a KEWLE Handout to each student. (See Appendix E, KEWLE Handout.)
 - Give students five minutes to write down their thoughts and questions in the “What do we think we know?,” “What evidence do we have?” and “What do we wonder?” sections of the handout.

5. Discuss with the class what they recorded under the “What do we know?” section of the handout to gauge student knowledge and to help students to access their prior knowledge. Incorporate the first evidence section as a class.
 - Ask questions to get students thinking about what they already know, especially if they have not used this type of graphic organizer before. Possible questions to ask students include:
 - *What do you know about hiking?*
 - *What do you already know about rescue operations?*
 - *What do you know about moving objects?*
 - *Why might it be necessary for someone to have medication before being rescued?*
 - Ask students to provide evidence for the things that they know.
 - Record student answers in the classroom discussion of “What I know” and “Evidence of learning” in the shared classroom space (whiteboard, shared document, etc.). Students can use prior knowledge and real-world experiences in the “Evidence” column while initially working on the KEWLE. Possible example of providing evidence: (*“Know:” If I hold a pencil in the air and drop it, then the pencil will fall instead of floating. “Evidence:” Gravity is pulling on the pencil; observation in class*)
 - Give students three minutes to add to the evidence section of their chart. Encourage students to help each other explain how they know what they know.

6. Discuss with the class what they recorded under “What do we wonder?”.
 - Record student answers from the classroom discussion of “What do we wonder?” in the shared classroom space. Possible questions to ask students include:
 - *How could something be given to a hiker at the bottom of a cliff without using electricity or sending someone else down into the dangerous situation?*
 - *What are some of the things that a trapped hiker might need?*
 - *What might be some limitations (constraints) in getting them what they need?*
 - *The KEWLE handout will be referenced and added to throughout the lesson. It is important to keep it somewhere that it can be easily accessed during the rest of the lesson.*



- An example of what a row in the KEWLE chart might look like at this point is below:

K	E	W	L	E
What do we think we KNOW ?	What EVIDENCE do we have?	What do we WONDER ?	What did we LEARN ?	What EVIDENCE do we have?
<i>If I hold a pencil in the air and drop it, then the pencil will fall instead of floating.</i>	<i>Gravity is pulling on the pencil; observation in class</i>	<i>How can I use gravity to do work for me?</i>		

7. Assign or form teams
 - Teams of 3-4 students are recommended for this design challenge.
 - Assign appropriate team roles based on the method preferred in your classroom.

B. NEEDS To The Rescue (80-90 Minutes)

1. Review the *engineer mindset* with students to prepare them to think like engineers. Ask students what they think it means to think like engineers.
 - *What do engineers do?* (Possible answers include: solve problems, design solutions, etc.)
 - *What kind of skills or traits do successful engineers have?*
 - *Open (Be open to all ideas and solutions, listen to everyone's ideas.)*
 - *Playful (Have fun! Wild and crazy ideas are welcome.)*
 - *Bold (Take risks, be confident and courageous.)*
 - *Curious (Ask questions, wonder, tinker, and ask more questions.)*
 - *Perseverance (Failure is the first attempt in learning.)*
 - *Collaborative (Work with others to reach a common goal.)*
 - *Today we are going to use all of these traits, but we are going to focus on developing our perseverance. Sometimes when we design it can be frustrating, especially when we are working with a very short amount of time. It is really important that we think, talk with our team mates, reflect on what we are observing, and keep trying.*
2. Introduce the engineering design challenge and guiding question from the perspective of an engineer.
 - *The guiding question for this lesson is: can you build a device that will deliver life-saving treatment to someone in a hazardous situation?*
 - *What might an engineer think about, if their friend was stuck on the ledge?* (Possible answers could include: Where is the ground stable? At what angle would a device need to travel to reach my friend? How far is my friend?)
 - *How would an engineer use **perseverance** in thinking about this problem?* (Possible answers could include: look for problems and iterate, keep trying, ask their friend for ideas, etc.)



3. Review or define the concepts of criteria and constraints:
 - What are criteria in engineering?
 - *Criteria are the goals for a project.*
 - *Justin is trapped in the ravine and needs medicine, what do you think are some criteria we may want to consider?*
 - Chart the ideas generated by the students. (Possible answers could include: to not fall into the ravine ourselves, to transport Justin's medicine down to him without anyone getting injured, to keep the medicine from being damaged.)
 - What are constraints?
 - *Constraints are the rules or limits for a project based on real-world limitations. Constraints always include budget and schedule. Budget is the cost (or in our case, the materials) and schedule is how much time you have.*
 - *What do you think some possible constraints are for this engineering design challenge?*
 - Chart the ideas generated by the students. (Possible answers could include: how much time (schedule) until Justin needs his medicine again, how far do we need to stay from the edge of the cliff for our safety, what is our budget in money or materials to solve this challenge?)
4. Introduce the engineering design challenge. Display this information for students to see and refer to as they work.

Design Problem:

- Medicine needs to be delivered to your friend stranded on a ledge in a narrow ravine.

Criteria (Design Requirements/Desired Features):

- Each team will be given a load to transport that will represent Justin's medicine. It must be protected. With the teacher's help, students will decide what "protected" means in this challenge.
- The load must land within the target area where Justin can reach it.
- Everyone in the rescue team must contribute and be able to say what they contributed to the solution.
- The rescue team will complete 3 trials for their device during testing and record data on the classroom data table.
- Include other practicable student-generated criteria.

Constraints (Design Limitations):

- Budget: The rescue team can only use provided materials that they found at the campsite. No electric options are available.
- Schedule: 15 minutes to build the device. Your friend needs his medication soon.
- Students must stay behind the safety zone at all times (30 cm from the edge). We don't want two hikers stuck in the ravine!
- Include other practicable student-generated constraints.



Testing:

- Testing rig can be a table, with the 30 cm safety zone identified with tape.
 - On the floor, create a target (ledge) for the students to aim for. (Optional: Set it up against a wall to simulate the ravine wall behind the hiker or add some type of backing to represent a wall.)
 - Set the table 40 centimeters away from the edge of the target area to represent the ravine between the ledge and the cliff (vertical drop will vary depending on the height of the table used; the higher the table, the more complex and/or challenging it will be for engineers).
 - A reference image for set-up is provided in Section II: Advance Set-up.
 - Educator note: Remember that this testing set-up makes it very difficult for the device operator to see the target area while in the “safety zone” and deliberately requires students to communicate during testing about how the device is functioning. The educator can ask students why in a real-world situation they would not safely be able to peek over the edge while using their device to help bring focus back to the nature of the design problem.
5. Introduce available materials on supply table.
- Hold up 3-5 different materials from the supply table and ask students what they might represent in a hiker’s backpack and or campsite. (Possible answers could include: string could be rope, a toothpick could be a log, a rubber band could be a bungee cord)
 - Have student teams walk by the table and look at the materials (but don’t touch), and discuss how they might use them to design a solution.
 - Give students 15 minutes to collect and explore materials. This is not time for building, but for students to see how the materials can work together.
 - Questions to ask might include:
 - *What questions do you have about the design challenge?*
 - *Which materials are you thinking of using? Why?*
6. Begin a 15-minute build time.
- While students are working, ask teams facilitative questions to help them guide their thinking and their process. Questions to ask students include:
 - *What might be added to or removed from the device to improve accuracy?*
 - *What features on the device help move the load?*
 - *What might happen if the vertical distance increased/decreased?*
 - *How can the delivery system be modified to make the load go farther or not as far?*
 - *Is this delivery system reliable? Can the outcome be repeated 3 times?*
 - *How might the impact to the load (medicine) be reduced?*
 - Students may test out their designs as they work.
 - If several groups are struggling to assemble a device within 15 minutes, consider giving a small amount of additional time (3-5 minutes).



7. Prepare for testing

- Have students return to their seats and put the materials down.
- Explain the rules or norms for testing. Ask students to refrain from building or dismantling during this time.
- Introduce the concept of **failure points**. (See Appendix C, Addressing Failure Points.)
 - *A failure point is the spot where your device stops working – a design element that can cause an unsuccessful result. Sometimes there is one failure point and sometimes there are many. As we work toward iterating our designs it is important to look for any points that specifically didn't work, so we can make our next design work better.*
 - Educator note: Begin testing with a delivery system that seems more likely to fail and model a positive and reassuring testing experience by highlighting innovative features, letting the students identify failure points and encouraging them to share what changes they would make. Celebrate student ideas and areas of success and focus less on the overall performance of the device.

8. Testing

- Have teams test their delivery devices one at a time while other teams observe.
- Every team must test their device regardless of completion. Testing a device is important so the whole class can benefit from design inspiration and observation of failure points. If the design is too incomplete to function, allow the group to show what they intended for it to do.
- Each team gets 3 opportunities to test and record their data on the class success/fail chart.
- Ask students questions before they test.
 - *Tell us about your design.*
 - *How is this delivery system designed to meet the criteria?*
 - *What do you hypothesize will happen when you test it? How do you think it will work?*
- If a team's initial design does not work at all, ask the students in the team:
 - *What are some changes that can be made to the delivery system that might make it work more like your team intended?*
- If a team's initial design does work, ask the students in the team:
 - *Are there any changes that you might consider for another iteration to make it work differently or more reliably?*
- At the end of the three tests the team will have an opportunity to summarize what they think worked and what they think could be improved in their next iteration.
- Peers may provide feedback that is kind, helpful, and specific. Encourage peer feedback to focus on what worked well or opportunities for improvement.
- Have students return to their desks and remind them to leave their delivery device as it is and not to disassemble or change it.



9. Distribute the journal handout. (See Appendix E, Journal Handout.)

- *What do you think will happen if we build a solution and it doesn't quite do what we want, so we start over and build a new device, and then another and then another? Would it be helpful to start over every time? Why not? (Possible answer: no, because if we start over, we won't know what changes made a difference in the design.)*
- *If we make lots of changes to our device at once, how will we know if the new parts worked as we planned? How can we identify which change made our device more successful?*
- *Each student will get a journal handout to record a sketch and information about your team's design. This journal is a place to record which criteria and constraints the delivery system meets and/or does not meet. This is also a tool for your team to document significant changes. Each student will make a journal about their team's current prototype to have a record of your ideas and to have the information in case a teammate is absent. Teams can discuss and share ideas for filling out the journal.*
- *What questions do you have about this handout?*
- Give students 5-10 minutes to discuss and complete the journal.
- See sample journals below:

Test Trials		
Test #1	Test #2	Test #3
Medicine delivered? Y/N Observations: <i>Medicine landed in front of the target, but traveled in a straight line. Spoon bent more than we expected.</i>	Medicine delivered? Y/N Observations: <i>Pulled rubber band tighter this time. Medicine went over the target and off to the right. Spoon bent in half.</i>	Medicine delivered? Y/N Observations: <i>Pulled rubberband to the end of the spoon. Medicine bounced off of the wall and landed on the target. Spoon is less stable than we want it to be.</i>

Criteria and constraints this solution DOES meet: <i>- made from available materials - operated from the safety zone - medicine is protected by padding we added</i>	Criteria and constraints this solution DOES NOT meet: <i>- medicine does not land on the target (does not go far enough) - one member of the team did not contribute to the design</i>
---	---

10. Reflect on the first engineering design challenge as a class.

- *What were some of the similarities in team designs? What were some of the differences?*
- *What was something that a team tried that didn't work, but was really interesting or inspiring?*
- *How do you want to iterate your prototype? Why?*
- *Are there other materials that might be useful for this challenge? What are they and why might they be useful?*
- *Are there materials that are not working for this challenge? Why not?*



C. Content Learning (70-80 Minutes)

1. Demonstrate a Newton's Cradle or show the students a video of a Newton's Cradle to begin a conversation about energy conversion and energy transfer. ("Newton's Cradle – Incredible Science" <https://www.youtube.com/watch?v=0LnbyjOyEQ8>)
 - *This is a Newton's Cradle. It has five equally-sized balls of the same material suspended next to each other. Watch and observe what happens. We are going to discuss our observations about what is happening afterwards.*
 - Have students use the KEWLE chart to record what they know and what they wonder about the Newton's Cradle as they watch.
 - Perform the demonstration or show the video.
2. Draw a Bubble Map on the board and write Newton's Cradle in the middle circle. Write down student observations surrounding the center bubble. Write similar ideas and concepts next to each other. (See Appendix E, Bubble Map.)
 - *What did you observe?* Encourage students to use adjectives. (Possible answers include: balance, when one ball was dropped the ball on the other side swung out, when two balls were dropped on one side then two balls on the other side swung out.)
 - *Why do you think that happened?* (Possible answers include: the energy from the dropped ball moves through the other balls, if you drop two balls then there is that much force to push the two balls at the other end.)
3. Define kinetic energy, potential energy, energy conversion, and energy transfer by using as much of the student-friendly language from the bubble map as possible.
 - **Potential energy** is when energy is stored and it has the potential to become another type of energy.
 - *Where does the Newton's Cradle have potential energy? (When the ball is lifted)*
 - **Kinetic energy** is the energy of motion.
 - *Where does the Newton's Cradle have kinetic energy? (When the ball is falling or moving)*
 - [4-5th Grade] **Converting** energy is when energy changes from one form to another. For example, dropping the ball in the Newton's Cradle **converts** the potential energy to kinetic energy using gravity when the first ball is dropped.
 - [4-8th Grade] Energy **transfer** is when energy moves from one place to another or one form to another. For example, in the Newton's Cradle the energy is transferred by the raised ball that has potential energy that converts to kinetic energy as it falls. When the ball hits the next ball the energy is **transferred** and continues to be transferred until the last ball swings out, showing how the energy has been transferred from the first ball.)
 - *Here is an analogy for the difference between energy transfer and conversion: if I hand you one dollar, then I have transferred a dollar to you. If I take a dollar and trade it for four quarters I have converted the dollar. It is worth the same amount, but it is in a different form.*



- *What questions do you have about conversion and transfer of energy?*
 - [6-8th Grade only] **Absorbed energy** is when the energy seems to disappear, but it is actually spreading out inside an object. An example is when a glass hits the ground the kinetic energy (the motion) is absorbed partially by the ground, but also spreads out as vibrations through the glass which may cause it to break. **Stored energy** is a way to describe potential energy when energy is built up for later, for example raising an object off the ground stores energy for a later fall or pulling back a rubber band stores energy for a later snap.
4. Give students 30 minutes to document domain specific vocabulary using the Energy Terms Organizer. For other vocabulary documentation options see Appendix C, Vocabulary Organizers. (See Appendix E, Energy Terms Organizer.)
- Domain Specific Vocabulary with possible student engineering design challenge examples includes:
- Potential Energy - when the medicine is at the top of the cliff, it has potential energy because of the distance it can fall.
 - Kinetic Energy - when the medicine is falling.
 - Load – the items transported by your device.
 - Mechanical Energy - the work that is done by the NEEDS device.
 - [4-5th Grade] Energy Conversion - when the load that was not moving (potential energy) is put into motion (kinetic energy).
 - [6-8th Grade] Energy Transfer - when the device moves the medicine it transfers energy to the medicine.
 - [6-8th Grade] Absorbed Energy - when the medicine hits the target and the energy moves into the ground and the medicine (as sound and vibration).
 - [6-8th Grade] Stored Energy - types include potential and gravitational energy.
5. Have students connect and build their vocabulary using their engineering design challenge experience.
- Post three statements on the board for students to discuss with their teammates. Give the teams five minutes to discuss.
 - When _____ was moving in our NEEDS device, kinetic energy was observed.
 - We got the load to move by _____.
 - Our NEEDS device used potential energy by _____.
 - Discuss answers as a class.
 - *Let's apply what we know about energy conservation and transfer to our engineering design challenge. Please raise your hand to share what you saw, notice, or wonder about energy and the NEEDS device your team made.*
 - Give students an opportunity to share their thoughts with the class.



6. Have students analyze and share designs solutions that were created during the design challenge by posting their journal designs on the wall and have the class do a gallery walk.
 - Students can practice applying the vocabulary by writing a post-it note to other teams based on what they observe in the data displaced for the gallery walk.
 - Sentence frames for practicing the content vocabulary and concepts are:
 - In your design, I see that you used potential energy to _____.
 - The kinetic energy in your design moved _____.
 - [4-5th Grade] In your design, energy was converted from _____ to _____ when _____.
 - [6-8th Grade] In your design, energy was transferred from _____ to _____.
7. Revisit KEWLE with students:
 - Remind students of what they said they knew and what they had wondered.
 - Ask students to brainstorm things that they have learned supported by evidence from the engineering challenge in part B and the content specific lesson in part C.
 - Ask students to add any new wonders they might have.

D. NEEDS Prototype Testing (45-90 minutes)

1. Introduce the second design challenge for students to incorporate what they have learned about energy.
 - *After saving Justin's life, the news shows a story of another person trapped on a cliff. It is apparent that this delivery device could be very useful to other people. Justin suggests that you have a professional model of your idea manufactured and then sell them to emergency responders. Maybe your device could even make you rich and famous! Before making an official model, more testing and fine-tuning is necessary. The next **prototype iteration** will be even better with improvements in function, durability and/or reliability (works every time).*
2. Discuss and Define vocabulary words iteration and prototype.
 - Lead students to an understanding of iterative design and prototyping by using their experiences in the first design challenge. Possible facilitative questions include:
 - *How many different solutions did you try when you built your device?*
 - *What did you do when something you tried didn't work?*
 - *When you try different solutions (create, test, reflect, imagine) over and over, we call this **iteration**. The models that you build to test before you get to your final design solution are called **prototypes**.*



- *A device must have only one identifiable change from one iteration to the next in order to understand whether that one iteration increased the success of the delivery of the medicine or not. If there were two or more changes it would be difficult to know where to attribute the success or failure of those changes. However, time will not allow us to journal about every iteration we do in the rapid prototyping time of 15 minutes. So each team is going to:*
 - *Identify a goal from the first prototype you made in the first engineering design challenge.*
 - *Take 15 minutes to complete a rapid prototyping session to address this goal.*
 - *At the end of 15 minutes, document significant changes and explain improvements in your prototype.*
- 3. Explain how to use failure points to inform iteration.
 - *Engineers test their prototypes by seeing how well they meet the criteria and constraints. They also look for failure points—places where the system failed—so they can improve that part of the design in the next iteration.*
 - Discuss failure points students discovered in their own designs and/or help them identify the failure point:
 - *Can someone share an example of something that failed or broke in their design? What happened?*
 - *Where did it break or fail? How?*
(A possible example is: maybe a piece of wood broke, or a rubber band broke. The failure point would be where the item broke.)
 - *How did you improve your design to address this failure point?*
(Possible answers include: Drew it out and labelled it so we could design a different iteration. Learned that rubber bands might not be strong enough and pick a different material, etc.)
- 4. Discuss with students how the criteria and constraints of a problem can help you use iterative design to improve your prototype each time you test. Possible questions include:
 - *What kind of information can testing a prototype give you?*
 - *Imagine you had a design that met all but one of the criteria. What would be your next step?*
 - *Imagine you had a design that didn't meet more than one of the criteria. What would you do in that case?*
- 5. Give students the journal handout with data collection for this iteration. (See Appendix E, Second Engineering Design Challenge Journal.)
- 6. Have teams pick a goal for iteration using one of the following:
 - A failure point from the initial prototype
 - A criterion that was not addressed in the initial prototype
 - A constraint that was not addressed in the initial prototype
 - An improvement in durability
 - An improvement in reliability
 - An improvement in functionality
 - [4-5th Grade] An experiment in energy conversion to improve durability, reliability, or function.
 - [6-8th Grade] An experiment in energy transfer to improve durability, reliability, or function.



7. Review and display the engineering design challenge criteria and constraints for students to see and refer to as they work.

Engineering Challenge: Iterate your NEEDS device to develop a final concept for a manufactured prototype.

Criteria (Design Requirements/Desired Features):

- Each team will be given a load to transport that will represent Justin’s medicine. It must be protected. With the teacher’s help, students will decide what “protected” means in this challenge.
- The load must land within the target area where Justin can reach it.
- Everyone in the rescue team must contribute and be able to say what they contributed to the solution.
- The rescue team will complete 3 trials for each iteration of their device during testing and record success/fail data on the Second Engineering Design Journal.
- Include practicable student-generated criteria.
- Teams develop an iterative goal based on a failure point from the first design challenge, or an improvement in function, durability, or reliability.
- [4-5th Grade] Journal work includes at least one labelled energy conversion at work in their device.
- [6-8th Grade] Journal work includes at least two labelled energy transfers at work in their device.

Constraints (Design Limitations):

- Budget: The rescue team can only use provided materials that they found at the campsite. No electric options are available.
- Schedule: 15 minutes to build device. Your friend needs his medication soon.
- Students must stay behind the safety zone at all times (30 cm from the edge). We don’t want 2 hikers in the ravine!
- Include practicable student-generated constraints.

Testing:

- Testing rig can be a table, with the 30 cm safety zone identified with tape.
- On the floor, create a target (ledge) for the students to aim for. (Optional: Set it up against a wall to simulate the ravine wall behind the hiker or add some type of backing to represent a wall.)
- Set the table 40 centimeters away from the edge of the target area to represent the ravine between the ledge and the cliff (vertical drop will vary depending on the height of the table used: the higher the table, the more complex and/or challenging it will be for engineers).



Extension Challenges for Students Experiencing Immediate Success:

- *How might you make a device using fewer materials?*
 - *How might your device change if your load was 2 pennies, 3 pennies, etc.?*
 - *How might you reduce impact to your load?*
 - *Is it reliable? Can it work three times in a row?*
 - *Is it durable and functional?*
8. Give students 15 minutes to build and test their new iteration of their prototype.
- Teams develop one goal for rapid prototype iteration within 15 minutes.
 - Teams record this goal on the Second Engineering Design Challenge Journal.
9. Test student NEEDS devices.
- After 15 minutes for building and testing gather students with their NEEDS prototypes at the front of the classroom.
 - All students must test their devices three times and share a summary of what they learned.
 - Teams will record their success/fail of the three tests in their journal handout.
 - Encourage peer feedback. Sentence frames for peer feedback can include:
 - I like _____.
 - I wonder _____.
 - Terrific work on _____.
 - I was surprised by _____.
 - Where did the idea for _____ come from?
 - [4-5th Grade] I saw energy converted in your NEEDS device where _____ did _____ and that showed _____ energy converted to _____ energy.
 - [6-8th Grade] I saw energy transferred in your NEEDS device where _____ touched _____ and that showed _____ energy transferred to _____ energy.
10. Have students document their design on the Second Engineering Design Challenge Journal. The feedback from peers can help inform new goals or iterative ideas for development.
11. Optional: have students repeat the process 1-2 more times.
- Educator note: for additional prototyping sessions, print additional copies of the journal handout. (See Appendix E, Second Engineering Design Challenge Journal.)
 - Allow for more guided practice of any of the following:
 - Journaling skills
 - Rapid iterative prototyping
 - Data collection
 - Practicing vocabulary and concepts
 - Shorten the amount of time provided for the next series of rapid prototypes to 7-10 minutes.



12. Reflect on the rapid prototyping activity.

- Discuss observations from the process.
 - *What worked well in the rapid prototyping process?*
 - *What was challenging in the rapid prototyping process?*
 - *What did your team discover as you worked toward an iterative goal?*
 - [4-5th Grade] *How did thinking about energy conversion affect your design solution?*
 - [6-8th Grade] *How did thinking about energy transfer affect your design solution?*
- Revisit the KEWLE
 - Have students share their learning from the experience.
 - Have students support their learning with data from their tests.
 - Additional wonders may be generated that might be valuable to subsequent lessons.
- An example of what a completed row in the KEWLE chart might look like is below:

K	E	W	L	E
What do we think we KNOW ?	What EVIDENCE do we have?	What do we WONDER ?	What did we LEARN ?	What EVIDENCE do we have?
<i>If I hold a pencil in the air and drop it, then the pencil will fall instead of floating.</i>	<i>Gravity is pulling on the pencil; observation in class</i>	<i>How can I use gravity to do work for me?</i>	<i>Gravity can add potential energy to an object that can be converted to kinetic energy.</i>	<i>Dropped objects can have energy that makes them roll or bounce after falling.</i>

E. Evaluation (60-75 minutes)

1. Discuss the role of manufacturing in creating a prototype.
 - *Before marketing or selling a product, an innovative engineer like yourselves will want to make an official prototype to test before putting money into manufacturing a whole line of products that might have unforeseen failure points. Therefore, our next step is to have a prototype manufactured and the manufacturer is going to require a plan describing what we want. We have to create a document to clearly show and tell what we want this **NEEDS** device to do and how it will work.*
2. Introduce the final assessment with the students. (Appendix E, Final Assessment.)
Final Project:
 - *Your **NEEDS** (Non-Electric Emergency Delivery System) worked well enough that you have decided to move forward to the manufacturing phase of product development. There is a manufacturer that will make an official prototype for an affordable price, but they will need you to thoroughly document your device and send the design right away.*
 - Discuss with students the importance of making detailed notes, so the product they get back from the manufacturer is what they want.



- *What will the manufacturer need to know to be able to make a working model?* (Possible answers could include: what types of materials to use, explain how they are supposed to work together, our goals for the delivery device, etc.)
- *Is there anything we can do to help convey this information to the manufacturer?* (Possible answers could include: we can draw diagrams, label the parts or materials, explain how the parts work together, etc.)

Criteria (Design Requirements/Desired Features):

- Students may use one of their team's designs OR create a new design that contains successful elements from their team's design.
- Create a final draft quality design plan for the manufacturer that includes:
 - A description of the prototype and the process to build it.
 - Use academic terms from the lesson.
 - A detailed drawing of the device with labeled transfers [6-8] and conversions [4-5] of energy.
 - Identify a specific goal addressed by this product. Provide data to support how this product will achieve this goal.
 - Explanation of how energy is transferred 1 time through the delivery device.

Constraints (Design Limitations):

- Schedule: 45 minutes to create the document to send to the manufacturer.
3. Review the rubric with students, so students have a clear understanding of how their assessment is being graded. (See Appendix C, Evaluating Student Learning using a Rubric.)
 - Handout the rubric. (See Appendix E, Rubric.)
 - Ask students if they have any questions about the rubric or the assessment of the final presentation.
 4. Give students materials and 45 minutes to create their manufacturing design.
 5. Hang student's designs around the room and have students do a gallery walk to see each other's delivery devices.
 6. Reflect on the whole lesson with students
 - *What similarities and differences are there between the final manufacturing plans?*
 - *What was something that surprised you about this lesson?*
 - *What was something that you learned during this lesson?*
 - *What are some of the questions you have now?*

IV. Appendices

A. Vocabulary

term	student-friendly definition
absorbed energy	A type of energy transfer where energy is transferred to a different medium. For example: when the medicine hits the target and the energy moves into the ground (as sound and vibration).
conservation of energy	Energy cannot be created or destroyed, but it can be converted from one form to another.
constraint	The limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions.
criteria	The requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
design problem	The identified challenge, goals, or needs that a design addresses; What you are trying to solve.
design process	A series of steps that engineers use to guide them as they solve problems. The process is nonlinear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating. These are steps used to come up with solutions.
energy	The capacity to do work. There are many types of energy including: potential, kinetic, chemical, thermal, electric, etc.
energy conversion	Converting energy from one form to another. For example, dropping the ball in the Newton's Cradle converts the potential energy to kinetic energy using gravity when the first ball is dropped.
energy transfer	Moving energy from one place to another or one form to another. For example, in the Newton's Cradle, energy is transferred when the first ball is dropped and the potential energy is turned into kinetic energy that is transferred through all of the balls and moves the final ball.
engineer	A person who designs and builds innovative solutions (machines, systems, or structures) to solve a problem or meet a need.
engineering	The process that engineers go through to create, design, test, and build a solution.





failure point	A place where the design or system failed.
function	The action or purpose of an object including how it moves or interacts with other objects.
iteration	When you try different solutions (create, test, reflect, imagine) over and over.
kinetic energy	This is the energy of motion.
load	Another word for force, or what the structure has to hold up to; in a machine doing work, like simple machines, a load is the weight or mass being supported and/or moved. The items transported by your device.
mechanical energy	This is the combination of kinetic and potential energy for an object to do work.
optimal design	The design or device that best meets the criteria and constraints.
phenomena	Observable facts, occurrences, or circumstances.
potential energy	Energy in an object based on its position. Sometimes this is called stored energy.
prototype	The models that you build to test before you get to your final solution.
stored energy	Type of potential energy including elastic and gravitational energy.
structure	The material or arrangement of parts in an object to make up the whole.
trade-off	A situation in which you must choose between or balance two things that are opposite or cannot be had at the same time.
trajectory	The path followed by an object moving under the action of other forces.
velocity	The speed of something in a given direction.



B. Resources

- "Angry Birds - Red Flies Scene (8/10) | Movieclips." YouTube. MovieClips. 2017. Accessed 21 July 2017. <https://www.youtube.com/watch?v=dmqo-EuR8Cw>
- "Arrow vs. Concrete." Phenomena for NGSS, NGSS. Accessed 14 Sept. 2017. <https://www.ngssphenomena.com/arrow-vs-concrete/>
- Arseneau, Ryan. "Acorn Falling." YouTube, YouTube, 6 Apr. 2011. Accessed 14 Sept. 2017. www.youtube.com/watch?v=MuhHNe8vKSM
- "Changing Forces." Phenomena for NGSS, NGSS. Accessed 14 Sept. 2017. <https://www.ngssphenomena.com/#/changing-forces/>
- DeStefano, Anthony. "The Law of Conservation of Energy." YouTube, 10 Apr. 2015. Accessed 14 Sept. 2017. www.youtube.com/watch?v=Lh5Hyl7b-KE
- "Exploding Seeds." Phenomena for NGSS, NGSS. Accessed 21 July 2017. <https://www.ngssphenomena.com/exploding-seeds/>
- Hall, Nancy. "Newton's Laws of Motion." NASA, First Gov, 5 May 2015. Accessed 14 Sept. 2017. www.grc.nasa.gov/www/k-12/airplane/newton.html
- "Hiking Half Dome In 5 Minutes W/ A GoPro HD Cam." YouTube. Robphillips83, 14 Sept. 2011. Accessed 21 July 2017. https://www.youtube.com/watch?v=XkMzfj1f_90
- Laskie, Alexandra. "Three women rescued from cliff face in Werribee Gorge." *The Age*, The Age, 21 May 2017. Accessed 14 Sept. 2017. www.theage.com.au/victoria/werribee-gorge-rescue-three-women-stuck-on-cliff-face-20170521-gw9qqe.html
- McKenzie, Sheena. "Humanitarian airdrops: How do they work?" CNN, Cable News Network, 4 June 2016. Accessed 14 Sept. 2017. www.cnn.com/2016/06/03/middleeast/airdrops-humanitarian-aid-syria/index.html
- "Pro Skier Survives 1,600-Ft Fall Down Mountain." YouTube. Associated Press, 11 Nov. 2011. Accessed 21 July 2017. <https://www.youtube.com/watch?v=NalMWW4eZrs>
- "Sinkhole." Phenomena for NGSS, NGSS. Accessed 21 July 2017. <https://www.ngssphenomena.com/sinkhole/>
- "Sledding Inertia." Phenomena for NGSS, NGSS. Accessed 14 Sept. 2017. www.ngssphenomena.com/new-gallery-1/6p4iss4zkpq7ghvbu1hy4nupieajx8
- "Woodpecker Slowmo." Phenomena for NGSS, NGSS. Accessed 14 Sept. 2017. <https://www.ngssphenomena.com/woodpecker-slowmo/>



C. Background Information

Addressing failure points

One important aspect about engineering that is vital to how engineers solve problems is the importance of failure to learn and improve solutions.

- As engineers work on creating solutions and improvements, it is important to remember that failure is not only part of the process, it is necessary in order to improve and find success.
- Every time an engineer fails to solve a problem completely, they learn a new piece of information about how the design functions and how to make it better.
- When engineers find a part of the design that doesn't work, it is called a **failure point**.
- A **failure point** is a design element that can cause an unsuccessful result. This is the point in a system that if it fails, the whole system fails.
- It is important to celebrate the failures that students may experience during the design process. Instead of "Oh no, that doesn't work!" try
 - *Now you know what happens when you try that! You have more information!*
 - *What did you learn from that?*
 - *What will you try next to improve your design?*
- Failure is an important part of the design process and should be celebrated as a positive way to learn. It is important to remind students that there is no single "right" answer in engineering; one problem can have many solutions.

Engineering Design Process:

Introduce the engineering design process graphic with students to show how engineers engage in fun, creative, problem-solving that is core to their work.

- Explain to students that as engineers go about solving problems and coming up with creative and innovative solutions to challenges, they follow the **design process**.
 - **Design process:** a series of steps that engineers use to guide them as they solve problems. The process is non-linear but cyclical, meaning that engineers can follow the steps in no particular order, repeat the steps as many times as needed, and make improvements along the way of imagining, creating, reflecting, testing and iterating.
- We represent this process with a graphic that shows the main steps someone goes through as they solve a problem.
 - Define your problems. What is the problem you are trying to solve? What are the criteria (design requirements that will determine the success of your solution)? What are the constraints (real-life limitations like budget and schedule) that you have to work within?
 - Test/reflect – imagine – create. This is the main part of the process that is cyclical. This is where engineers go through multiple designs as they have ideas, try something out, test it, have new ideas, and incorporate it all into more building and testing. This process can go through many rounds as an engineer gets more information from each test and design that is tried.
 - Share your solution. Engineering is about teamwork, and engineers frequently learn from each other as they solve problems. It's important for students to communicate and share throughout the process so that, just like real engineers, they can learn from each other and improve their solutions. It's particularly important to culminate a project with a formal sharing of solutions and perhaps even a showcase or other authentic way to share lessons learned with the broader community (community members, family members, principal, younger students, etc.).



- When you see the design process in action, you'll notice that it's rarely the smooth succession of steps that the diagram implies. The steps often overlap and blur, and their order is sometimes reversed – it's a creative, fluid way of working that must be adapted to each individual situation.
- As you guide students through the design process, you'll want to be flexible and receptive to the different approaches your students may try.
- Ask students to notice where they are in the design process and even to trace their path through the steps, so they can see how messy it can be.

Evaluating Student Learning using a Rubric:

Review the rubric with students at the introduction of the project so they know what their learning goals are. It is important to allow students to begin with the end in mind, just as teachers “backwards plan,” using standards and assessments to inform units, topics, and day-to-day activities.

The rubric in the lesson guide is designed to evaluate student mastery of the “met” standards using the categories *Below Standard*, *Approaching Standard*, *Meeting Standard*, and *Above Standard*. This allows teachers to give individual feedback particularly for the students who are *Below Standard* or *Above Standard* in particular areas.

- In the Below and Above Standards sections of the rubric, the idea is that no student should be receiving these scores without personalized attention from the teacher – either as remediation or as extension to reach students where they are.
- With that in mind, the descriptions and observations in these two sections are simply examples of what you might see for students performing at that level. The comments and notes in these sections should be tailored to the specific student and should accompany individualized support and conversations.
- To learn more about Understanding by Design and rubrics, see ASCD's Understanding by Design in the reference section. (See Appendix D, References.)

Vocabulary Organizers

Vocabulary organizers are a useful way to teach and reinforce vocabulary knowledge. Physical graphic organizers are provided in Appendix E for this lesson. However, there are some online tools that might work for your classroom's needs. Here are a few options to consider.

- MindMeister is an online collaborative mind map.
www.mindmeister.com
- Popplet is a tool for the iPad and web to capture and organize your ideas.
www.popplet.com
- Stormboard online brainstorming and collaboration
www.stormboard.com



D. References

- ASCD. "Understanding by Design®." Understanding by Design® framework - Videos, Articles, Resources, Experts. Web. Accessed 18 Aug. 2017. www.ascd.org/research-a-topic/understanding-by-design-resources.aspx
- Hulse, Joel. "Metro West rescuers bring trapped person to safety." KSDK, A TEGNA Company, 18 Mar. 2017. Accessed 14 Sept. 2017. www.ksdk.com/news/local/metro-west-rescuers-bring-trapped-person-to-safety/423689435
- "Lost hiker in dramatic cliff rescue." YouTube, The Telegraph, 4 July 2014. Accessed 14 Sept. 2017. www.youtube.com/watch?v=Kpf8P7IRgDI
- Mindmeister. Accessed 14 Sept. 2017. www.mindmeister.com
- "Newton's Cradle - Incredible Science." YouTube, IncredibleScience, 28 Dec. 2010. Accessed 14 Sept. 2017. www.youtube.com/watch?v=0LnbyjOyEQ8
- "Popplet for School." Popplet. Accessed 14 Sept. 2017. www.popplet.com
- Stormboard. Accessed 14 Sept. 2017. www.stormboard.com



E. Lesson Handouts

Handout Title	Page
Engineering Design Process <i>Graphic representing the design process</i>	27
KEWLE Handout [4-8 th Grade] <i>Graphic organizer of learning throughout the lesson</i>	28
Journal Handout [4-8 th Grade] <i>Data collection for team's initial prototype in Part B</i>	29
Bubble Map [4-8 th Grade] <i>Vocabulary tool for Part C</i>	30
Energy Terms Organizer [4-5 th Grade] <i>Vocabulary tool for Part C</i>	31
Energy Terms Organizer [6-8 th Grade] <i>Vocabulary tool for Part C</i>	32
Second Engineering Design Challenge Journal: [4-5 th Grade] <i>Data collection for Part D</i>	33
Second Engineering Design Challenge Journal: [6-8 th Grade] <i>Data collection for Part D</i>	34
Final Assessment [4-5 th Grade] <i>Final Assessment planning document</i>	35-36
Final Assessment [6-8 th Grade] <i>Final Assessment planning document</i>	37-38
Rubric [4-5 th Grade] <i>Rubric for assessing student mastery and progress on standards</i>	39
Rubric [6-8 th Grade] <i>Rubric for assessing student mastery and progress on standards</i>	41



Engineering Design Process and Innovator Mindsets





KEWLE Handout - Save the Hiker

Student Name:

K What do we think we KNOW ?	E What EVIDENCE do we have?	W What do we WONDER ?	L What did we LEARN ?	E What EVIDENCE do we have?



Journal Handout: Save the Hiker

Draw a diagram of your **Non-Electric Emergency Delivery System**. Include labels for:

- A. all materials and measurements
- B. any failure points

Test Trials		
Test #1	Test #2	Test #3
Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:

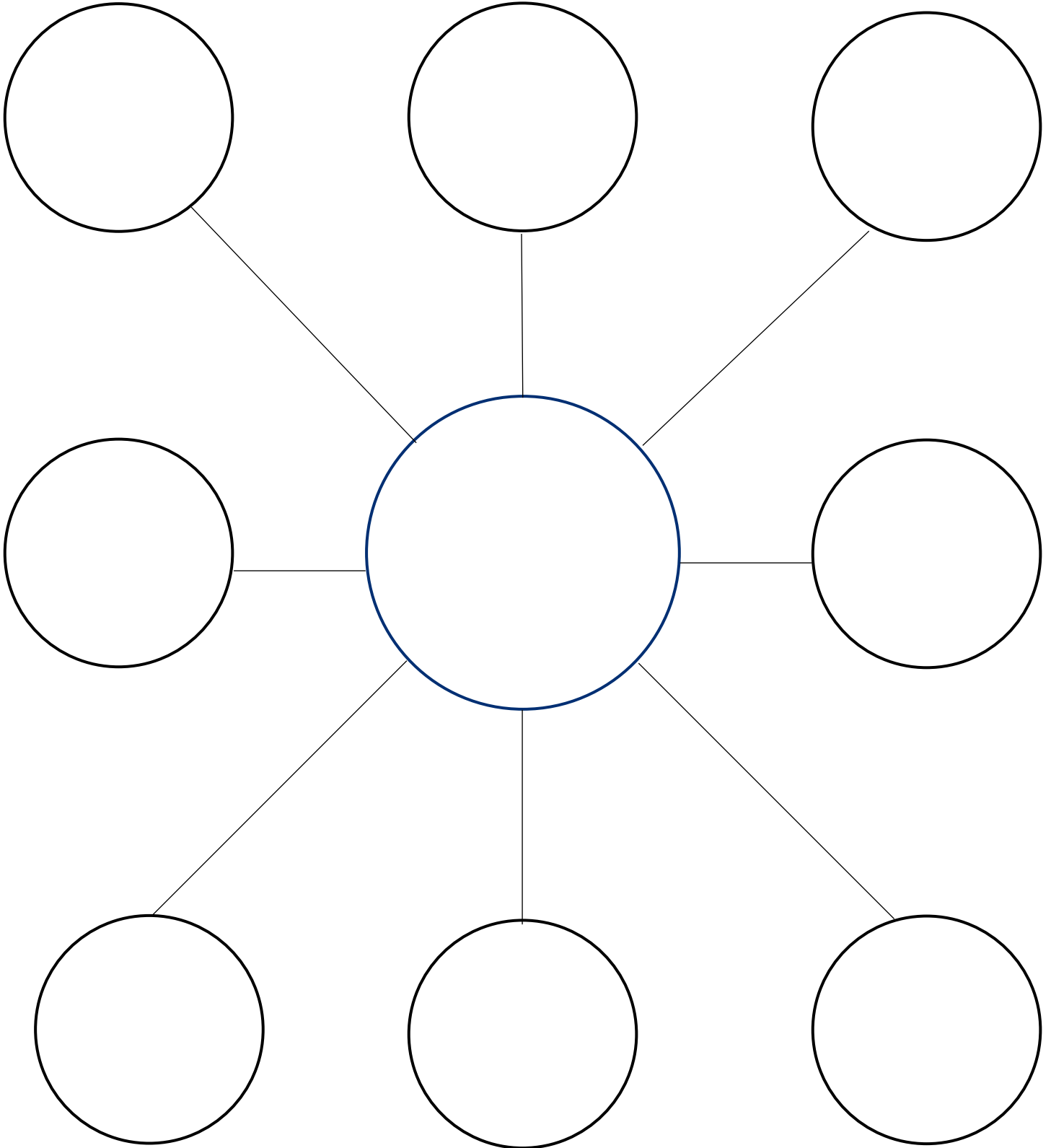
Date:	Prototype #:	Name:
-------	--------------	-------

Criteria and constraints this solution DOES meet:	Criteria and constraints this solution DOES NOT meet:
---	---

To improve on our prototype, some improvements we can make are:



Bubble Map - Save the Hiker





Energy Terms Organizer - Save the Hiker

[4-5th Grade]

Name: _____

Directions: Use the following table to define and draw a representation of each energy term.

Term	Definition	Draw a picture to represent the term.
Potential Energy (PE)		
Kinetic Energy (KE)		
Load		
Mechanical Energy		
Energy Conversion		
Energy Transfer		



Energy Terms Organizer - Save the Hiker

[6-8th Grade]

Name: _____

Directions: Use the following table to define and draw a representation of each energy term.

Term	Definition	Draw a picture to represent the term.
Potential Energy (PE)		
Kinetic Energy (KE)		
Load		
Mechanical Energy		
Energy Transfer		
Absorbed Energy		
Stored Energy		



Second Engineering Design Challenge Journal - Save the Hiker [4-5th Grade]

Draw a diagram of your **Non-Electric Emergency Delivery System**. Include labels for:

- A. all materials and measurements
- B. any failure points
- C. energy conversion and transfer points

Test Trials		
Test #1	Test #2	Test #3
Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:

Date:	Prototype #:	Goal:	Name:
<div style="background-color: #e0e0e0; border: 1px solid #ccc; padding: 5px;"> <p style="font-size: 8px; margin: 0;">A grid of small squares for drawing or notes.</p> </div>			
Criteria and constraints this solution DOES meet:		Criteria and constraints this solution DOES NOT meet:	

What are some improvements you can make in your design based on what you observed in your tests?



Second Engineering Design Challenge Journal - Save the Hiker [6-8th Grade]

Draw a diagram of your **Non-Electric Emergency Delivery System**. Include labels for:

- A. all materials and measurements
- B. any failure points
- C. energy transfer points

Test Trials		
Test #1	Test #2	Test #3
Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:	Medicine delivered? Y/N Observations:

Date:	Prototype #:	Goal:	Name:
Criteria and constraints this solution DOES meet:		Criteria and constraints this solution DOES NOT meet:	

What are some improvements you can make in your design based on what you observed in your tests?



Final Assessment - Save the Hiker [4-5th Grade]

MANUFACTURING REQUEST

Company Name: _____ **Date:** _____

Student Name: _____

Product Description: Describe your device and the iterative engineering process used to build it. Include at least 2 examples of iteration.

Diagram: Draw an illustration of your device below. Label the parts and show the function of the device. Label at least one place where potential and kinetic energy **conversion** happens.



MANUFACTURING REQUEST

Specifications of Device: What is the goal for using this device? Explain with data, how this device will achieve the goal.

Materials Specifications: What types of materials should be used in building the model?

Claim: Explain how energy is **transferred** through the materials to the load using the vocabulary from the lesson including all 6 of these academic terms (potential, kinetic, load, mechanical, conversion, and transfer).



Name: _____

Date: _____ Class: _____

Final Assessment - Save the Hiker [6-8th Grade]
MANUFACTURING REQUEST

Company Name: _____ **Date:** _____

Product Description: Describe your device and the engineering process used to build it.

Diagram: Draw an illustration of your device below. Label the parts, show the function of the device. Indicate how energy is transferred throughout the system. Label at least two places where energy is transferred from one part of the device to another.



MANUFACTURING REQUEST

Specifications of Device: What is the goal for using this device? Explain with data, how this device will achieve the goal.

Materials Specifications: What types of materials should be used in building the model?

Claim: provide evidence to support how features of your device use changes in **kinetic energy** and energy **transfer** to transport the load.

Rubric – Save the Hiker [4-5th Grade]

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Next Generation Science Standards 4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> • Testing their designs. • Refining their design. • Identifying types of energy and/or transfer of energy. • Documenting and explaining their ideas. • Using academic vocabulary words 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> • Student can describe, in writing, their team’s Non-Electric Emergency Delivery System (NEEDS) and identify one change they made during the design process. • Student can describe conversion of energy, but cannot apply it to their device. • Student can incorporate 4 or fewer of the lesson vocabulary in their writing OR incorporates 6 academic words with some misunderstanding of the meanings (kinetic, potential, load, mechanical, conversion, and transfer). 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> • Student can communicate, in writing, how the Non-Electric Emergency Delivery System (NEEDS) has been tested and iterated, more than one time, through the engineering process to meet their identified goal. • Student can identify and locate 1 conversion of energy within the system and correctly explains how energy is converted within the system. • Student incorporates lesson vocabulary into their writing by including all 6 focus terms correctly (kinetic, potential, load, mechanical, conversion, and transfer). 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> • Students can explain the function of their device in great detail using all lesson vocabulary and incorporates accurate explanation of trajectory and velocity (with/without use of those specific terms). • Student identifies 2 or more conversions of KE and PE OR identifies (motion, gravitational, sound, and elastic energies). <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> • Device will address different loads.
<p>Planning and Carrying Out Investigations (SEP 3 ES) Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> • Identifying failure points. • Identifying the criteria and constraints. • Scientific journals. 	<p>In the Journal:</p> <ul style="list-style-type: none"> • 1 NEEDS prototype is documented with a detailed diagram. • Failure points and/or design improvements are not clearly documented or design improvements are not based on test data/observations. 	<p>In the Journal:</p> <ul style="list-style-type: none"> • Data is collected from 2 NEEDS prototypes, tested 3 times each, and documented with detailed diagrams. • Multiple failure points and/or design improvements based on test data/observations are clearly documented. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> • Students analyze and synthesize data to justify design attributes. • Students make three or more iterations. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> • Research a real-world project that used data to modify solutions (Consider NASA, Solar City, or Tesla projects)



	Below Standard	Approaching Standard	Meeting Standard	Above Standard
Energy & Matter (CCC 5 ES) Energy can be transferred in various ways and between objects .	<i>Areas that individual students may need one-on-one support with:</i> <ul style="list-style-type: none"> Identifying types of energy. Identifying ways that energy is transferred between objects. 	In the Manufacturing Request: <ul style="list-style-type: none"> Students identify some points of transfer accurately but some points of energy transfer may not be accurate. 	In the Manufacturing Request: <ul style="list-style-type: none"> Student accurately explains how energy is transferred through the NEEDS to the load. 	<i>Areas where students may exceed:</i> <ul style="list-style-type: none"> Includes ways that energy is transferred out of the system (e.g friction, sound) <i>Ideas for next steps for growth:</i> <ul style="list-style-type: none"> Create a model of how energy is transferred between objects in their lives. Consider possible projects on devices like: household appliances, sports, or a musical instrument.

Rubric – Save the Hiker [6-8th Grade]

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
<p>Next Generation Science Standard 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.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Distinguishing potential and kinetic energy Effect forces have on a load traveling between elevations. What transfer of energy means 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> Design and build a Non-Electric Emergency Delivery System (NEEDS) that demonstrates a transfer of energy from one object to another. Student can partially explain (or only identify one place) where kinetic energy is transferred to or from objects observed in their investigations. 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> Design, build and diagram a Non-Electric Emergency Delivery System (NEEDS) that demonstrates a transfer of energy from one object to another. Student will support a claim about how kinetic energy is transferred to or from objects in at least 2 specific places in their device. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Addressing the heat and sound as transfers of energy. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Predict or plan for a different load.
<p>Planning and Carrying Out Investigations (SEP 3 MS) Collect data about the performance of a proposed object, tool, process or system under a range of conditions.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Identifying failure points. Collecting data. Scientific journals. 	<p>In the Journal:</p> <ul style="list-style-type: none"> 1 solution tested and documented (data). Failure points and/or design improvements are not clearly documented or design improvements are not based on test data/observations. Solution's alignment with criteria and constraints is incomplete. 	<p>In the Journal:</p> <ul style="list-style-type: none"> Data is collected from solutions tested 3 times each and documented with detailed diagrams. Multiple failure points and/or design improvements based on test data/observations are clearly documented. Solution's alignment with criteria and constraints is clearly documented. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Journal includes drawings/ sketches of proposed (future) iterations. <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Encourage students to reflect on their individual and group investigative process.
<p>Energy and Matter (CCC 5 MS) The transfer of energy can be tracked as energy flows through a designed or natural system.</p>	<p><i>Areas that individual students may need one-on-one support with:</i></p> <ul style="list-style-type: none"> Identifying energy transfer Identifying solutions Identifying a system 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> Evidence of energy transfer is partially identified in the process and/or the solution to the problem. Students can distinguish where energy is transferred within most of the system. 	<p>In the Manufacturing Request:</p> <ul style="list-style-type: none"> Energy transfer is correctly identified in the proposed solution to the problem. Students can distinguish where energy is transferred within the system. 	<p><i>Areas where students may exceed:</i></p> <ul style="list-style-type: none"> Includes ways that energy is transferred out of the system (e.g friction, sound). <p><i>Ideas for next steps for growth:</i></p> <ul style="list-style-type: none"> Encourage students to identify how energy transfer outside of the system might impact the function of the device and transfer of the load (ex: wind).