NEXT ENGINEERS

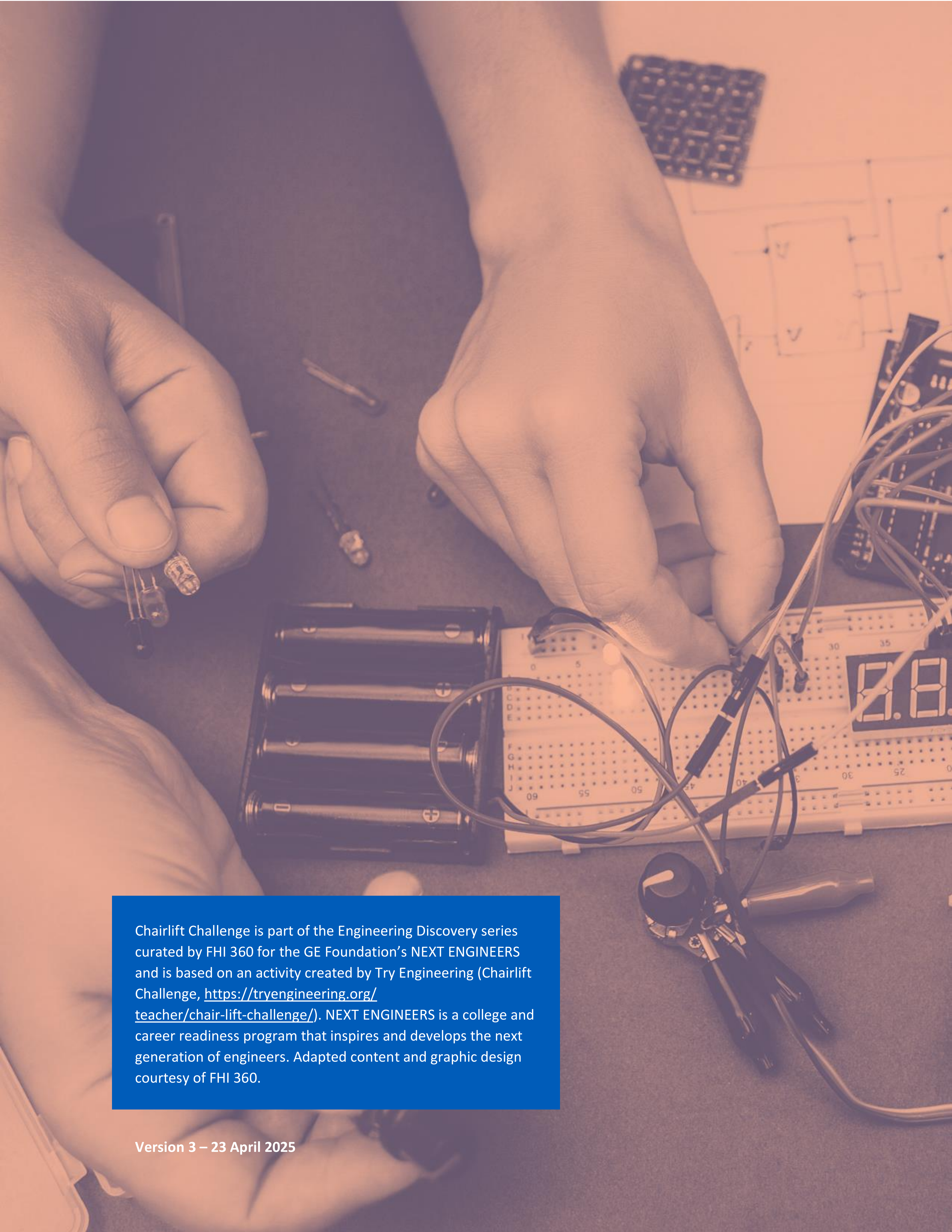
ENGINEERING DISCOVERY

Difficulty Level 1

Chairlift Challenge

Transportation Engineering
Civil Engineering
Mechanical Engineering

NEXT ENGINEERS



Chairlift Challenge is part of the Engineering Discovery series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS and is based on an activity created by Try Engineering (Chairlift Challenge, https://tryengineering.org/teacher/chair-lift-challenge/). NEXT ENGINEERS is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

Version 3 – 23 April 2025

Chairlift Challenge

HANDS-ON ACTIVITY

Time	Ages	Cost	Group size (teams)	Activity type
60 minutes	8 - 15	Low	3 - 4 students	Hands-on Activity

Engineering Areas	
• Transportation Engineering • Mechanical Engineering	• Civil Engineering

Activity Description

This activity focuses on transportation engineering and devising solutions to problems such as transporting skiers or hikers safely to the top of a mountain or moving people around congested urban centers. Students will work in teams to design a 'chairlift' out of everyday items that can transport a ping pong ball in a chair of their own design from the bottom of a 'valley' to the top of a 'mountain' and back again along a wire without the ball falling out.

About the Engineering Design Challenge

Students design and construct a model chairlift out of everyday materials. The chairlift must carry a ping pong ball up a line from the 'valley' to the top of the 'mountain' and back down again without the ball falling out of the chair. The one-way distance to be travelled should be at least 1.5 m (5 ft).

Success Criteria

- The chairlift must carry the ball up a line and back down without the ball falling out of the chair.
- The total distance travelled must be at least 3 m (10 ft).
- The total journey may not take longer than 30 s.

Constraints

- The chairlift may only be controlled and operated from one end.
- Students may only use the materials provided, however, teams can trade unused materials.
- Teams must compete the challenge in the time provided.

STUDENT DISCOVERIES

Students will:

- Know more about engineering and engineering careers
- Learn the about the Engineering Design Process
- Participate in a team-based learning experience
- Learn about people transportation systems
- Have fun experiencing engineering

Materials

Students will need blank paper and pens/pencils to draw their designs.

The following materials will be required **per team** for this activity:

- 1 ping pong ball (or similarly sized small, light object)
- 10 m (33 ft) of string
- A pair of scissors
- Masking tape
- 1 copy of the Engineering Design Process Summary (below)
- 1 copy of the Student Worksheet (below)

The following materials will be required for the materials table for the **whole group:**

- About 60 pipe cleaners (or easily bendable wire)
- About 60 straws
- About 30 popsicle sticks
- About 30 paper cups
- About 30 paper towel tubes
- About 100 paper clips
- About 20 balloons
- About 20 A4 or letter sized sheets of aluminium foil

The following additional materials are required for **testing** the chairlifts:

- Desks and/or chairs (to create the 'mountain')
- A timer (the app on your mobile device will work well)

KEY WORDS

- Ropeway
- Constraints
- Criteria
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Iteration
- Prototype

Facilitation Principles

Working with Youth: Facilitation Tips (https://www.nextengineers.org/resource/working-youth-facilitation-tips) is a handy summary of the key facilitation principles that volunteers need to keep in mind when facilitating any activity with students.

Facilitator Preparation

1. Read the step-by-step instructions.
2. Collect the materials.
3. Practice doing the activity yourself to identify where students may struggle.
4. Plan when and how you will share your story and career journey in a relevant and personal way. Try to integrate your story into the demonstration as much as possible. You can find the following volunteer resources for how to tell your story on the Next Engineers website:
    a. **I'm an Engineer! Storytelling Worksheet** (https://www.nextengineers.org/resource/im-engineer-storytelling-worksheet)
    b. **I Work with Great Engineers! Storytelling Worksheet** (https://www.nextengineers.org/resource/i-work-great-engineers-storytelling-worksheet)

5. Practice asking and answering questions students may ask. See **Frequently Asked Student Questions** (https://www.nextengineers.org/resource/frequently-asked-student-questions).
6. Print out copies of the Student Worksheet for each group.
7. Set up each group's materials before the start of the activity.

Step-by-Step Instructions

Time	Instructions	Materials
2 min	**Welcome & Introductions** • Welcome students to the activity and briefly introduce yourself, noting what kind of engineer you are. • Briefly describe what a chairlift is using the information contained in the **Activity Background** section.	Activity Background
3 min	**Pre-Challenge Exploration** • Ask students if they have been in a chairlift, ski lift, or similar kind of aerial transportation system. What was the experience like? • Ask students what challenges they think are involved in designing and building such systems. Think about distance, topology, speed and safety. • Ask students where they think chairlift systems could be useful in moving people or goods around in their own communities.	Activity Background
2 min	**Challenge Overview** • Give students their engineering design challenge and show them the materials that they will have to work with. • Briefly describe the engineering design process that teams will follow using the Engineering Design Process Summary.	Engineering Design Process Summary
45 min	**Engineering Design Challenge** • Divide the group into teams of three or four and hand each team their materials. Tell them that they will only be able to access materials from the central store after they have produced a sketch of their system indicating which materials they need. After this time, they can trade and swap materials with other teams. • Have students work through the engineering design process to design, build, and test their chairlifts.	Building Materials Student Worksheet Testing Materials

TIPS FOR WORKING WITH STUDENTS

- **Be prepared** by practicing the activity beforehand. Being prepared is the best start to leading confidently and having fun.
- **Facilitate like an engineer** by reflecting during and after each session. What worked? What could be improved? How could you do things differently next time?
- **Teamwork is critical** in engineering so encourage it among students. Make sure no one dominates and everyone gets to play.
- **Give one instruction at a time** to keep a large group on task and doing what you need them to do.
- **Give regular time updates** to keep students on track.

	• Assist teams with timekeeping by announcing when they should move on to each part of the Student Worksheet.
	  ○ Research and planning – 3 min
	  ○ Design – 7 min
	  ○ Build it! Test! – 35 min
	• While teams are working, set up the test site. Make sure that there is some elevation between the start and end points and that they are at least 1.5 m (5 feet) apart.
	• While teams work, circulate and ask students what they have discovered. Where you see teams struggling, suggest some approaches they might not have thought of, but remember not to tell them what to do. The process of learning through failure is valuable.
	• As teams are ready, invite them to come and test their chairlifts. If the test fails, remind teams to fail productively by asking themselves what they can improve on.	

8 min	**Reflection and Closing** • Ask teams to answer the reflection questions at the end of their Student Worksheets. • After about 5 min, bring the groups together again to discuss their answers to these reflection questions.	Student Worksheet

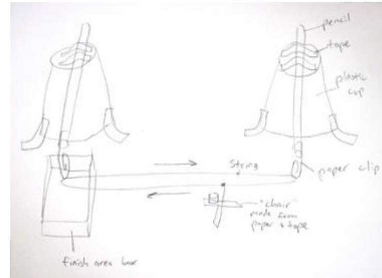
Extension

This activity can be extended in the following ways:

- Substitute the ping pong ball with a heavier and/or larger object.
- Design a system that has two seats able to carry two balls at once.
- Design a system that has one seat going up while another seat comes down.
- Increase the distance over which the chairlift needs to operate.
- Reduce the time permitted for the return journey.
- Require the object to be automatically ejected at some point in the journey.

Key Words

- **Ropeway:** An aerial cable moved by a stationary engine and used to transport goods or people. The ends of the cable are almost always joined to form a continuous loop.



An example sketch for a chairlift design by Science Buddies is used under fair use https://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p100/physics/ski-lift-legos

TIPS FOR MAKING CONNECTIONS

- **Give constructive feedback** to help students grow and improve.
- **Ask open-ended questions** to better understand what and how students are thinking.
- **Be respectful** by listening actively and responding openly and authentically. Give students your undivided attention and the respect you want them to give you.
- **Be honest** about what you know. Say if you don't know something. Encourage students to keep trying by sharing some of your own failures and the lessons you learned.

- **Constraints:** Limitations of materials, time, budget, size of team, etc.
- **Criteria:** Conditions that the design must satisfy to be considered successful.
- **Engineering Design Process (EDP):** The iterative process of researching, designing, prototyping, and testing engineers use to solve problems and design solutions.
- **Engineering Habits of Mind (EHM):** Six unique ways that engineers think.
- **Engineers:** Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (have a look at the infographic at https://tryengineering.org/wp-content/uploads/18-EA-381-InfographicEngineering_R2-6.pdf).
- **Iteration:** The process of repeated design, testing, and redesign.
- **Prototype:** A working model of the solution to be tested.

An example of a chairlift by Science Buddies is used under fair use https://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p100/physics/ski-lift-legos

Activity Background

A chairlift (or aerial lift) is an elevated passenger ropeway which consists of a continuously circulating steel cable loop strung between two end terminals and usually supported by intermediate towers which carries a series of chairs. They are used extensively in ski areas but are found at amusement parks as well as in some densely populated urban centers. Depending on carrier size and loading efficiency, a passenger ropeway can move up to 4,000 people per hour, and the swiftest lifts achieve operating speeds of up to 12 m/s (43.2 km/h or 26.8 mph).

"Sierra Nevada Laguna skilift 3" by kallerna is licenced under CC-BY-SA https://commons.wikimedia.org/wiki/File:Sierra_Nevada_Laguna_skilift_3.jpg

Over 600 years ago, aerial systems were used in China to help move people and goods over streams. During the 1800s, the technology was improved by the mining industry to assist in the transport of minerals over difficult terrain. Chairlifts are an increasingly popular means of transportation in urban environments where ground space is at a premium.

Safety is always a concern on chairlifts, which is why engineers have incorporated many safety features into them, including lift bars (which provide the passenger with a horizontal bar to hold onto) and locking devices so the cable cannot move backwards.

The mechanism at the top of a chairlift allows for the steel rope to wind horizontally, returning empty chairs down a mountain.

"Linea Verde" by Prensa Palacio Bolivia is used under fair use https://www.flickr.com/photos/presidenciabolivia/15921672856/in/set-72157649199592288

Additional Resources

- ***Arial People Movers***
  http://aerialpeoplemovers.com/
- ***Garaventa***
  http://www.doppelmayr.com
- ***How seats are heated on Okemo's Sunburst Six orange-tilted bubble chairlift*** (2:58)
  https://youtu.be/orwm0r0Yh-0
- ***Behind the Scenes - How Detachable Ski Lifts Work*** (5:28)
  https://youtu.be/589uRMy4Ty4

References

This activity is based on **Chairlift Challenge** originally created by **Try Engineering** and available at https://tryengineering.org/teacher/chair-lift-challenge/.

Visit the **Try Engineering** (https://tryengineering.org/) website for a host of other great engineering activities and resources.

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TRY Engineering

Chairlift Challenge

STUDENT WORKSHEET

NOTES

Challenge Overview

You are part of a team of engineers who have been given the challenge of building a chairlift to carry a ping pong ball up the mountain (from the floor of your classroom to the top of a desk or chair), a distance of at least 3 m, (10 feet) using materials provided to you. Your lift must both carry the ball up the mountain and back down without the ball falling out.

Success Criteria

- Your chairlift must carry the ball up a line and back down without the ball falling out of the chair.
- The total distance travelled must be at least 3 m (10 ft).
- The total journey may not take longer than 30 s.

Constraints

- Your chairlift may only be controlled and operated from one end.
- You may only use the materials provided. Unused materials may be shared or traded with other teams.

Total Time: 45 minutes

Research & Planning (3 minutes)

Think about the kind of people that might benefit most from this kind of transportation system.

- Where do they live?
- What shape and size does the chairlift need to be?
- What safety concerns might people riding the lift have?
- What materials might work best?

Design Phase (7 minutes)

Before you start building anything, share ideas about how you might design your system.

- How will you keep your ping pong ball safe and secure?
- How will you control and operate your chairlift?
- How will the string slide?
- How will you secure your chair to the ropeway?

The more ideas, the better. Remember crazy ideas are welcome. In fact, they are often the launchpad to the winning idea.

There are a number of different materials available to you with which to design and build your system. Which ones do you think will work best for different parts of your system? Why?

Remember, that you will only be able to access these materials once you have drawn a sketch of your design which notes which of the materials you intend to use.

Also remember that, as you keep going to can swop and trade materials with other teams.

Build it! Test it! (35 minutes)

Now, build your chairlift and test it. Be sure to watch what other teams are doing and consider the aspects of different designs that might be an improvement on your team's plan.

You may decide to completely change your design during the build process. If so, you may also ask for additional materials or try different solutions as you build. You may also share or trade unused building materials with other teams.

When you are ready to test your chairlift, bring your prototype to the facilitator.

Reflection

As a team, discuss the following questions:

1. How similar was your original design to the actual chairlift your team built?
2. If you found you needed to make changes during the build phase, why did your team decide to make these changes?
3. Was your chairlift able to carry the ping pong ball up and down the mountain without it falling out of the chair you designed?
4. Which chairlift system that another team developed was the most effective or interesting to you? Why?
5. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?
6. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

AT HOME

When you get home today, why not tell your family about the chairlift that you designed and operated? Tell them about how you worked in a team to design, build, and test your chairlift and what you learned about engineering.

After telling your family about today's activity, tell them what you liked/didn't like about it and what you would change or add to the activity.

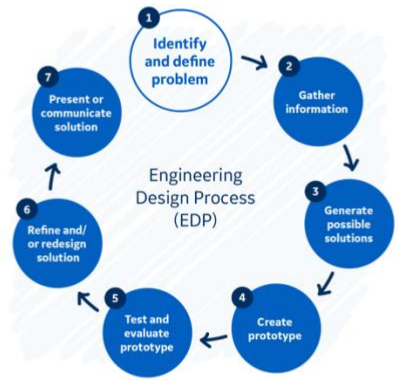
If you like, you can also discuss some of the reflection questions with them.

The Engineering Design Process

STUDENT HANDOUT

The engineering design process (EDP[1]) is the key process engineers follow when they solve problems and design solutions.

1. Identify and define the problem



Engineers start by asking lots of questions. What problem must be solved? Who has the problem? What do we want to accomplish? What are the project requirements? What are the limitations? What is the goal? Through this process, engineers start to identify the **criteria** (the conditions the solution must satisfy to be considered successful) and the **constraints** (the limitations they need to design within).

2. Gather information

Engineers dig deep into the problem by collecting **information and data** about the problem and any existing solutions that might be adaptable. They talk to people from many different backgrounds and specialties to assist with this research.

3. Generate possible solutions

Now the fun really starts! Engineers start to **brainstorm** ideas and develop as many solutions as possible, sometimes even crazy ones. This is the time for wild ideas and deferred judgment. It is important to build on the ideas of others while staying focused on the core problem and keeping the criteria and constraints in mind. For example, if there is a budget, can the potential solution be developed within that budget?

4. Create a prototype

Engineers choose one or more of the most promising solutions to **prototype**. A prototype is a working model to be tested.

5. Test and evaluate the prototype

Most prototypes **fail**, but that is good. It tells engineers which ideas they should focus on. Engineers also need to decide if the design really does solve the original problem.

6. Refine and/or redesign the solution

After learning through testing, engineers **redesign and retest** until they have the best solution possible – one that balances the criteria and constraints.

7. Present or communicate the solution

Finally, engineers reach a point where they are satisfied with their solution. It does not need to be perfect, but it should '**satisfice**' - meet the criteria within the constraints. Engineers now communicate their solution to others.

[1] Adapted from https://www.teachengineering.org/design/designprocess

Chairlift Challenge Volunteer Guide

This guide highlights some important information, questions, and principles to help you support teams in this challenge. Start by watching a video that explains some of the *Principles for Supporting Young Engineers* (9:40) and then *An Introduction to the Design Challenges* (6:08). You can also read about some general *facilitation tips* when working with youth.

The design challenge

Chairlifts or gondolas are not just for ski resorts. Under certain conditions, they can form an important and cost-effective part of a public transport system, just like in many Latin American cities. The video *The Surprising Success of Gondola Transit Systems* (23:26) (https://www.youtube.com/watch?v=a5126u88E7E) offers an excellent overview of the topic.

In this challenge, students will work in teams to design a chairlift system out of everyday items that can transport a ping pong ball from the bottom of a 'valley' to the top of a 'mountain,' and back again without the ball falling out.

The criteria and constraints for this challenge are as follows:

- Success criteria
  - The chairlift system must carry the ball up a line and back down without the ball falling out of the chair.
  - The total distance travelled must be at least 3 m (10 ft).
  - The total journey may not take longer than 30 s.
- Constraints
  - The chairlift system may only be controlled and operated from one end.
  - Students may only use the materials provided; however, teams can trade unused materials.
  - Teams must compete the challenge in the time provided.

Possible design solutions

There are two basic parts of the design of the chairlift system – the moving ropeway system and the chair itself.

In order for the ropeway system to be controllable from one end, the ropeway will need to be a closed loop. However, teams will need to decide if they want to design a system where they pull the ropeway in one direction to move the chair up and in the opposite direction to move it down (a simpler design), or whether they will build a system that allows the ropeway to always travel in the same direction (like a real gondola system). They will also need to decide if their system will include one cable that supports and moves the chair, or separate cables to support and move the chair.

FACILITATION NOTE

This challenge is customizable in terms of the distance the chairlift system needs to transport the ball, whether it needs to transport a heavier object, or whether the system requires the transport of more than one object at a time. Check with the facilitator what specific criteria and constraints they have set for the challenge.

FACILITATION NOTE

Remember, you are not here to give answers, but to help students think like engineers! Encourage them to explore, ask questions, reflect, and iterate. Their learning comes from trying, failing, and trying again.

For the chair, teams will need to figure out how to create something that keeps the ball from falling out while moving and that can be attached to the ropeway. Ideally, their chair connection system should include some sort of pivot that allows the chair to remain level irrespective of the gradient of the ropeway.

Key design questions

As teams start to design their bridges, encourage them to draw as detailed sketches as possible. Drawing sketches first will help them share and think through their designs in more detail.

Some key questions to have teams think about include:

1. What will keep the ball from falling out?
2. How will you attach the chair to the line so it can move?
3. What forces will act on the chair as it moves up and down?
4. How will you control and operate your chairlift system from one end?
5. How will you make sure your ropeway (the piece of string) will slide so that your chair moves?
6. How will you secure your chair to the ropeway?
7. What materials do you think will work best for different parts of your chairlift?
8. Have you thought about how the weight of your chair might affect its movement?
9. How are you making sure everyone's ideas are included in your plan?

FACILITATION NOTE

Many teams are likely going to jump straight into building. Encourage them to pause and think first. They should think about what it is they need to accomplish and what materials they have available. Explain that engineers always think on paper first and use these sketches to share and discuss their design ideas with others.. this helps them come up with the best ideas possible.

Key testing questions

Encourage teams to test early and often. They should experiment with different ways of attaching their chair to the ropeway (their string) to make sure it is secure and stable. They can gently shake the ropeway to mimic the movement the chair may experience while moving.

It is very likely that teams will encourage repeated failure in this process. Remind them that failure is a necessary part of learning what works, and all great engineers fail all the time.

Challenge teams that meet the basic criteria to go further and to build a system that can transport the ball further than 3 m (10 ft), or that can even transport multiple balls at a time (in one or more chairs).

Here are some questions you can ask to steer teams through the testing and redesign phase:

1. What part of your design is working well so far? Can you improve on it even more?
2. What part is giving you the most trouble? How can you address the problems?
3. Is your chair staying balanced on the line?
4. What's happening when you test your lift? Why do you think that is?
5. If your ball falls out, what changes could make the chair more secure?
6. How might you simplify or strengthen your design?