FIRST® Robotics Engineering Explorations

Teacher Guide — Welcome to *FIRST*®

Unit 1

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Activity 1: Robotics Engineering Explorations

Driving Questions

- How do we prepare for *FIRST*® competitions using robots?
- What are the Core Values and philosophies of *FIRST*?
- Why are we working in teams?

Objectives

- Teams will be introduced to *FIRST* through videos from the *FIRST* YouTube channel.
- Teams will learn about the six Core Values of *FIRST*.
- Teams will be introduced to the concepts of *Gracious Professionalism*® and *Coopertition*®.
- Teams will practice teamwork by completing engineering design tasks as a group.
- Teams will discuss the importance of teamwork in their team and 21st-century workplaces.

Materials

Each team will need:

- Engineering Notebooks
- Sandwich-size bag (can be filled with random items)
- Tape
- String
- Paper
- Objects and weights

Getting Started

BEFORE THE START OF CLASS:

- Place these posters around the room:
  - Core Values
  - Engineering Design Process
  - Inquiry Thinking
- Sort students into teams:
  - Teams should have about four students. Students will be in this team for the whole course.
  - Try to pair students who have solid skill sets with students who are developing their abilities.
  - All groups should be made up of a diverse range of students of different ethnicities, ages, genders, ability levels, and socioeconomic backgrounds.
  - If a team is unable to work together, be prepared to move students to different teams.
- Ensure you can play YouTube videos on your school network.
- Ensure students have a notebook to use as their Engineering Notebook. The notebook can be an online shared document or a physical notebook they use to document, share, and collaborate with their team.
- Prepare the resealable bag and tape, string, and paper for each team in Task 1.
- Clear an area so that bags can be placed a few feet away from each team.
- In Task 1, teams will be working to retrieve the bag while they are “stranded” on a desert island. Create an area with clearly defined boundaries for each team to work within.
- Prepare some paper and tape for teams to build tables in Task 3. They will be testing their tables with weights or other objects.

DURING CLASS:

- Get students into their teams and distribute Engineering Notebooks.
- Play the "*Gracious Professionalism* with Woodie Flowers" video.
- Present the *FIRST* philosophies of *Gracious Professionalism* and *Coopertition*.
- Ask teams what *Gracious Professionalism* means and why it is an essential aspect of *FIRST*.
- Play the "About *FIRST*" video.
- Ask teams what *Coopertition* means and why it is an essential aspect of *FIRST*.
- Introduce the six Core Values of *FIRST* to the class:
  - **Discovery**: We explore new skills and ideas.
  - **Innovation**: We use creativity and persistence to solve problems.
  - **Impact**: We apply what we learn to improve our world.
  - **Inclusion**: We respect each other and embrace our differences.
  - **Teamwork**: We are stronger when we work together.
  - **Fun**: We enjoy and celebrate what we do!
- Give teams time to think of examples of 21st-century workplaces where teamwork is essential (professional kitchens, manufacturing centers, design companies, and others).

Student Tasks

TASK 1: DESERT ISLAND DILEMMA

Identify the Problem:

- Teams work together and utilize the Core Values to solve a problem. Each team must remain in a set area. Using simple materials including tape, paper, string, or any other items they find around the room, they must retrieve the bag that has been set out for them.

Design and Prototype:

- As teams create a plan for retrieving their bag, ask them to try to use the *FIRST* Core Values.
- Prompt students with the following questions while they try to retrieve their bag:
  - Could your team complete the task with fewer team members?
  - Would the task be easier to complete with more team members?
  - How did your team decide on what method to use to retrieve the bag?
  - What was each team member's role in this task?
  - What was the most challenging aspect of this task?
  - Did your team use *Coopertition* while you worked toward a solution?

TASK 2: LINK TO THE FUTURE

Brainstorm and Explore:

- Teams apply what they have learned about teamwork to a 21st-century workplace. Teams think about the number of people involved in the car manufacturing process from start to finish and how those people would use teamwork to complete the process.
- Students should answer the following questions in their Engineering Notebooks:
  - How many people are involved in creating a new car from start to finish?
  - What would the first step be?
  - How many people would be involved in that first step?
  - How many steps are there between having an idea for a new car and having that car ready for sale?
  - What other sorts of 21st-century workplaces would use teamwork?
- If students struggle to think of different workplaces where teamwork is used, ask them to think about some of the following fields: video game design, aviation design, journalism, writing, or music.
- When students have identified some workplaces where teamwork would be essential, ask them if those same workplaces would value *Gracious Professionalism* and/or *Coopertition*.

TASK 3: THE IMPORTANCE OF SUPPORT

Design and Prototype:

- Ask teams if they think the engineers who designed the table(s) around the room used teamwork.
- To apply the concepts of teamwork, teams work together to build a table using only paper and tape. Teams should be open to working with other teams to brainstorm ideas or work through problems while competing to build a better table. The table should be able to support as much weight as possible.

Test and Improve:

- Provide each team with some paper and tape to build their table. Remind all teams that every team member should contribute to the construction of the table. Every member of each team should have an opportunity to share their ideas.
  - In their Engineering Notebooks, students should record:
    - Each team member's role in designing and building their table.
    - A sketch of the final design of their table.
    - How much weight their table was able to support.

Suggested Extensions/Modifications

- Extension – Move teams to a hallway for Task 1. Moving an object a greater distance will require a higher level of teamwork.
- Extension – Ask teams to explain why cooperation and teamwork are essential for a 21st-century workplace other than a car manufacturer.
- Modification – If a team struggles to work together, ask them to think about why that is and what they can do to fix the problem.
- Modification – If a team struggles to identify the importance of teamwork and cooperation in car manufacturing, give them some time to research the automotive industry for ideas.

Guiding Questions

- How are workplace skills changing?
- What are some ways that you use teamwork in your everyday lives?
- Why do you think *FIRST* created a list of Core Values?
- What does *Gracious Professionalism* mean to you?
- Why might *Coopertition* be important in 21st-century workplaces?

Teacher Reflection Questions

- Were my students able to recognize the importance of *FIRST* Core Values?
- Do my students understand the concept of *Gracious Professionalism*?
- Do my students understand the concept of *Coopertition*?
- What skills do students need for today's workforce?
- Were teammates able to cooperate?
- Are my students recording data in their Engineering Notebooks?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- The six *FIRST* Core Values, *Gracious Professionalism*, and *Coopertition*.
- Responses to the questions in Task 2.
- Every team member's role in Task 3, a sketch of their table, and how much weight the table could support.

Checkpoint

- Have students explain *FIRST* Core Values and philosophies.
- Check for documentation of all responses to questions in Task 2.

Activity 2: Engineers Rock

Driving Questions

- What are engineers? What do they do? How do they do it? Why are they important?
- What is the purpose of an Engineering Notebook?
- How can we use the Engineering Design Process to solve a problem?

Objectives

- Teams will learn about different types of engineers, products made by engineers, and the importance of engineers in the 21st century.
- Teams will learn how to use Engineering Notebooks and why they are essential.
- Teams will learn about the steps of the Engineering Design Process and its purpose.
- Teams will use the Engineering Design Process to create a zip line that moves a ball from one place to another.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- Sets of materials for building a zip line (There should be enough sets for teams to work into pairs.)
  - 1 Ping-Pong ball
  - 5-10 assorted paper clips
  - Fishing line (10 feet)
  - Tape
  - 4-6 plastic straws
  - 1-6 paper cups
  - 4-6 pipe cleaners
  - 4-6 marbles

Getting Started

BEFORE THE START OF CLASS:

- Print some examples of pages from an actual Engineering Notebook or have them ready to distribute digitally.
- Gather the set of items each team will need for their zip line.

DURING CLASS:

- Introduce Dean Kamen as an example of an engineer and note that he is the founder of *FIRST*.
- Show the "What is Engineering" video from the National Science Foundation News to introduce different sorts of engineers and their purpose.
- Show the "Meet Dean Kamen, inventor extraordinaire" video by CBS Sunday Morning, where Kamen discusses innovation.
- Provide examples of Engineering Notebooks.

Student Tasks

TASK 1: A NOTEBOOK OF YOUR OWN

Identify the Problem:

- Teams are introduced to the purpose of Engineering Notebooks, which are for:
  - Keeping a record of design ideas.
  - Keeping track of problems with designs and their solutions.
  - Noting ideas for future design ideas.
- Teams learn that the shape and format of the pages in their Engineering Notebook can vary based on what they are recording.

Design and Prototype:

- Distribute examples of real-world Engineering Notebook pages to the teams.
- Teams investigate examples of Engineering Notebooks and record their thoughts in their own notebooks.
- Teams should consider all team members' ideas while recording information in their Engineering Notebooks.

TASK 2: FIND A PROBLEM, DESIGN A SOLUTION

Identify the Problem:

- Teams are introduced to the steps of the Engineering Design Process. Some of the steps are directly tied to the *FIRST* Core Values. Encourage teams to think about how *FIRST* Core Values could be integrated into all the steps in the Engineering Design Process.

Identify the Problem

- Before you can create things to help a community, you need to understand the community you are working to improve. (Inclusion)
- Not everyone sees the world in the same way. To create meaningful change, it is essential to remember that everyone's experience is different. (Discovery)
- If you want to learn, asking questions is the best way to start.
- Try viewing a problem from a different perspective. (Discovery)
- Who does the problem affect? How does it affect them? Where and when does the problem take place? Why is the problem occurring?

Brainstorm and Explore

- Finding the perfect solution for a problem rarely happens right away. The more ideas you can generate, the more material you have to pull from to create a solution. (Innovation)
- Think about all the people affected by the problem you are focused on. How would they approach the issue? (Inclusion)
- Use your imagination; inspire your team to go beyond obvious solutions. (Teamwork)

Design and Prototype

- Take your team's ideas and turn them into something you can touch. You don't have to build a perfect robot immediately; you may want to draw an outline or write a storyboard.
- Don't try to build the perfect solution right away; start small.
- When you've created something you think would help address the issue, build multiple copies to keep improving your work.

Test and Improve

- Put what you've built into the community you are working with.
- Test what you've built to learn more about the problem you are trying to solve and improve your design.
- You might find that what you've built doesn't solve the problem like you wanted. Learning from failures is an essential part of the Engineering Design Process, and it's an opportunity to improve your design further.

Brainstorm and Explore:

- Teams brainstorm some examples of classroom problems that they could solve using the Engineering Design Process.

Real-World Connections

In the real world, civil engineers do what you are going to do every day. They are responsible for designing and building the roads and bridges you travel on every day. Civil engineers often work closely with structural engineers to ensure bridges, tunnels, and roads are as safe and strong as they can be. Emily Warren Roebling was responsible for guiding, planning, and managing the construction of a structure used by millions of people. What was her contribution? The Brooklyn Bridge!

TASK 3: ZIP, ZAP, ZOP

Identify the Problem:

- Teams divide themselves into pairs or groups of three for this task.
- Each group designs and builds a basket carrying a Ping-Pong ball from the top of a zip line to the bottom.
- Constraints:
  - It must take 3 seconds or less for the basket to travel from the top to bottom.
  - The zip line must be at least 6 inches long.
  - Only tape, straws, lightweight cardboard (the back of your notebook, for instance), fishing line, marbles, pipe cleaners, and paper cups may be used to build the basket.

Brainstorm and Explore:

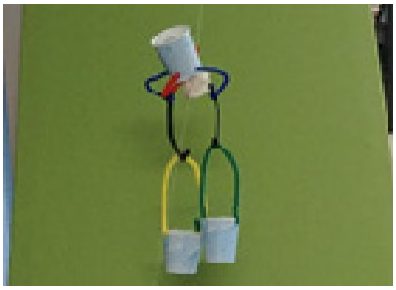
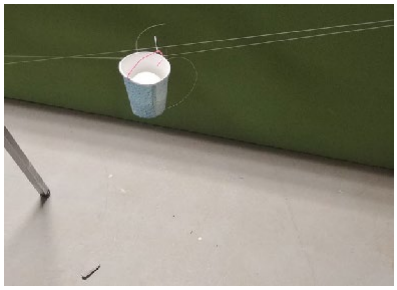
- Students will brainstorm to explore how their materials might go together.

Design and Prototype:

- Teams have been divided into smaller groups, so all students should be part of designing and constructing a zip line.
- Teams should keep the *FIRST* Core Values and philosophies in mind while working. They are trying to build the best zip line, but that doesn't mean they can't help other groups.

Test and Improve:

- After teams have built their zip line, they attempt to change their design to move more slowly, move more than one ball, and launch a ball out of the basket.
- After the design and build components of the task, teams reflect on the experience and record in their Engineering Notebook:
  - What they found most challenging about the activity.
  - Any aspect of the task they were unable to complete.
  - How they dealt with the challenges they faced during the design process.
  - A sketch of their final design with the materials they used clearly labeled.
- These are some examples of zip lines the students could design:


Guiding Questions

- Why do you think engineers are important?
- What kinds of engineers designed the materials around the classroom/school?
- Why do you think Engineering Notebooks are important to real-world engineers?
- What do you think the purpose of the Engineering Design Process is?
- Which steps of the Engineering Design Process do you think are the most important? Which are the most difficult?

Suggested Extensions/Modifications

- Extension – Ask teams to think about their commute to school. What engineering projects do they see on their commute? What types of engineers would be responsible for those projects?
- Extension – Ask teams what information different types of engineers would record in their Engineering Notebooks. Why would different engineers record different types of information?
- Modification – Provide as many examples of Engineering Notebooks as possible. Giving teams context for using their Engineering Notebooks will inspire them to think about what information they should be recording and why.

- Modification – If teams are having trouble designing or building their zip line, pair them with another team so they can work together.

Teacher Reflection Questions

- Were my students engaged in the discussion about types of engineers?
- Did my students find the information in the Getting Started section of the activity interesting?
- Were team members able to work together during Tasks 1 and 2?
- Were teams able to split into smaller groups to complete Task 3?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- A few examples of the different types of engineers, their purpose, the projects they work on, and what they might use their Engineering Notebooks for.
- How engineers could use *FIRST* Core Values to improve the products that engineers design.
- The four steps of the Engineering Design Process.
- The classroom problem to which they have decided to apply the Engineering Design Process and how they used the first two steps to find solutions.
- A sketch of the final design of their zip line clearly labeled with its materials.
- A reflection on the process of designing a zip line.

Checkpoint

- Have teams explain the purpose of engineers and some of the fields they work in.
- Ask teams to explain the practical applications of an Engineering Notebook.
- Have teams explain the four steps of the Engineering Design Process and the purpose of the process.
- Check for documentation of critical takeaways in their Engineering Notebooks.

Activity 3: Problems and Innovation

Driving Questions

- Why is identifying a problem an important part of the Engineering Design Process?
- What are some problems our community has faced in the past, and how were they solved?
- What is a problem our community is currently facing?

Objectives

- Teams will learn about fundamental innovations that have changed the world.
- Teams research their community to identify a problem it faces today.
- Teams research their community to learn about its past problems and any innovations that led it to where it is today.
- Teams pick one issue their community is currently facing and work to define it in as much detail as possible.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- Resources about your local community:
  - Newspaper articles
  - People/experts from your community (in person or virtual)
  - Historic/demographic information about your community
  - Information on local government/institutions responsible for caring for the community

Getting Started

BEFORE THE START OF CLASS:

- Consider and gather materials you could provide your students that would help them research problems their community has faced in the past.
- Consider and gather materials you could provide your students that would help them research problems their community is currently facing.
- The more resources you have available for students, the more context they will have for identifying a community problem. They should be able to relate the community problems to the Engineering Design Process and think about how they could impact their community.

DURING CLASS:

- Present students with the Getting Started section of their activity.
  - Discuss how inventions like the wheel came about.
  - Introduce the rationale behind the first step in the Engineering Design Process: Identify the Problem.
- Teams consider other simple innovations used today. They will investigate the nail in Task 1.

Student Tasks

TASK 1: WHO NEEDS NAILS?

Identify the Problem:

- Teams discuss the importance of the nail in construction.
- Like the wheel, the nail is a simple tool that came about as a solution to a problem.
- Have students consider where nails are used in buildings and other materials.

Brainstorm and Explore:

- Teams record their responses in their Engineering Notebooks to these questions:
  - What sort of materials would nails have been first used on?
  - What materials did people need to create nails?
  - What wouldn't we be able to build today without nails?
  - What innovation could be used to join things together if we hadn't created nails?

TASK 2: MODERN PROBLEMS

Identify the Problem:

- Identifying the local community's problem uses the first step of the Engineering Design Process.
- Sometimes, a community's problem might not be obvious, so teams should be prepared to try and search for problems themselves.
- Sometimes, identifying different groups of people living in a community and their needs can help in the search for a problem to solve.

Brainstorm and Explore:

- Using the resources you prepared before class, teams should research their community for a problem they can focus on.
- The problem should be one that they can approach with the Engineering Design Process
- Using the following questions, teams will attempt to focus on a community problem:
  - What are the basic needs for people to survive? Are those needs being met?
  - How do you make sure people feel safe?
  - Are there areas in your community where people struggle more than others? Why?
  - What do people in your community need that other communities might not?
  - Can you separate your community into different groups of people?
  - Is sorting people into different groups a good idea?
  - What are some benefits of sorting people into groups?
  - What are some dangers of sorting people into groups?
  - Are there members of your community that are at more of a disadvantage than others? Why?
  - What are some environmental factors that might be affecting your community?
  - Are green spaces important to your community? Why?
- Teams should continue researching their community problems after they finish the activity. Direct teams to use whatever resources they think would be helpful in their research.

TASK 3: PROBLEMS OF A BYGONE AGE

Identify the Problem:

- After teams have decided on an issue in their community, they should look to the past to see the relationship between problems and innovations.
- Considering a larger community will help ensure that all students in a team feel personally invested in the research.
- The innovations students discover will vary depending on the size, age, and location of the community they are researching.

Brainstorm and Explore:

- Using the resources you prepared before class, teams should research their community's history.
- This research aims to identify innovations that led the community to where it is today.
- Building on what teams learned during Task 2, they should search for problems that led to the integration of innovation in the community.
- Teams use the following questions to guide them in their research:
  - When was your community founded?
  - Why did people decide to settle in your community?
  - Where did the people who first settled in your community come from? How did they get from there to here?
  - How were the first buildings in your community built?
    - Who built them?
    - Why were those specific buildings built first?
- Teams record in their Engineering Notebooks:
  - The questions they focused on while researching the innovations their communities used in the past and the answers to those questions.

- The essential innovations from their community's past and why they are important.

Guiding Questions

- Think about the last activity where you designed a zip line. Did the first step of the Engineering Design Process affect the zip line that you built? How?
- Is your Engineering Notebook an important part of the first step of the Engineering Design Process? Why?
- What sort of problems does the world currently face that people are creating innovations to solve?

Suggested Extensions/Modifications

- Extension – Ask teams to think about more than one problem in their community and compare the problems they've identified.
- Extension – Ask teams to describe the population of their community in as much detail as possible.
- Modification – Pair teams together during the research phase of Tasks 2 and 3.

Teacher Reflection Questions

- Did teams find the information in the Getting Started section of the activity interesting?
- Do teams understand the importance of simple innovations?
- Do teams understand the importance of the first step of the Engineering Design Process?
- Were team members able to work together during the research components of Tasks 2 and 3?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- A list of things people wouldn't be able to build today without nails.
- A list of innovations that could join things together if there were no nails.
- The community problem that teams identified in as much detail as possible.
- The questions and answers they identified for their community problem.
- The groups of people affected by the problem they discovered.
- The questions and answers they asked while searching for innovations important to your community.
- The innovations important in the development of your community.

Checkpoint

- Have teams explain how understanding a community relates to innovation.
- Have teams explain the importance of understanding past innovations when considering community problems.

Activity 4: Solve Your Own Problem

Driving Questions

- Are there robots in our community right now?
- Can we use a robot to solve the community problem we identified?
- What would a robot need to do to solve our community problem?

Objectives

- Teams will think back to the research they performed in the previous activity and consider robots that could have solved problems from their community's past and robots that are currently addressing needs in their community.
- Teams will discuss what their robot would need to do to solve their community problem and use the steps of the Engineering Design Process to design and build a prototype to solve it.
- Teams will create a plan for future iterations that could help them bring their design to life to make an impact in their community.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- Video(s) showing games from past *FIRST* seasons
- Resources to research contemporary robots that are addressing needs in their community
- Materials for prototyping a robot, such as cardboard, toothpicks, rubber bands, tape, and glue

Getting Started

BEFORE THE START OF CLASS:

- Ensure you have game introduction videos from previous seasons prepared for teams. You can play these videos as a way to introduce *FIRST* and how there is a season challenge that the students design robots to solve every year. Two examples:
  - "2023-2024 CENTERSTAGE℠ presented by RTX Game Animation" video from *FIRST* Tech Challenge
  - "2023 *FIRST* Robotics Competition CHARGED UP℠ presented by Haas Game Animation" video from *FIRST* Robotics Competition
- Prepare some research materials so teams can investigate robots used in their community.

DURING CLASS:

- Remind teams to keep essential thoughts and information in their Engineering Notebooks.
- Introduce teams to Gutenberg's printing press as an innovation that improved an invention.
- In the previous activity, teams learned about the relationship between a problem and innovation.
- In this activity, they will discover that innovations can build on innovations from the past.
- Encourage teams to think about innovations their community has used in the past when they begin designing a robot that would solve their community problem.

Student Tasks

TASK 1: WHERE IS THE CLOSEST ROBOT?

Brainstorm and Explore:

- Teams consider innovations being used in their community and the inspiration/innovations that led to their inception.
- Teams have the example of Gutenberg's innovation. Gutenberg's plates with movable text depended on the existence of a printing press.
- Teams relate what they've been discussing and researching to practical robotic applications.
- This task is the first-time teams rely on the quality of their notes in their Engineering Notebooks.
- Teams use the notes in their notebooks to reflect on the use of robotics in their community.

- After looking at their notes, teams discuss the following questions and record their answers in their Engineering Notebooks:
  - Are any problems you discovered in your community solved using a machine?
    - Are the machines automated? What sort of tasks do they perform?
    - Would a person be able to perform the same job?
  - What is the difference between a machine and a robot?
  - If you can't find any robots being used in your community, can you think of how robots could be used in the future?

TASK 2: A ROBOT OF YOUR OWN

Brainstorm and Explore:

- Before they begin working on the design for their robot, teams should look back at their notes in their Engineering Notebook to ensure they are considering all the details they recorded in the previous activity. This is an excellent place to stress the importance of clear and accurate notes.
- Explain to teams that while they researched their community to identify a problem, they also worked through the first two steps of the Engineering Design Process.
- Ask teams to review their notes on the Engineering Design Process to identify what parts of the first two steps they were focusing on and why.

Design and Prototype:

- Working from their notes on their community problem, students will begin the third step in the Engineering Design Process: Design and Prototype.
- Show students the example robots from previous *FIRST* seasons. Research online for examples. Have them use those robots as examples to understand some tasks that robots might do.
- To help guide their thinking, teams break down the requirements of their robot into parts using the following questions:
  - What will the robot have to do to solve the problem? How is it going to perform those tasks? What tools will it need to do them?
  - Will the robot run automatically or be controlled remotely?
- Teams record their ideas and answers to those questions in their Engineering Notebooks, along with a sketch of what they think their robot might look like.

TASK 3: MORE THAN ONE PROBLEM? NO PROBLEM!

Identify the Problem:

- Teams think about instances where a single innovation did more than solve the problem it was initially designed to address. They use Gutenberg's printing press as an example.

Design and Prototype:

- Students answer the following questions in their Engineering Notebooks as they create a model of their community robot:
- How can you create a model or prototype of your community robot to illustrate your design idea to others?
- What other knowledge might you need about robots to develop your prototype further?
- What other knowledge and materials might you need to test your prototype?
- Create a need-to-know list of things you might want to learn.

Guiding Questions

- How could/do robots improve the quality of people's lives in your community?
- How did the research you did in the previous activity address the first two steps in the Engineering Design Process?
- What is an example of an innovation that solved multiple problems?
- What problems did it solve? How did it solve them?

Suggested Extensions/Modifications

- Extension – Show teams *FIRST* Tech Challenge championship games from previous years and ask them to design their robot to compete in one game of their choosing.
- Extension – Ask students to research robots in a different community.
- Modification – Ask teams to work together to search for robots in their community.
- Modification – Provide teams with links to various videos from previous seasons so they can watch them again before they start Task 3.
- Modification – Distribute a copy of some of the one-page game descriptions from previous seasons for teams to review.

Teacher Reflection Questions

- Did my students find the Getting Started activity section engaging/helpful?
- Were my students able to connect this activity and the importance of the first two steps of the Engineering Design Process?
- Do my students understand the importance of understanding the context of a problem before designing a solution?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- Responses to the questions in the Getting Started section of the activity.
- Responses to the questions from Tasks 1-3.

Checkpoint

- Have teams explain how an innovation designed to solve one problem can be used to solve problems the designer might not have thought of at the time.
- Have teams explain why the Engineering Design Process focuses so heavily on the community affected by a problem before a solution is designed.

Activity 5: Help Wanted, Positions Available

Driving Questions

- How do we know if we've successfully used the Engineering Design Process?
- What sorts of skills do we need for big design and engineering projects?
- What professions are needed for big engineering design projects?

Objectives

- Teams will look at an engineering design project and think about the skills needed to complete it.
- Teams will explore ways of measuring the success of a design project.
- Teams will make connections between the skills required in a design project and some trades and professions.
- Teams will apply what they've learned to their community problem.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- Access to the Internet to research a real-world engineering design project and professions

Getting Started

BEFORE THE START OF CLASS:

- Think about what professions are linked to engineering or design projects other than engineering. A few examples would be accountants, project managers, and construction workers.
- Reach out to community members who work in engineering-adjacent roles and invite them to come and speak with the teams (in person or virtually) about their skill sets and how they relate to the Engineering Design Process.
- Having community members available to the teams will help provide context for their community problems. Introducing teams to the various professions and trades involved in the Engineering Design Process beyond engineers will help them as they think about their own future careers.
- If you can bring in community members for the teams to talk to, ensure they will have access to the student tasks so they can follow along with the challenge.

DURING CLASS:

- Teams think about the Engineering Design Process regarding the skills involved and the professions associated with those skills.
- This activity aims to illustrate the range of professions involved in engineering projects. The practical context of various engineering-adjacent occupations can help inspire students to consider their future career choices.
- In this activity, teams discover that building requires teamwork, communication, and organization.
- Teams use complex projects, such as skyscraper construction, to learn how projects need to be broken down into steps and roles. Teams also learn the importance of communication, safety, and organization while working on such projects.

Student Tasks

TASK 1: THE FOUNDATIONS OF A SKYSCRAPER

Identify the Problem:

- Teams think about the work that goes into designing and building a skyscraper in a city's downtown. Their team oversees the entire process from start to finish.
- Teams are told they have funding from some businesses that want to work in the building.
- Teams should break down the entire operation into the steps of the Engineering Design Process before deciding what professionals they would need to recruit for each job.

Brainstorm and Explore:

- Teams are guided through some positions involved in managing a project like building a skyscraper via the following questions, which they should answer in their Engineering Notebooks. Each question directs teams to think about a specific aspect of the project and the corresponding success criteria.
- First, teams investigate the project's financial aspect and learn about the roles of accountants or business managers.
  - How will you manage your money?
    - Who would oversee setting a budget?
    - How will they ensure the project stays on budget?
    - How will they know if they've been successful?
- Then, teams examine a skyscraper's design aspect and learn about an architect's role.
  - How will you decide what the building will look like?
    - Who will design the building?
    - Who will decide on the materials you need for the building?
    - What goals will they try to achieve, and how will they know if they've been successful?
- Finally, students think about how a building is built from the ground up and learn about the role of construction workers.
  - Who is going to construct your building?
    - What different skills are involved in putting a building together?
    - Will the people creating the structure for your building also install the windows and elevators?
    - What goals will the people building your skyscraper try to achieve, and how will they know if they've been successful?

TASK 2: PHASE TWO

Brainstorm and Explore:

- After teams have investigated the construction and funding of their skyscraper, they look inside their building.
- Teams should keep customer needs in mind while they consider their building's layout.
- Encourage teams to be creative when discussing the inside of their building. The content and design of their building are entirely up to them.

Design and Prototype:

- As in Task 1, teams will use the following guiding questions to investigate the professions involved in creating a skyscraper.
- Teams think about the internal structures, such as floors and walls, as well as the aesthetics of the interior. Teams think about contractors and interior designers. They should also consider the professionals needed to ensure their building is functional and contains all necessary utilities such as electricity, water, heating, Internet, and phones
  - Who is going to ensure the inside of your building looks great and meets the needs of the companies moving in? How is it going to perform those tasks?
    - What sort of skills are involved with making a space look nice?
    - Who will install floors, paint walls, and ensure everything is put together?
  - Teams should think about how all the hired professionals would communicate. Teams might think of a role like a project manager to ensure all individuals on the project work as a team.
  - How will you ensure all the people working on your skyscraper are working as a team?
    - Is communication between the various professionals working on your building important? Why?
    - What would happen if the different professionals working on your building were unaware of each other's work?
    - Who will oversee communication between the different groups of people working on your building, and what skills would that person need?
    - What goals would a person in charge of communication need to set? How will they know if they've been successful?
- Remind teams to always consider what makes each job successful. What are their success criteria and how will they ensure each position meets their goals?
- Teams may consider adding a quality assurance professional to their company.

TASK 3: THE RIGHT PERSON FOR THE JOB

Identify the Problem:

- Teams should now have a firm grasp of some skills and professions associated with the Engineering Design Process.
- To apply what they've learned in this activity, students look back in their Engineering Notebooks to find their notes on the Engineering Design Process steps related to their community problem.
- As a team, students discuss the various skills and professions related to the steps outlined in their notes.

Brainstorm and Explore:

- Team members select a role to fill in solving the community problem and building their community robot based on their strengths. Team members should try to support each other as they identify their strengths.

Guiding Questions

- Why is setting goals in a design project important?
- Are any skills more critical than others in the different steps of the Engineering Design Process?
- What skills are most important for each step?
- What professions would match with each step?

Suggested Extensions/Modifications

- Extension – Ask teams to pick two real-world design projects and break them down into the different steps of the Engineering Design Process.
- Extension – Ask students to list a few professions that would be particularly helpful in each step of the Engineering Design Process.
- Extension – Encourage teams to think about the skyscraper project beyond the listed questions to find other examples of professionals they might want to hire to work on the project.
- Modification – Provide teams with an example of a design project, such as the development cycle of a video game, and a list of the different types of professionals that would be involved.
- Modification – If a team struggles with the first two tasks, pair them with another team and ask them to discuss the questions as a group.

Teacher Reflection Questions

- Did my students find the Getting Started portion of the activity engaging?
- Do students understand the importance of establishing success criteria?
- Were my students able to make a connection between the professions they discussed in this activity and the different professions involved in the field of robotics/their community problem?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- The winning conditions from the games they discussed in the Getting Started section of the activity.
- The steps of the Engineering Design Process from the real-world example they chose to investigate in the Getting Started section.
- Their responses to the questions in Tasks 1-3.

Checkpoint

- Have students explain why different skills are needed for the various steps of the Engineering Design Process.
- Have students explain the role of the different professions they identified in this activity.

Activity 6: Safety and the Kit

Driving Questions

- What do we need to know so we can stay safe while working with our robot?
- What will we use to build the robot?
- What is in the robotics kit?

Objectives

- Teams will learn about some of the safety hazards engineers have to be aware of.
- Teams will learn the rules they need to follow to stay safe while working with their robotics kit.
- Teams will open their robotics kit and identify some parts they will work with.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- A robotics kit with an inventory list
- Any safety materials you have for students to work with (such as safety glasses)
- Tape and markers for students to label their robotics kit

Getting Started

BEFORE THE START OF CLASS:

- Identify the closest first aid kit and fire extinguisher to point out to your class while discussing safety.
- Ensure you have a robotics kit for each team. Check the kit to ensure all the materials on the inventory sheet are present.
- Take some time to look at the manufacturer of your kit of parts.
- Share links to the kits so the students can explore the building guides available and know where to find them. For the scavenger hunt, use the following vendor links to help guide you in what you might look for at each program level.
  - *FIRST* Tech Challenge Building Resources and Guides (TETRIX and REV)
  - REV DUO
  - TETRIX *FIRST* Tech Challenge Competition Kit
  - XRP User Guide
  - AndyMark Robits Core Kit
  - AndyMark AM14U6 – 6 Wheel Drop Center Robot Drive Base

DURING CLASS:

- Prompt teams with situations where they would have to think about safety.
  - What would you do if your robot's battery broke open and leaked?
  - What would you do if one of your team members was injured?
- Remind teams about the importance of teamwork. Every team member should be able to work with the different parts of the kit.
- *FIRST* suggests having a student safety captain who has a role in ensuring all team members are working in a safe environment.
- Ask teams to keep their materials as organized as possible. Having a neat kit will reduce the time spent looking for parts.
- At the end of class, ask students to:
  - Plug in their battery using the charger included in the kit.
  - Charge any other batteries needed for the kit in the Drive Station.
- Introduce the Getting Started section of the student activity. Ask students if they know any safety protocols around the school or anywhere else. Have them consider how learning safety protocols might help them in a future career.

Student Tasks

TASK 1: SAFETY SLOGANS

Identify the Problem:

- Teams learn about some of the safety precautions by reviewing the *FIRST* Safety Manual.
- Consider having students use the Jigsaw reading method to share important information from the manual.
- Ask students if they have heard of OSHA or similar systems and where they are used.

Brainstorm and Explore:

- Teams use the safety information from the safety manual discussion to create five safety slogans.
- Teams should watch some entries from previous *FIRST* Robotics Competition Safety Awards and then consider what information was repeated in the student videos and what may have been missing.
- The safety slogans teams create should be short and to the point.
- When all teams have created five slogans, each team will choose a member to share a few of their slogans with the class.

TASK 2: THE KIT

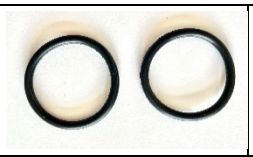
Identify the Problem:

- Teams learn about some of the materials in their robotics kits.
- Assign each team their kit of parts and ensure they have enough space to open their kits and lay out some of the pieces.
- As teams begin looking at the kit's parts, ask them to think about how those parts might be used in a robot.

Brainstorm and Explore:

- Students use a scavenger hunt list to familiarize themselves with some pieces they will use in the coming activities.
- Teams work to complete the scavenger hunt before the other teams while keeping *Coopertition* in mind.
- Ensure teams are mindful of the parts they are taking out of their kit. Anything they take out of the kit should go back in when they are finished.
- Use this chart as a reference to double-check students' scavenger hunt findings.

QUESTION	XRP	*FIRST* TECH CHALLENGE	*FIRST* ROBOTICS COMPETITION
What part that sends and receives electrical signals and acts as the robot's brain?		Control Hub 	roboRIO 
What do gears look like? Draw a picture of one.	N/A		
What components hold other parts together? Draw a picture of one.			
What parts are used to build the structure of your robot?	N/A		
What do the parts that connect structure pieces look like? Draw a picture of one?	None		

What parts in the kit will help the robot move?			
What parts in the kit convert electrical energy from the battery to rotational movement?			

TASK 3: CHECK YOUR KIT

Identify the Problem:

- Teams think about the importance of understanding the materials they have available to them.
- Teams consider some issues that an incomplete set of materials might present.
- Teams learn about the importance of a well-organized kit and the relationship between a complete knowledge of their materials and best safety practices.

Design and Prototype:

- Now that teams have identified some of the kit parts, they go through the inventory list to ensure all the parts listed are present.
- When teams have completed checking their kit against their inventory list, they will refill their kit of parts so the parts are organized in a configuration of their choosing.
- Students should record their method of organization and explain in their Engineering Notebooks how a comprehensive knowledge of their materials will ensure they are working safely.
- Provide teams with masking tape and markers. They should label their parts kit with their team's name and decorate the exterior of the kit with some safety slogans they created in Task 1.

Guiding Questions

- What are some general safety rules for working with the parts in your robotics kits?
- Are there any school safety procedures that you need to be aware of while you work?
- What parts are you expecting to find in your robotics kit?

Suggested Extensions/Modifications

- Extension – Ask teams to think of some safety procedures technicians who work on practical effects for movies would all need to know and have them explain why.
- Extension – Ask teams to create a set of guidelines or a procedure to follow if they find a broken piece in their kit or if a part breaks while they are working with it. Ask them to share their procedures with the class.
- Extension – Ask teams to create their scavenger hunt list while checking their kit against their inventory list.
- Modification – If teams have trouble with safety slogans, ask them to create easy-to-remember safety rules.
- Modification – Ask teams to pair up as they work through the scavenger hunt.
- Modification – Ask teams to share their kit organization method with the rest of the class.

Teacher Reflection Questions

- Were my students engaged with the scenario from the Getting Started section of the activity?
- Do my students understand the importance of following safety rules while working with their kits?
- Were all teams able to complete the scavenger hunt?

Student Artifacts

In their Engineering Notebook, students should have recorded:

- Responses to the questions from the Getting Started section of the activity.
- Their safety slogans.
- Notes on the different parts they identified during the scavenger hunt.
- Their kit organization method and the justifications for that method.
- Some methods for ensuring all team members are safe while working with the kit.

Checkpoint

- Have students explain how safety procedures can affect the Engineering Design Process.
- Have students explain how to ensure their team is safe while building their robot.
- Have students explain the importance of having a well-organized kit of materials.

Activity 7: Ball Game

Driving Questions

- How can we design our own ball game?
- How can we work with another team as an alliance to win a game?
- How can we use the *FIRST* Core Values, *Gracious Professionalism*, and *Coopertition* while we work to win a game?

Objectives

- Teams will individually create a few rules and methods of scoring points in a ball game.
- Teams will share their rules and scoring methods with the class.
- As a class, students will decide on a complete set of rules and scoring methods for the game.
- Teams will use the Engineering Design Process to design a game field with provided materials.
- Teams will present their game design to the class.
- The class will choose a ball game competition to work toward competing in throughout the course.

Materials

Each team will need:

- Engineering Notebooks
- Pens or pencils
- Something that could be used to score in (e.g., basket, bucket, or box)
- Ball (These can be whatever balls you have available and are easy to source in your classroom.)
- Robotics kit
- One-page game description for a game from a previous *FIRST* season
- Any other items you might have that could be obstacles

Getting Started

BEFORE THE START OF CLASS:

- Ensure you have game materials (balls, boxes, and obstacles) for each team to use.
- Provide students with the game animation and one-page game description for the previous year's game.
  - *FIRST* Tech Challenge archived game descriptions
  - *FIRST* Robotics Competition 2023 game description
  - "2023-2024 CENTERSTAGE presented by RTX Game Animation" video from *FIRST* Tech Challenge
  - "2023 *FIRST* Robotics Competition CHARGED UP presented by Haas Game Animation" video from *FIRST* Robotics Competition
- Create any design constraints you want the students to abide by while designing the game, such as:
  - The ball should be picked up and placed in the scoring area instead of thrown. Throwing an object could require a complex design and might be difficult for a first-time robot.
  - The game height should not extend beyond 48 inches high. If the game height is too high, they cannot complete the task with their parts kit.

DURING CLASS:

- Instruct teams to keep all their work in their Engineering Notebooks.
- Explain the basic rules of a *FIRST* competition and distribute a one-page game description from a previous season to teams for context.
  - Teams form alliances and compete together.
  - There are several methods for scoring points.
  - There are autonomous, remote-control, and endgame periods in the game.
- When teams have had time to review some examples of game descriptions and play the video examples prepared before class, remind students to keep the *FIRST* Core Values and philosophies in mind as they work through the activity.
- If there's time, allow teams to form new alliances and compete again after they've played their first game.

Student Tasks

TASK 1: OUR GAME, OUR RULES

Identify the Problem:

- Before teams can begin designing their games, the class needs to agree on a set of rules. Prompt students to think of the first two steps in the Engineering Design Process while they create rules.
- Teams need to work out the rules for the game and methods for scoring points.
- Ensure teams are referencing the one-page game description for a game from a previous season.
- To practice *Gracious Professionalism* and *Coopertition*, teams decide on the game rules as a class.

Brainstorm and Explore:

- Teams should create rules and goals that are clear.
- Teams will consider the following questions when they are discussing ideas for rules and goals:
  - How big should the playing field be?
  - Will the game have a time limit? What should it be?
  - How will you score points?
  - Will you have possibilities different game strategies (offensive and defensive)?
  - Will there be practice rounds before teams compete?
  - What are the penalties for breaking the rules?
  - Who will watch the teams to ensure everyone follows the rules?
- When each team has prepared a few rules and goals, all teams will share their ideas and decide on the game's rules as a class. If the class is having trouble staying on track, suggest that one team shares at a time.
- Hold a vote if teams have difficulties agreeing on rules and goals.
- Ensure the rules the class has agreed on are available for all teams.
- Students should record the outline the class has created in their Engineering Notebooks.

TASK 2 THE COMPETITION FIELD

Design and Prototype:

- All teams now have the rules and goals of the game and are ready to start designing.
- Teams will gather building and game materials and use the Engineering Design Process to design, build, and test their field designs.
- Guide teams with the options you have given them with your supplies available. (The ball is a scoring mechanism, score in the box, avoid the trash can obstacle, and so on.)
- Have students get a ball and determine the field playing area in your classroom. Guide teams to review what materials are available and think about how the components could fit together to form a ball game. This step of the design process is an opportunity for everyone to innovate and be creative with their game options. Use discretion if teams ask to integrate other materials into their ball game.
- Teams should test their ball game by becoming human robots to ensure the game components and rules will work as intended.
  - Students should act out the robot's actions, like moving the ball from one place to another. Consider the timing of an autonomous period, driver-controlled period, and endgame. What are the different scoring options available?
- If teams are frustrated with issues they discover during testing, remind them that the Engineering Design Process aims to identify problems and iterate on their innovative solutions.
- In their Engineering Notebooks, teams sketch their ball game and reflect on its design.

TASK 3: ALLIANCES

Identify the Problem:

- Many games in *FIRST* pair teams into alliances that work together as they compete; these are groups of two teams or more that compete against other groups of two or more. Being in an alliance comes with all sorts of advantages.
- Remind teams to keep *FIRST* Core Values and ethos in mind while they work in alliances.
- Teams may make their own alliances, or you may pair teams as you see fit.

Design and Prototype:

- When teams have paired up, ask each team to look at their partner team's design and compare it to their own. Comparing the two designs might inspire them to change their original design. Teams should record their thoughts in their Engineering Notebooks.
- After reviewing each other's design, alliance members work together to combine their ball games.

- When teams successfully combine their games, they sketch the final design in their notebooks.

Guiding Questions

- How do alliances change the perspective of game design?
- Why is knowing and following the Engineering Design Process an important part of preparing for the game at the end of the course?
- How could the game complexity increase innovation and creativity of a robot design?

TASK 4: GAME TIME

Test and Improve:

- Each alliance should challenge another alliance to compete against and find an area in the room to set up their ball game.
- The class may have included a rule relating to practice rounds in their game outline. If they haven't, remind students that the final step of the Engineering Design Process stresses the importance of testing a design before implementing it.
- If the class has decided on a timed element for the competition, ensure teams can access a timer.
- When all alliances are ready, they may start their games.
- Depending on your class rules, you may have multiple rounds of play.
- After alliances have finished competing, they should discuss their game's outcome and record their thoughts in their Engineering Notebooks.
- If time permits, allow teams to discuss the pros and cons of each game idea. Teams should reflect on their experience after each game.
- After each team has competed and presented their game to the class, have a class brainstorming session to determine which elements from each group's game you would like to include in the final class game they will compete in.

Suggested Extensions/Modifications

- Extension – Ask teams to draw robot ideas to ensure that tasks of the robot can be completed with the parts you have.
- Extension – Ask the class to include an endgame section in their game where there are more or different methods for scoring points.
- Modification – Provide teams with as many examples of different *FIRST* games as possible. Borrowing ideas from other *FIRST* games might help them with their initial design.
- Modification – Allow teams to take as much time as they need for their initial design.
- Modification – Encourage teams having difficulties to discuss their initial design with another team. Collaborating on their initial design is a great opportunity for teams to practice *Gracious Professionalism* and *Coopertition*.

Teacher Reflection Questions

- Were my students able to work as a class to create an outline for a game?
- Did students demonstrate *Coopertition* and *Gracious Professionalism* while they were outlining the game? Did students enjoy building their ball game?
- Were teams able to form alliances and work collaboratively during the last half of the activity?

Student Artifacts

- In their Engineering Notebook, students should have recorded:
- What they learned from the examples of *FIRST* games they looked at.
- How they can use *Gracious Professionalism* and *Coopertition* while competing in games.
- Ideas they generated while brainstorming rules and methods for scoring points in their game.
- The game rules and scoring methods decided on by the class.
- A sketch of the ball game they designed with the materials they used labeled.
- A reflection on the experience of designing a ball game.
- Their thoughts on their alliance's ball game and a sketch of their final combined ball game.
- A reflection on the outcome of their game.

Checkpoint

- Have students explain the importance of *Gracious Professionalism* and *Coopertition* while competing in a game.
- Ask teams to explain the importance of following the Engineering Design Process during an engineering project.
- Ask teams what they've learned about the Engineering Design Process after using it in a competitive situation.