FIRST® Robotics Engineering Explorations Teacher Guide

Introduction and Getting Started

Summary

CURRICULUM GOALS AND EXPECTED OUTCOMES

- Introduce fundamentals of robotics and engineering while building and programming a robot.
- Serve as bridging experience for students and teams transitioning from *FIRST*® LEGO® League to *FIRST*® Tech Challenge, and/or *FIRST*® Robotics Competition.
- Provide an introductory experience where students develop basic skills essential for *FIRST* Tech Challenge and/or *FIRST* Robotics Competition programs.
- Build confidence and generate enthusiasm for the fields of engineering and robotics.
- Incorporate fundamental principles of *FIRST* including Core Values, *Gracious Professionalism*®, and *Coopertition*®.
- Practice 21st century skills such as technical writing, presentation skills, communication, project management, collaboration, and teamwork.
- Cover concepts of engineering design process, engineering in our society, safety, building a robot, computational thinking, and programming.

USING THIS CURRICULUM

The activities and units within this curriculum build upon each other. The activities should be completed in the order in which they are presented. The estimated time range to complete each activity is provided. Keep in mind your students' experience and skill level when planning your curriculum implementation.

This curriculum is targeted toward middle school and high school students. Additionally, secondary teachers could use this curriculum as a basis for a full high school course on robotics or engineering. Be sure to follow proper safety procedures when working with robots.

Prior to starting this curriculum, take time to review each of the possible robotics sets (under Material Needs) to decide which is best for your students and classroom. Consider factors such as budget, space, access to hand tools, and safety.

Checklist

USE THIS CHECKLIST TO HELP YOU GET STARTED.

- ☐ Ensure you have all the materials needed to use this curriculum.
- ☐ Identify the space where you will implement the program and store materials. Think about the robot sets and where assembled robots will be stored. Do you need robot sets for multiple cohorts of students within the school day?
- ☐ Think about the size of the final challenge at the end of the curriculum and what type of an event you want to have. Your event could be in your classroom or be a bigger event in the school.
- ☐ Create an implementation plan and timeline for how you will use the curriculum. Determine how it will fit within your intended school or program standards and outcomes.
- ☐ Determine how you will place the class into teams. The recommended team size depends on the robot set that you use with your students.

Material Needs

Look over the following list for what materials and space is recommended for your classroom. Each team will need space to design, build, and program their robot. They will need space to participate in teamwork activities. It is also important for each team to have access to electronic devices (specific device requirements depend on robotics set) and the Internet.

FOR THE CLASSROOM SPACE:

- Small workstations/tables for each team (enough space for robot building, computers, and team activities)
- Portable or permanent storage
- Internet access
- Electrical support

FOR EACH TEAM (WITHIN CLASS):

- Electronic device with access to the Internet
- General engineering and makerspace consumables and materials (basic hand tools, cardboard, string, tape, rubber bands, resealable bags, measuring tape)
- General classroom supplies (pens, pencils, paper)
  - Note: Supplies needed for each activity are provided within the unit guides.
- Robotics set (choose one):
  - *FIRST* Tech Challenge Kit of Parts options (1 kit recommended per team of 3-5 students):
    - REV EDU kit
    - REV *FIRST* Tech Challenge Starter Kit and Control & Power Bundle
    - TETRIX® *FIRST* Tech Challenge Competition Set and REV Control & Power Bundle
  - *FIRST* Robotics Competition Kit of Part options (1 kit recommended per team of 5-10 students):
    - AndyMark Robot Chassis and Control System
    - REV KitBot and Control System
    - 118 Everybot and Control System
  - Experiential Robotics Platform (XRP)
    - XRP Kit

Storage and Material Management

Before getting started, you might want to play a game where the teams identify pieces in their robot sets. It is recommended that students organize their robot sets to help in taking ownership of materials. This would allow you to start processes and procedures for keeping the sets organized. After you have gathered or purchased all the materials your students will need, you could use plastic storage tubs or other containers to create a kit for each team in your class. You could assign and label each robot set with the team's name or number so the students know what materials to grab each time. Designate a safe area for the robot sets, computers, and materials that students have been working on, so they remain safe between class periods.

Classroom Implementation

First and foremost, use your professional judgment to adjust this curriculum to meet the needs of your students, class space, class timing, and additional school or curricular requirements. Set student expectations for participation based on the student growth mindset of holistic and STEM skills.

WORKING IN TEAMS

- Teamwork provides opportunity for collaboration and communication.
- Student teams promote deeper learning of content and build holistic skills to share out learning with other team members.
- Fewer materials are needed, and they can be used by more students.

HOW TO RUN STUDENT TEAMS

- Be comfortable with talking and movement within and between teams.
- Orient students to daily goals for learning using the Driving Questions and Objectives found in each activity.
- Have individual check-ins with each team at the start of class.
- Determine the length of time for daily tasks ahead of class and share with students.

TEACHER ROLE

The role of the teacher in this curriculum is more of a facilitator. Your teaching style should include a focus on developing holistic skills, building STEM confidence, embracing challenging activities, and using play, discovery, and exploration. Important considerations when using the facilitator mindset are:

- Reinforce *FIRST* Core Values.
- Ask guiding questions to get students thinking.
- Be comfortable with not having all the answers.
- Let students learn for themselves through problem-solving.
- Create opportunities for students to have ownership of the learning process and outcomes.
- Reflect on student and team goals and how they are working to achieve them.
- Guide students to the resources to help them achieve their goals.
- Celebrate mistakes and see learning opportunities.

STUDENT GROWTH MINDSET

As you guide students through their experience, having the right mindset is important. Creating student ownership of learning can assist with this. Ownership can be achieved by allowing students to focus on the skills they are developing and what they want to achieve and to use their problem-solving skills. There are no right or wrong solutions, just different ways of solving problems. As a teacher, if you can establish perseverance and resilience as traits to celebrate and be grateful for, students will be more likely to strive for them. Students need to be challenged just enough that it stretches their minds and creativity without overwhelming them. Promote inquiry by using open-ended questions that lead to more student discovery and investigation.

Project-Based Learning

HOW DOES THIS *FIRST* PROJECT FIT INTO PROJECT-BASED LEARNING (PBL)?

One of the hallmarks of PBL is the applicability of solutions to real-world problems. In this project, students face a series of challenges in which they will have to use teamwork, critical thinking, and new skills like *Gracious Professionalism®* and *Coopertition®. Gracious Professionalism* is one of the *FIRST* Core Values and urges students to engage with each other in a professional and courteous manner. *Coopertition* reminds students to cooperate while they compete. Because students are put into teams, they need to repeatedly exercise both of these skills.

SO, WHAT DO STUDENTS DO?

Students tackle questions and challenges provided to them but are also encouraged to develop their own questions. Students are asked to think about a community problem and brainstorm what kind of robot might help to solve the community problem. Students get to look at their own community, and the solution they come up with is an authentic means of addressing the problem. By focusing their work around a community problem, student learning has immediate practical applications.

CONSTRUCTIVE CRITICISM

Constructive criticism is another hallmark of PBL. Throughout the *FIRST* project, students carefully consider the purpose and utility of their community robot. When they work in teams, they are able to offer constructive criticism to each other as well as to other teams. Both students and educators conduct reflections in each activity to solidify goals and learning outcomes. The modules also encourage teachers to invite community experts into the classroom. Students can work with these experts to gain meaningful context for their problems and receive mentorship from real-world professionals.

UNIQUE PROBLEMS, UNIQUE SOLUTIONS

Students use the Engineering Design Process to construct robots that can complete a variety of tasks using sensors, telemetry, and moving parts. Each team member gets to contribute their own ideas during the activities, and their ideas and suggestions are taken seriously. Students are able to create unique solutions and are given a high degree of agency to do what they think will work best.

PROJECT-BASED LEARNING RESOURCES

- PBL defined: https://www.pblworks.org/what-is-pbl
- Learning about PBL: https://www.edutopia.org/project-based-learning
- TED talk by Carol Dweck and her growth mindset approach: https://youtu.be/J-swZaKN2Ic

Curriculum Overview

Curriculum Setup

The Robotics Engineering Explorations contains six units. Each unit comes with a Teacher Unit Guide and a Student Unit Guide. Each unit contains multiple activities. Each activity is generally organized with the sections listed below.

STUDENT ACTIVITY FORMAT

- Driving Questions – poses questions that the students will solve and answer in the activity
- What Will I Be Doing? – outlines what each team should accomplish during the activity
- Getting Started – provides an initial scenario for the students to consider and talk about
- What's Next – tells the students what to gather and what they will do next
- How Will I Do It? – explores a series of tasks where the students will experiment, learn, and explore
- Engineering Notebook prompts – essential component of every unit that gives students a specific list of items to document in their Engineering Notebook
- Tasks – provides instructions of what the team should do
- Career Connections callouts – provides careers linkages to activity topic
- Tips callouts – provides additional instruction and guidance
- Cleanup Tips callouts – provides specific cleanup instructions after the activity is complete
- Reflection – provides a series of questions for the students to think about after they have completed the activity
- Checkpoint – lists what the students should have documented in their Engineering Notebook

TEACHER ACTIVITY FORMAT

- Driving Questions – poses questions that the students will solve and answer in the activity
- Objectives – outlines what each team should accomplish during the activity
- Materials – tells the teacher what to gather
- Student Tasks – provides instructions of what each team should do broken into steps of Engineering Design Process
- Guiding Questions – provides questions that the teacher can ask students
- Suggested Extensions/Modifications – provides ideas on ways to extend or modify activity
- Teacher Reflection Questions – provides a series of questions for the teacher to think about
- Student Artifacts – lists what students should have documented in their Engineering Notebook
- Checkpoint – suggests ways to check for understanding before moving onto the next activity

General Unit and Activity Guidance

GENERAL ACTIVITY EXTENSIONS/MODIFICATIONS

- Modification – If a team is struggling to work together, ask them to think about why that is and what they can do to fix the problem.
- Modification – Provide examples where possible. Being able to borrow ideas from something existing might help teams with their initial designs and ideas.
- Modification – Encourage teams that are having an issue to discuss it with another team. This as a great opportunity to practice *Gracious Professionalism* and *Coopertition*.
- Modification – If a team is struggling, pair them with another team for support.
- Extension – Ask teams to pick real-world design projects and break them 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 find examples of professions that relate to concepts covered in the activity.

GENERAL ACTIVITY TEACHER REFLECTION QUESTIONS

- Are students recording data in their Engineering Notebooks?
- Did students demonstrate *Coopertition* and *Gracious Professionalism*?
- Did students achieve their objectives?
- Did students find the Getting Started section of the activity engaging or helpful?
- Do students understand the importance of establishing success criteria?

- Do students demonstrate skills needed for today's workforce?
- Was I able to support my students so that they could achieve their objectives?
- Were students able to recognize the importance of *FIRST* Core Values?
- Were students able to work together in teams?
- What can I change or do better for next time?

GENERAL ACTIVITY STUDENT ARTIFACTS AND CHECKPOINTS

In their Engineering Notebook, students should have recorded:

- Responses to the questions from the Getting Started section of the activity.
- Their responses to the questions in the tasks.
- Ideas they generated while brainstorming.
- Sketches of their thoughts and ideas.
- Data analysis including charts and tables.
- What they've learned.
- Responses to the questions from the Reflection.
- Reflection on what they learned during the activity.
- Reflection on how they can use *Gracious Professionalism* and *Coopertition* during the activity.
- The importance of the Engineering Design Process in relation to the activity.
- Key takeaways in their Engineering Notebooks.

General Course Overview

The *FIRST* Robotics Engineering Explorations course provides students with experiences in engineering, robotics, programming, and game-based learning. *FIRST* revolves around a defined set of Core Values and gives students authentic, real-world learning experiences. Working as part of a team, students use what they learn through *FIRST* to research and design an innovative solution to a real-world problem. At the same time, students will work in teams to build their own game-ready robot to show off at an event at the end of the course. Students practice 21st century skills such as technical writing, presentation skills, communication, project management, collaboration, and teamwork.

UNIT	LEARNING OBJECTIVES	TIMING
Unit 1: Welcome to *FIRST*	• Explore what it means to be a part of *FIRST*. • Research and think about ways robots can improve people's lives. • Explore a variety of career options and the varying levels of education. • Use basic materials to solve engineering challenges. • Design a game for the teams to compete in.	12 hours
Unit 2: Build a Bot	• Design and build a robot chassis that can complete a game-based challenge while researching ways in which robotics is used in your community. • Get to know your kit of parts. • Explore real-world chassis designs. • Introduce movement, control, and power.	12 hours
Unit 3: Make It Move	• Configure and program a robot to perform driver-controlled movements. • Develop and troubleshoot driver-controlled programs. • Collect data about your robot using telemetry.	24 hours
Unit 4: Programming Autonomous Robots	• Develop and troubleshoot autonomous programs and sensors. • Explore the differences between driver-controlled and autonomous modes. • Explore sensor configuration and functions.	12 hours
Unit 5: Build and Program Manipulators	• Build and program an arm and manipulator that works in autonomous and driver-controlled modes. • Research basic arm and manipulator designs. • Program and test a robotic manipulator in autonomous and driver-controlled modes.	20 hours
Unit 6: The Ball Game	• As a team, present the final innovative solution and showcase your robot in the *FIRST* robot game. • Demonstrate your robot by participating in a game designed in Unit 1.	10 hours

Scope and Sequence

UNIT 1 — WELCOME TO *FIRST* (12 HOURS)

Objectives

- Explore what it means to be a part of *FIRST*.
- Research and think about ways robots can improve people's lives.
- Explore a variety of career options and the varying levels of education.
- Use basic materials to solve engineering challenges.
- Design a game for the teams to compete in.

ACTIVITY	DRIVING QUESTIONS	TIMING
Robotics Engineering Explorations	• How do we prepare for *FIRST* competitions using robots? • What are the Core Values and philosophies of *FIRST*? • Why are we working in teams?	1 hour
Engineers Rock	• 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?	1 hour
Problems and Innovation	• 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?	2 hours
Solve Your Own Problem	• 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?	1.5 hours
Help Wanted, Positions Available	• 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?	1.5 hours
Safety and the Kit	• 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?	2 hours
Ball Game Challenge	• 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 *FIRST* Core Values, *Gracious Professionalism*, and *Coopertition* while we work to win a game?	3 hours

UNIT 2 — BUILD A BOT (12 HOURS)

Objectives

- Design and build a robot chassis that can complete a game-based challenge while researching ways in which robotics is used in your community.
- Get to know your kit of parts.
- Explore real-world chassis designs.

ACTIVITY	DRIVING QUESTIONS	TIMING
A Robot Skeleton	• What is a frame? • What is a chassis? • How do we build a frame from the parts in our robotics kit? • How will the chassis design help our team compete in the ball game?	3 hours
Get Your Chassis Moving	• Why are different wheels used for different jobs? • How do we mount wheels to our chassis using the robotics kit? • What sorts of wheel configurations can you create from the robotics kit?	3 hours
Mounting Motors	• How will the robot move? • How do we mount motors onto the chassis? • Where should we mount motors on the chassis?	2.5 hours

Power and Control	• How do we power our robot? • What is a control system and what does it do? • How do we connect all the electronic components of my robot?	1.5 hours
Fine-Tuning	• How can we improve the design of our robot? • Are all the parts of our robot secure? • Is our robot ready for programming?	2 hours

UNIT 3 — MAKE IT MOVE (24 HOURS)

Objectives

- Configure and program a robot to perform driver-controlled movements.
- Develop and troubleshoot driver-controlled programs.
- Collect data about your robot using telemetry.

ACTIVITY	DRIVING QUESTIONS	TIMING
Configure It Out	• Now that the robot is built and wired, how do we drive it around? • How can we communicate with the robot so it can do its job?	3 hours
Programming Is Everywhere	• How can we use a gamepad to move our robot? • How and why should we use a similar strategy with our ball game robot?	3 hours
Troubleshooting Is Everywhere	• How can we troubleshoot a program? • Why is troubleshooting important?	3 hours
Think like a Robot	• How can we write directions for a person to do exactly what we want and nothing else? • How can we get our robot to do exactly what we want and nothing else? • Why is this important?	3 hours
Let's Get Moving	• Can we program our motors to change the way the robot moves? • What role will the programming of the motor play in their robot design?	3 hours
Information Exchange	• How do we retrieve data from our robot? • What sort of data can we get from our robot? • How can we use data feedback to improve our robot?	3 hours
I'm in Complete Control	• What sort of tasks can we make our robot do? • Can we create a set of instructions based on what we want our robot to do? • How do we translate a set of instructions for completing a job into a program for our robot?	3 hours
The Big Race	• Can we control our robot well enough to drive it in a relay race against another team? • Can we use the Engineering Design Process to create the best possible program for winning a relay race? • Why is the level of control we have over a robot important, and how does it apply to our ball game?	3 hours

UNIT 4 — PROGRAMMING AUTONOMOUS ROBOTS (12 HOURS)

Objectives

- Develop and troubleshoot autonomous programs and sensors.
- Explore the differences between driver-controlled and autonomous modes.
- Explore sensor configuration and functions.

ACTIVITY	DRIVING QUESTIONS	TIMING
Autonomous Functionality	• How can we control a robot when it is not driver controlled? • What do we need to know to make our robot move autonomously? • How do we write instructions that will make our robot complete a task autonomously?	3 hours
Better Control Through Encoders	• What are encoders? • How can we use the encoders built into our motors to gain better control of our robot's movement? • What algorithms do we need to use to take advantage of our encoders?	3 hours

Robot Senses	• What are sensors, and how can we use them to improve our robot? • What sensors that are available in our kit of parts? • What additional sensors will be most useful in the ball game challenge?	3 hours
Collision Avoidance	• How can we store data in our program? • How can we reuse and call stored data? • What are variables and how do we use them in our program?	3 hours

UNIT 5 — BUILD AND PROGRAM MANIPULATORS (20 HOURS)

Objectives

- Build and program an arm and manipulator that works in autonomous and driver-controlled modes.
- Research basic arm and manipulator designs.
- Program and test a robotic manipulator in autonomous and driver-controlled modes.

ACTIVITY	DRIVING QUESTIONS	TIMING
Ball Grabber	• What is an actuator? • How do we use the actuators in our kit?	4 hours
Iterate, Feedback, and Improve	• How do we improve the robot mechanically and through programming? • How can we improve our designs to perform better? • How can programming enable our robot to have more control? • How can sensors improve the automation process?	4 hours
Robot Arms	• How can we do more complex actions with our ball game robot? • What is a robotic arm? • Where are robotic arms used in manufacturing? • How do we choose the correct motors for the robot arm?	4 hours
Actuating Your Manipulator	• How are the motors in our robotics kit different? • How do we ensure we choose the right motor to make our manipulator work? • How can we integrate the proof of concept into our robot?	4 hours
Project Sprints	• How can a project sprint help to improve iteration cycles? • How does a project sprint help us track the tasks that need to be completed? • How can project sprints help us improve teamwork and innovation?	4 hours

UNIT 6 — THE BALL GAME (10 HOURS)

Objectives

- As a team, present the final innovative solution and showcase your robot in the *FIRST* robot game.
- Demonstrate your robot by participating in a game designed in Unit 1.

ACTIVITY	DRIVING QUESTIONS	TIMING
Preparing for the Game	• How can we involve the team during competition? • How do we plan our competition day? • How do we know if we are prepared for the game?	3 hours
More than Robots!	• What are our next steps for the community event? • What needs to be done to our robot for the ball game challenge? • How will we market the community event? • How will we present our robot and our design in our community?	2 hours
Welcome to the Game	• Are we ready to have fun competing? • Are we ready to share our knowledge and what we have learned? • How does *Coopertition* impact our approach to competing?	5 hours

Standards Alignments

COLOR KEY
The standard is clearly addressed by the curriculum activities.
The standard could be addressed as part of the curriculum with additional actions by teacher.

CSTA COMPUTER SCIENCE STANDARDS

Grades 6-8

ALGORITHMS & PROGRAMMING		COMPUTING SYSTEMS	DATA & ANALYSIS	IMPACTS OF COMPUTING	NETWORKS & THE INTERNET
2-AP-10 2-AP-11 2-AP-12 2-AP-13 2-AP-14	2-AP-15 2-AP-16 2-AP-17 2-AP-18 2-AP-19	2-CS-01 2-CS-02 2-CS-03	2-DA-07 2-DA-08 2-DA-09	2-IC-20 2-IC-21 ***2-IC-22*** ***2-IC-23***	***2-NI-04*** ***2-NI-05*** ***2-NI-06***

Grades 9-10

ALGORITHMS & PROGRAMMING		COMPUTING SYSTEMS	DATA & ANALYSIS	IMPACTS OF COMPUTING	NETWORKS & THE INTERNET
3A-AP-13 3A-AP-14 3A-AP-15 3A-AP-16 3A-AP-17 3A-AP-18	3A-AP-19 ***3A-AP-20*** 3A-AP-21 3A-AP-22 3A-AP-23	3A-CS-01 3A-CS-02 3A-CS-03	3A-DA-09 3A-DA-10 ***3A-DA-11*** 3A-DA-12	3A-IC-24 ***3A-IC-25*** ***3A-IC-26*** 3A-IC-27 ***3A-IC-28*** ***3A-IC-29*** ***3A-IC-30***	***3A-NI-04*** ***3A-NI-05*** ***3A-NI-06*** ***3A-NI-07*** ***3A-NI-08***

NGSS STANDARDS

Middle School and High School

FORCES & INTERACTIONS		ENERGY		ENGINEERING DESIGN	
MS-PS2-1 ***MS-PS2-2***	***HS-PS2-3***	***MS-PS3-1*** ***MS-PS3-2*** ***MS-PS3-3*** ***MS-PS3-4*** MS-PS3-5	HS-PS3-3	MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-ETS1-1 HS-ETS1-2 HS-ETS1-3 ***HS-ETS1-4***

ISTE STANDARDS

Middle School and High School

EMPOWERED LEARNER	DIGITAL CITIZEN	KNOWLEDGE CONSTRUCTOR	INNOVATIVE DESIGNER	COMPUTATIONAL THINKER	CREATIVE COMMUNICATOR	GLOBAL COMMUNICATOR
1a 1b 1c 1d	***2a*** 2b ***2c*** ***2d***	3a 3b 3c 3d	4a 4b 4c 4d	5a 5b 5c 5d	6a 6b 6c 6d	***7a*** 7b 7c ***7d***

COMMON CORE STATE STANDARDS – ENGLISH LANGUAGE ARTS/LITERACY

Middle School and High School

WRITING	SPEAKING & LISTENING	LANGUAGE	READING IN SCIENCE AND TECHNICAL SUBJECTS	WRITING IN SCIENCE AND TECHNICAL SUBJECTS
W.6-8.6 W.6-8.10 W.9-10.6 W.9-10.10	SL.6-8.1 SL.9-10.1	L.9-10.1 L.9-10.2 L.9-10.3 L.9-10.1 L.9-10.2 L.9-10.3	RST.6-8.3 RST.6-8.4 RST.6-8.7 RST.9-10.3 RST.9-10.4 RST.9-10.7	WHST.9-10.10 WHST.9-10.10

Reproducible Pages

Listing

- Inventory Checklist Template
- Engineering Notebook Templates
- Student Reflection Guide
- Engineering Design Process
- Glossary

Inventory Checklist

CONTROL SYSTEM AND SENSORS

QTY	ITEM	NOTES

MOTORS

QTY	ITEM	NOTES

SERVOS AND ACCESSORIES

QTY	ITEM	NOTES

STRUCTURE AND BRACKETS

QTY	ITEM	NOTES

GEARS

QTY	ITEM	NOTES

WHEELS

QTY	ITEM	NOTES

BATTERY

QTY	ITEM	NOTES

MOTION

QTY	ITEM	NOTES

TOOLS

QTY	ITEM	NOTES

FASTENERS AND HARDWARE

QTY	ITEM	NOTES

HARDWARE

QTY	ITEM	NOTES

MISCELLANEOUS

QTY	ITEM	NOTES

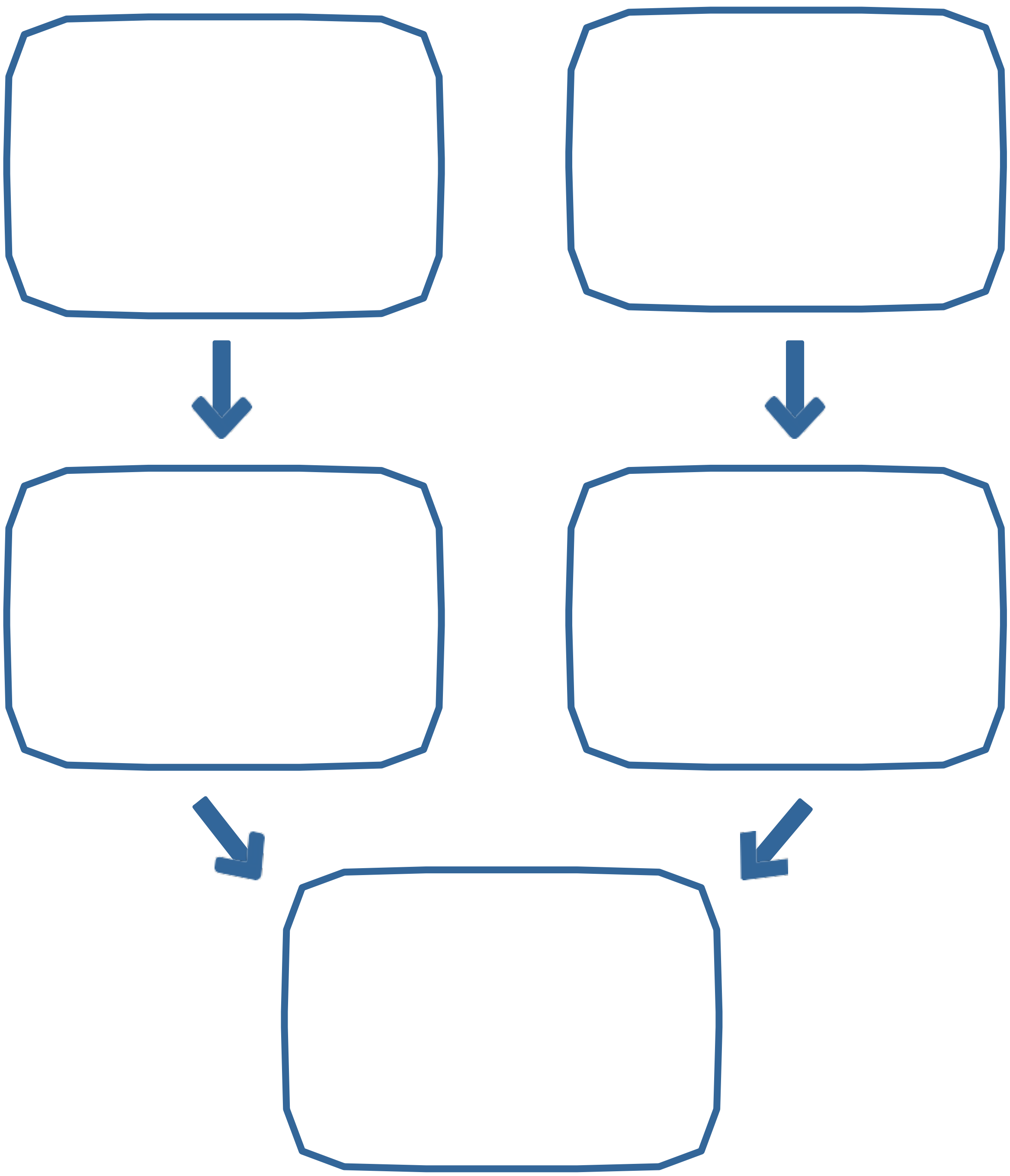
Engineering Notebook

HAVE A LIST? SAVE IT HERE!

Engineering Notebook

NOTES

MIND MAP



Engineering Notebook

TOPIC: ____

KNOW What do you think you already know about this topic?	WONDER What do you think about this topic? Write your questions.	LEARNED After you complete your activity, write what you learned.

Engineering Notebook

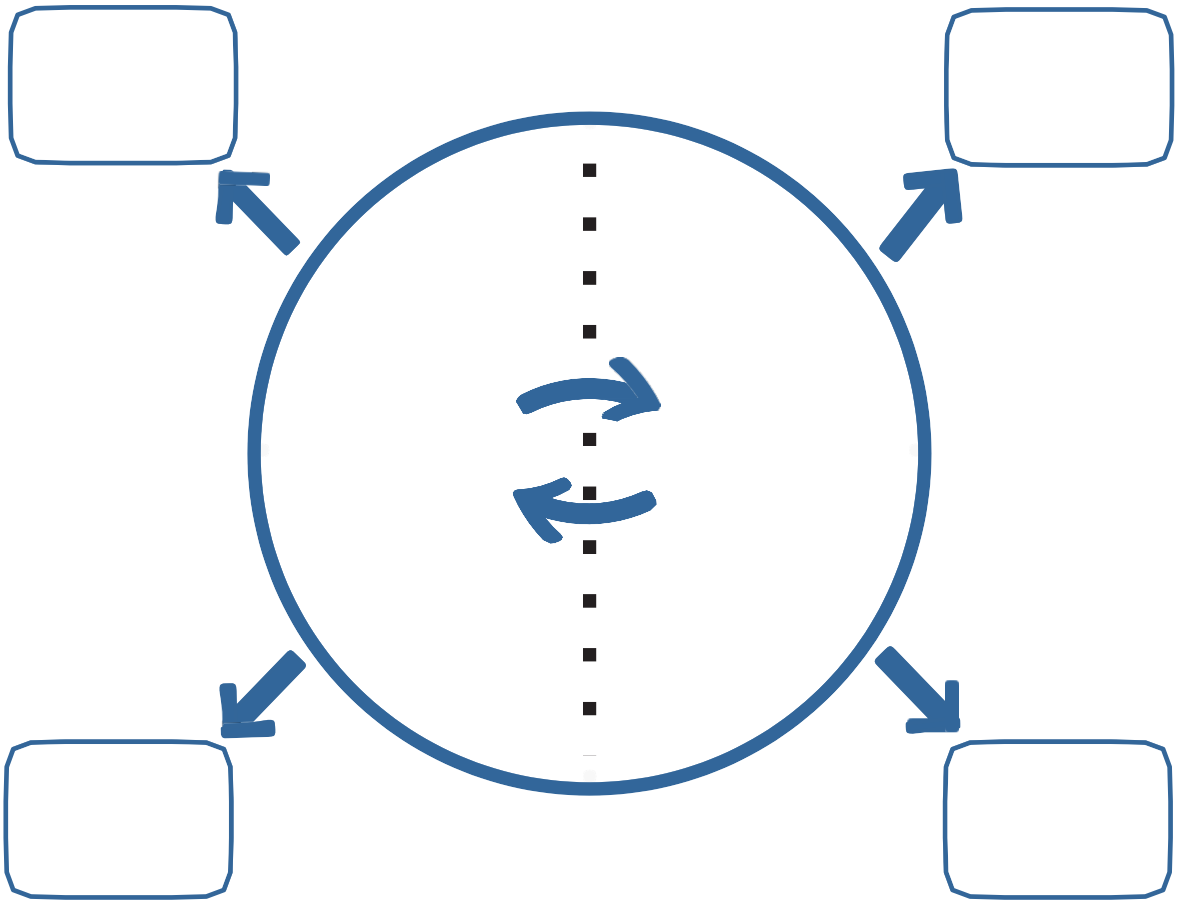
Engineering Notebook

NOTES

CHART

Engineering Notebook

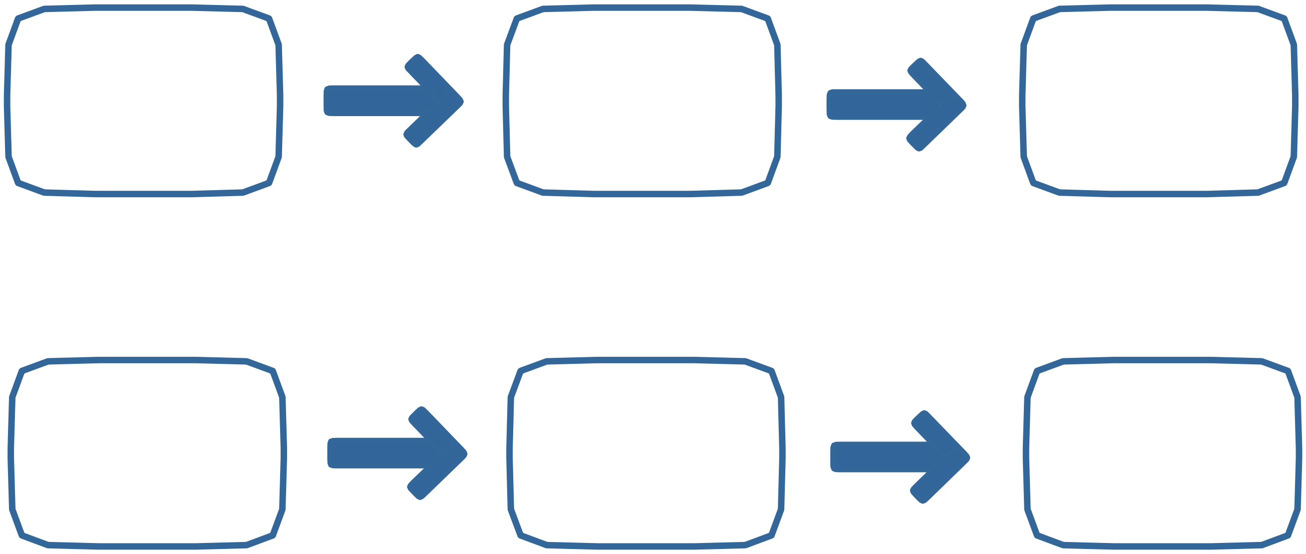
MIND MAP



NOTES

Engineering Notebook

MIND MAP



NOTES

Student Reflection Guide

WHAT IS PROJECT-BASED LEARNING (PBL)?

- PBL teaches you to find solutions to real-world challenges.
- PBL is a different way of learning. In PBL, you explore, create, inquire, research, build, and test out solutions to relevant problems.
- PBL prepares you for real-life challenges, successful careers, and a passion for lifelong learning.

PBL IN THE CLASSROOM:

- Instead of just listening to a teacher, a PBL classroom encourages you to ask and answer your own questions.
- In trying to solve a community problem, your learning has immediate, practical applications.
- Working in teams promotes constructive criticism and encourages you to practice *Gracious Professionalism* and *Coopertition*.

PBL BEYOND THE CLASSROOM:

- PBL encourages you to reflect on the outcomes of your projects in order to extend your learning experience beyond the project itself.
- You can apply a PBL approach to all your subsequent learning opportunities.
- With PBL, there is no defined end point to your learning; there is always room for more discovery and innovation.

REFLECT ON YOURSELF:

- What did you learn from the game?
- What did you learn from the community problem?
- If you did this course again, what would you do differently?
- How did it feel to work on a community problem?
- Did the course meet your expectations?

REFLECT ON YOUR TEAM:

- Overall, did you and your team get along well?
- What parts of the course did your team do well together?
- What parts of the course can your team improve on?
- What was it like to compete against a former ally?
- What was it like to work on a community project together?

REFLECT ON THE GAME AND ROBOT:

- What part of the game did you enjoy the most?
- What part of the community problem did you enjoy the most?
- Was the game a fun or stressful experience? Why?
- Was the community problem a fun or stressful experience? Why?

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 important to keep in mind that everyone's experience is different. (Discovery)
- If you want to learn, the best way to start is by asking questions.
- 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; try and inspire your team to go beyond obvious solutions. (Teamwork)

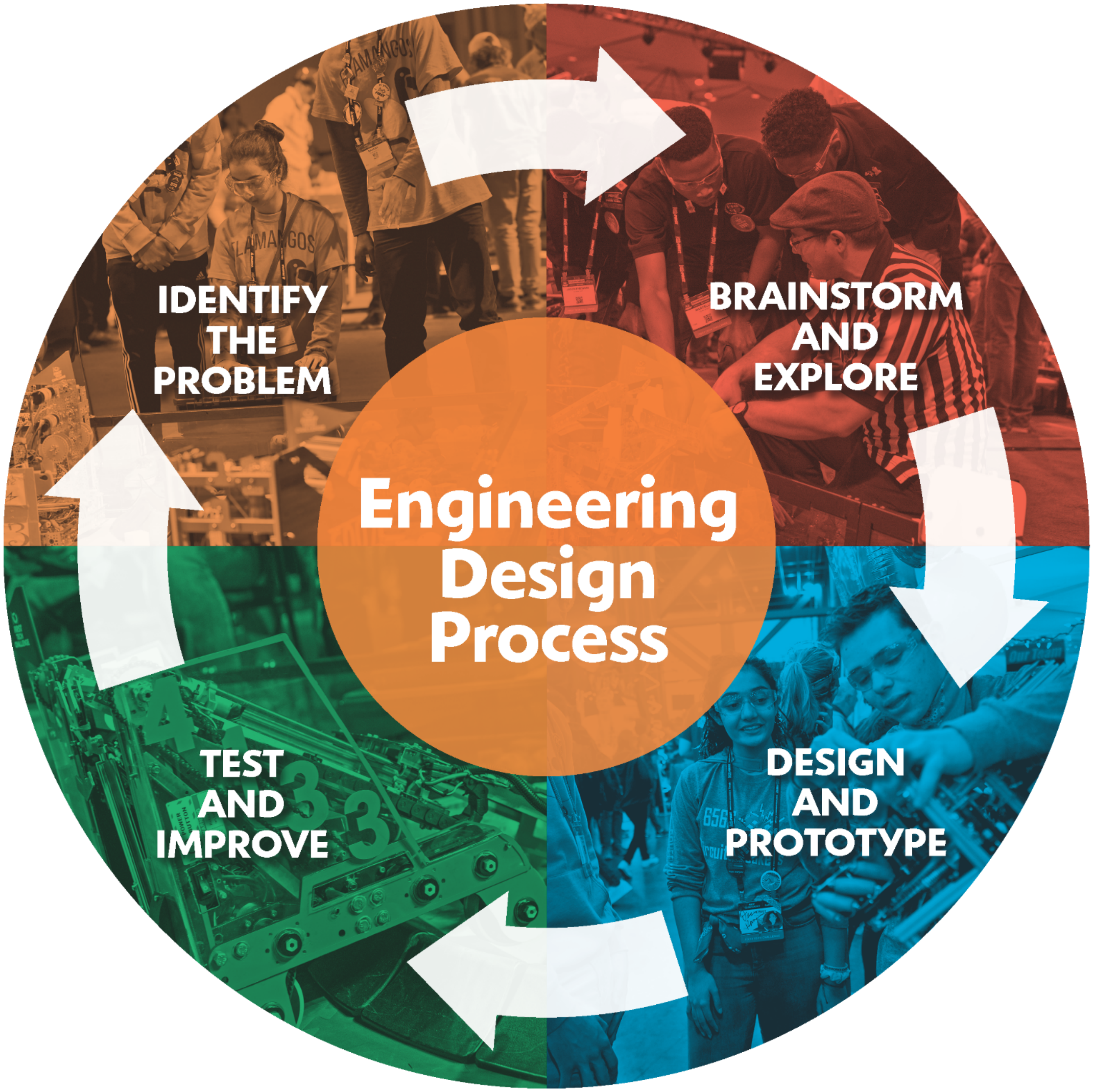
DESIGN AND PROTOTYPE

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

TEST AND IMPROVE

- Put what you've built into the community you are working with.
- Testing what you've built will help you improve your design and tell you more about the problem you are trying to solve.
- You may find that what you've built doesn't solve the problem the way you wanted it to. Learning from failures is an important part of the Engineering Design Process.

Engineering Design Process



Glossary

VOCABULARY WORD	DEFINITION
Acceleration	an object's ability to gain speed over a relatively short amount of time
Accessibility	the design of products, devices, services, or environments for people with disabilities
Accuracy	the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard
Actuator	a component of a machine that is responsible for moving and controlling a mechanism or system
Agile Project Management	an iterative approach to managing software development projects that focuses on continuous releases and incorporates customer feedback with every iteration
Algorithm	a procedure or formula, used for solving a problem, that conducts a sequence of specified actions; these actions describe how to do something and are performed exactly that way every time
Alliance	a cooperative of two robots and their drive teams during a match
Alliance Station	the designated red or blue alliance area next to the playing field
Alternating Current (AC)	an electric current which periodically reverses direction
Angular Velocity	the rate of change of angular position of a rotating object
Animatronics	the technique of making and operating lifelike robots, typically for use in film or other entertainment
Autonomous	operational without direct human control
Autonomous Period	a timed period during the match in which robots operate and react only to sensor inputs and commands pre-programmed by the team onto its onboard control system
Axle	a rod or spindle (either fixed or rotating) passing through the center of a wheel or group of wheels
Battery	one or more cells connected together that provide power to the robot so it can move
Binary	a mathematical language where only "1" or "0" exist
Boolean	a binary variable that can be used to create either "true" or "false" statements
Chassis	See *frame*.
Circumference	the distance around a circle
Command	an instruction or signal that causes a computer to perform basic functions
Computational Thinking	a set of problem-solving methods that involve expressing problems and their solutions in ways that a computer could execute
Condition	something that must be true in order for something to happen
Configure	to arrange or order a computer system or its element(s) for a designated task
Constraint	a limitation or restriction
Control System	a computer that controls various parts of the robot
Controller	the device used to operate the robot
Coopertition	collaboration between competitors, in the hope of mutually beneficial results
Core Values	Discovery, Innovation, Impact, Inclusion, Teamwork, Fun
Dead Reckoning	the calculation of one's current position by using a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time and course
Debug	to find and resolve defects or problems within a computer program that prevent correct operation of your code
Disable/Disabled	to deactivate a robot/a robot that is no longer active
Driver Station/ Dashboard	the designated operator responsible for sending signals to the robot's control system so you can operate the robot
Driver-Controlled Period	the time during the match/gameplay when humans operate the robot using the gamepad
Electrostatic Discharge	the release of static electricity when two objects come into contact

VOCABULARY WORD	DEFINITION
Encoder	a device that converts physical information to another type of data for the purpose of standardization, speed, or compression.
End Effector	the last link on a robot's arm where it makes contact with an object
End Game	the time after the driver-controlled period prior to the end of the match
End of the Period/Match	the moment when the match timer reaches 0:00
Engineering Design Process	Identify the Problem, Brainstorm and Explore, Design and Prototype, Test and Improve
Engineering Notebook	a place to document, in chronological order, all work, designs, and ideas that are associated with a specific design project
Frame	the main supporting structure of a vehicle; all other components attach to it
Function	a named section of a program that performs a specific task
Game Element	any item a robot interacts with to play the game
Gamepad	a handheld controller
Gearbox	a set of gears and their casing
Gracious Professionalism	doing your best work while treating others with respect and kindness; it's what makes *FIRST*, first
Hardware	any element of a piece of technology that's physical
If-then statements	a type of conditional statement; a statement with a hypothesis followed by a conclusion
Inadvertent	an outcome that is not a planned strategy and not the predictable result of persistent or repeated actions
Initialize	to put in the condition appropriate to the start of an operation
Innovation	the practical implementation of ideas that results in the introduction of new goods or services or improvement in offering goods or services
Integrated Development Environment (IDE)	a software application that provides comprehensive facilities for software development, normally consisting of at least a source-code editor, build automation tools, and a debugger
Invert	to flip a value from true to false or vice versa; often used in programming Boolean variables
Iteration	the process of doing something again and again, usually for improvement
Light-Emitting Diode (LED)	a semiconductor light source that emits light when a current flow through it
Loop	a sequence of instructions that is continually repeated until a certain condition is reached; if an exit condition is not defined, the program will never end
Match	a head-to-head competition between two alliances
Mobility	the ability to move or be moved freely and easily
OpMode	a block programing term that is the equivalent of a function
Pairing	a process that helps set up an initial linkage between computing devices to allow communication between them
Parameter	a numerical or other measurable factor that defines a system or sets the conditions of its operation
Precision	the quality, condition, or fact of being exact and accurate
Program	a set of instructions that a computer follows in order to perform a particular task
Prototype	a first or preliminary model of something, especially a machine, from which other forms are developed or copied
Pseudocode	a description of the steps in an algorithm using a mix of conventions of code with informal, usually self-explanatory, notation of actions and conditions
Quality Assurance (QA)	a way of preventing mistakes and defects in manufactured products and avoiding problems before the final product is delivered
Revolutions per Minute (RPM)	a measure of how fast motor spins
RGB	red (R), green (G), and blue (B) colors that can be sensed by a robot's color sensor

VOCABULARY WORD	DEFINITION
Robot Initialization Routine	a set of programming instructions that runs after a robot's Init button is pressed but before the driver-controlled or autonomous periods begin in a robot match
Sensor	a device that can detect and send information to the "brain" of the robot
Software	a set of instructions or programs used to operate computers and execute tasks
Stall Torque	the torque produced by a device whose output rotational speed is zero (It could be the torque load that causes the device output speed to become zero and stall.)
Subsystem	a collection of robot hardware and/or software that operates together as a unit inside the robot
Telemetry	an automated communications process where measurements and other data are collected at remote or inaccessible points and transmitted to receiving equipment for monitoring
Torque	a measure of the force that can cause an object to rotate about an axis
Troubleshoot	to anticipate or correct observed problems
Variable	a value that can change depending on conditions or information passed to the program
Wiring Diagram	a simplified conventional pictorial representation of an electrical circuit that shows the circuit's components as simplified shapes and connections

Rubrics

Core Values Self-Reflection

	COULD BE BETTER	MAKING PROGRESS	GREAT JOB	AMAZING SKILL
Discover	I depended on others to make the discovery for me.	I approached tasks but needed assistance multiple times to reach a point of discovery.	I approached the tasks and asked questions from one other person but persevered to discover the answer on my own.	I approached the tasks looking for all possible answers independently and used perseverance to discover the answer on my own.
Innovation	I struggled with being creative, used only the information given, and needed a lot of encouragement from others to complete the tasks.	I used creativity but struggled with perseverance to solve problems on my own.	I used creativity and perseverance to solve problems on my own and came up with different solutions for the tasks I was given.	I used creativity and perseverance to solve problems on my own and came up with unique solutions for the tasks I was given.
Impact	I understood the tasks but did not approach the information with understanding the impact it can have on my future or others.	I understood the tasks but struggled to apply how the information would impact my future or influence on others.	I approached the tasks knowing and applying the information with impact it can have on me and my future.	I approached the tasks applying understanding of the information and the impact it can have on me and my future as well as how I could help others.
Inclusion	I did not approach tasks with inclusion of others' ideas. I tried to understand others' views and include them in my projects and my work. My solution is not inclusive of different types of people.	I approached some tasks with inclusion of others' ideas. I tried to understand others' views and include them in my projects and work. My solution meets only a few needs of others.	I approached most tasks with inclusion of others' ideas. I tried to understand others' views and include them in my projects and work. I mostly incorporated the needs of others in my solution.	I approached all tasks with inclusion of others' ideas. I showed tremendous kindness by including others' views in my projects and work. I approached my solution thinking about how all people would interact with the solution.
Teamwork	I only sometimes used collaboration, communication, and project management and accomplished a few tasks for myself and others.	I used collaboration, communication, and project management to get some tasks accomplished for myself and others.	I used collaboration, communication, and project management to get most tasks accomplished for myself and others.	I used collaboration, communication, and project management to get all tasks accomplished for myself and others.
Fun	I only saw struggle in completing my tasks and did not look for times to have fun.	I kept a positive attitude throughout and found opportunities to have fun even through struggle.	I kept a positive attitude throughout and found opportunities to have fun even through struggle.	I saw the enjoyment and fun after the activity but struggled to see it during.

Engineering Notebook Weekly Assessment

Initiating the Inquiry

What is the evidence that the student can formulate questions and develop designs related to solving a problem?

	EMERGING	DEVELOPING	PROFICIENT	ADVANCED
Asking Questions	• Formulates a general question • Provides limited or irrelevant content information	• Formulates a specific question • Provides general content information that is related to the question	• Formulates a specific and testable question related to the problem • Provides specific and relevant content information to support the question	• Formulates a specific, testable, and challenging question related to the problem • Provides specific and relevant content information to provide insight into the inquiry
Developing and Using Models	• Drawings, diagrams, or models relevant to the problem include major conceptual or factual errors or are missing. • Discussion on limitations or accuracy of models as a representation of the system or process is flawed or missing.	• Constructs generally accurate drawings, diagrams, or models to represent the process or system to be investigated • Makes note of limitations or accuracy of model as representation of the system or process	• Constructs accurate drawings, diagrams, or models to represent the process or system to be tested • Explains limitations and accuracy of model as a representation of the system or process	• Constructs accurate and detailed drawings, diagrams, or models to represent the process or system to be investigated and provides an explanation of the representation • Explains limitations and accuracy of model as a representation of the system or process and discusses how model might be improved

Planning and Testing Prototypes

What is the evidence that the student can plan and test prototypes to explore design strategies?

	EMERGING	DEVELOPING	PROFICIENT	ADVANCED
Designing the Prototypes	• Design is not aligned to the testable question. • Discussion of how the model can guide or inform the design or an aspect of the design is missing.	• Relates but does not explicitly align design to testable questions • States in general terms how model was used to guide, inform, or test the design or aspect of it	• Aligns design with testable question • Explains how model was used to guide, inform, or test the design or an aspect of it	• Explains the alignment between the design and the testable question • Explains how model was used to guide, inform, or test the design or an aspect of it
Testing Prototypes	• Includes vague or incomplete testing procedures or uses inappropriate tools, instruments, or types of measurements	• Describes testing procedures including tools and instruments used but is not clear or detailed enough to be replicated	• Describes detailed, clear, and replicable testing procedures including tools, instruments, and measurements gathered	• Describes detailed, clear, and replicable testing procedures including rationale for using the tools, instruments, and measurements gathered
Documenting Tests	• Gathers data from a single test of the design • Limitations of the tests are not mentioned	• Documents results from several tests • Mentions limitation of the tests	• Documents results from several tests of the design that explore unexpected circumstances • Explains limitations of the tests	• Documents results from several tests of design that explore extensive circumstances • Explains limitation of tests and impact on future designs

Engineering Notebook Weekly Assessment

Representing, Analyzing, and Interpreting Test Results

What is the evidence that the student can organize, analyze, and interpret test results?

	EMERGING	DEVELOPING	PROFICIENT	ADVANCED
Analyzing the Results	• Analyzes data using inappropriate methods or with major errors or omissions • Does not compare consistency of outcome with initial expectations when appropriate	• Accurately analyzes data using appropriate methods with minor omissions • Compares consistency of outcome with initial expectations when appropriate	• Accurately analyzes data using appropriate and systematic methods to identify patterns • Compares consistency of outcome with initial expectations when appropriate and identifies possible sources of error	• Accurately analyzes data using appropriate and systematic methods to identify and explain patterns • Compares and explains consistency of outcome with initial expectations when appropriate and explains possible sources of error and impact of errors
Generating Interpretations	• Inferences drawn from results are absent. • Makes no mention of design adjustments needing further investigation	• Draws inferences from results without discussing strengths or weaknesses • Makes note of design adjustments that need further investigation	• Explains the strengths OR weaknesses of the inferences drawn from results • Suggests design adjustments worth further investigation	• Explains the strengths AND weaknesses of the inferences drawn from results • Suggests design adjustments worth further investigation and poses new analysis or design

Constructing Evidence-Based Arguments and Communicating Conclusions

What is the evidence that the student can articulate evidence-based explanations and effectively communicate conclusions?

	EMERGING	DEVELOPING	PROFICIENT	ADVANCED
Communicating Results	• Attempts to use multiple representations to communicate results with inaccuracies or major inconsistencies • Implies results with no discussion of next steps	• Uses multiple representations (words, tables, diagrams, graphs, etc.) to communicate results with minor inconsistencies • States results and general discussion of next steps	• Uses multiple representations (words, tables, diagrams, graphs, etc.) to communicate clear results • Explains results with specific discussion of next steps	• Uses multiple representations (words, tables, diagrams, graphs, etc.) to communicate clear and specific results • Explains results and impact on next steps
Following Conventions	• Uses language and tone inappropriate to the purpose and audience • Attempts to follow the norms and conventions of scientific writing with major or consistent errors, such as in the use of technical terms, quantitative data, or visual representations	• Uses language and tone appropriate to the purpose and audience with minor lapses • Follows the norms and conventions of scientific writing with consistent minor errors, such as in the use of technical terms, quantitative data or visual representations	• Uses language and tone appropriate to the purpose and audience • Follows the norms and conventions of scientific writing, including accurate use of technical terms, quantitative data, and visual representations	• Uses language and tone appropriate to the purpose and audience • Consistently follows the norms and conventions of scientific writing, including accurate use of technical terms, quantitative data, and visual representations

Get started with *FIRST*

Steps to Register

FIRST is the world's leading youth-serving nonprofit advancing science, technology, engineering, and math (STEM) education.

FIRST programs are *More Than Robots*® and participants are guided by a signature set of Core Values to conduct research, fundraise, design, build, and showcase their achievements. Our thrilling, sports-like challenges build their self-confidence and collaborative problem-solving skills and have a proven and lasting impact on STEM learning and interest.

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*ages vary by country