Introduction

LEGO® Education is pleased to bring you the LEGO MINDSTORMS® Education EV3 Design Engineering Projects, innovative materials that allow students to design, build, and program robots to solve specific problems.

Who Is It For?

Educators can use the Design Engineering Projects to immerse their students in important concepts in the areas of physical science, technology, and mathematics. The curriculum package integrates digital documentation tools with a software programming environment that enables students to creatively apply key concepts in problem solving projects, emphasizing technical writing, oral and written communication skills, and teamwork.

No prior knowledge of LEGO building, or LEGO MINDSTORMS programming concepts is required before using this material.

What Is It For?

As students work on the Projects, they are the engineers. Each student is a member of a small team in which they brainstorm ideas for solving a design challenge. Once they have a solution, they build, program, and test their model to evaluate how well it worked. As they are learning and having fun, students are applying science, technology, and mathematical skills, and developing their technical language and other communication skills.

What Is in the Pack?

Each of the fifteen projects in the Design Engineering Projects Curriculum Pack includes multimedia materials for students and teachers. Each Project is framed by the engineering process.

Student materials consist of Building Ideas and Key Concepts Projects, which include background information, vocabulary, and programming tools.

Teacher materials include an example of a solution for each Project, with videos of working models, step-by-step building instructions, and downloadable programs.

The LEGO MINDSTORMS Education EV3 Design Engineering Projects are designed for use with the 45544 LEGO MINDSTORMS Education EV3 Core Set and LEGO MINDSTORMS Education EV3 Software.
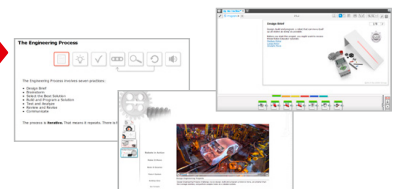
Design Engineering Projects: Student Version

Each Project presents a design challenge within the LEGO® MINDSTORMS® Content Editor with features for multimedia presentation, interaction, and documentation, including:

• Robots In Action videos to provide inspiration, examples of mechanisms and programmed behaviors, and discussion questions
• Building Ideas to support brainstorming and generating creative ideas
• Tables to encourage organization of test data and observations
• Software buttons to easily add video clips, photographs, and other images, text, audio recordings and weblinks

Each student project includes the following pages related to the engineering process:

• Design Brief
• Brainstorm
• Select the Best Solution
• Build and Program
• Test and Analyze
• Review and Revise
• Communicate

Three other pages have been added to the student projects to support assessment. See the Assessment section for more details.
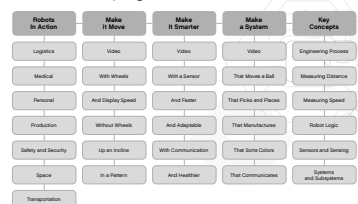
Building Ideas and Key Concepts Projects provide information and *tools-to-think-with* as students work on their projects.

See "Suggested Lesson Planning Routes" later in this guide for information on sequencing design projects for a coherent unit in your classroom.

Design Engineering Projects Overview
Please see page 19.

Design Engineering Projects: Teacher Version

The teacher installation of the Design Engineering Projects opens the Teacher Notes pages for each Project. Teacher Notes include:

• Objectives
• Vocabulary
• Materials Needed
• Prerequisites
• Classroom Tips
• Extensions

In addition, there are comments, suggestions, and links to other useful materials throughout the Project's Teacher Notes.

A sample solution for the design brief is also included, it contains the following pages:

• An overview of the solution
• A video showing the robot moving and responding, demonstrating the solution
• Step-by-step building instructions
• A downloadable program

See "Suggested Lesson Planning Routes" later in this guide for information on sequencing design projects for a coherent unit in your classroom.
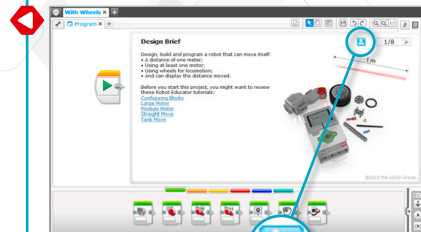
Student page
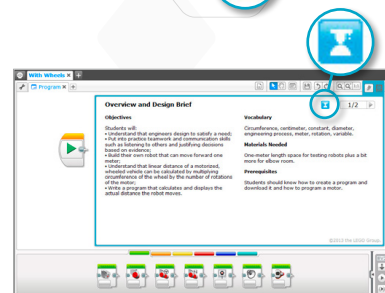
Teacher Notes

Click the button to toggle between student pages and Teacher Notes on project pages.

Assessment

Where Can I Find the Assessment Materials?
Assessment materials are provided for all fifteen Projects.

You can find the materials in two places:

- As PDF documents in the **Make It Move**, **Make It Smarter** and **Make a System** Categories. Each PDF includes assessment pages for the five Projects. Using the PDF form, assessment pages can be easily opened and printed as handouts for students, or for yourself.
- As pages within each of the fifteen Design Engineering Projects. With this option, the assessment is directly integrated into the student's electronic documentation. The EV3 projects are fully editable so you can modify the learning goals or formatting.

What Learning Goals Are Assessed?
Three pages are included within each Project:

1. **Describe Your Ideas:** A page to be used after brainstorming to help students identify three ways to solve the design problem. This page provides specific student support for considering multiple ideas, which is part of the Next Generation Science Standards performance expectations.

2. **Evaluate Design and NGSS Goals:** A rubric page on which students can evaluate their project work according to engineering-related learning goals from the Next Generation Science Standards:
   - How well did their design meet the requirements of the design brief?
   - How well did they use a selected Next Generation Science Standard engineering practice? In the example shown, the practice is "analyzing and interpreting data."

3. **Evaluate Creativity and Collaboration:** A second rubric page on which students can evaluate their project work according to learning goals which are prominent in both the Common Core and 21st century learning literature, specifically:
   - How creative was their solution?
   - How well did their team work together?

Each rubric includes four levels: Bronze, Silver, Gold and Platinum. The intention is to help students reflect on what they have done well in relation to the learning goals and what they might do better. Students can write comments or questions in the Notes column.

Students should mark an X to indicate the appropriate rubric level. If you prefer to emphasize formative assessment, ask the students to record dates in the rubric that correspond to their completion of each level.

You can also use the rubrics for your own evaluation of the students' work, marking your own X or date in the appropriate column, and adding optional comments in the Notes column.
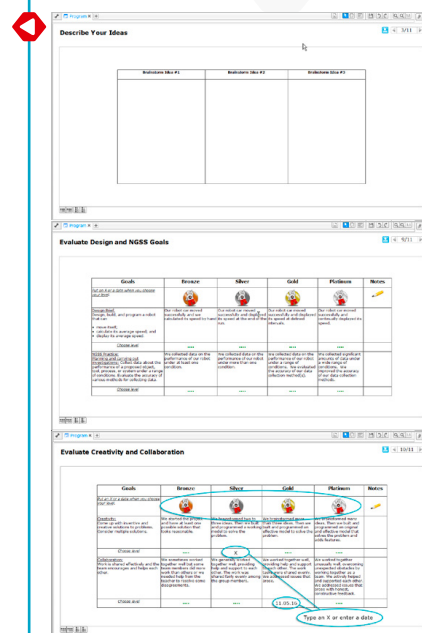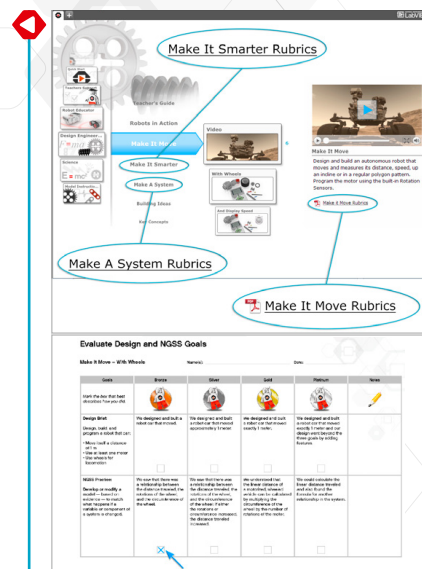
How Do I Get Started?

If you are new to the LEGO® MINDSTORMS® Education EV3 Software, go to the Teacher's Support section and open the LEGO MINDSTORMS Education EV3 Introduction PDF in the Teacher's Information Category, to become familiar with the building and programming environment.

Then select Design Engineering Projects from the EV3 Software menu.

1. Open the **Make It Move With Wheels** Project. Read the design brief.

2. Read the Brainstorm page, these are ideas to help the student brainstorm, they are not complete solutions. Click on one of the Building Ideas links on the page to open the Project and see the building steps.

3. Click to open the **Measuring Distance** Project. Build the suggested model and download the program to experiment with moving the wheel and changing the distance moved based on circumference.

4. Skim through the rest of the **Make It Move With Wheels** Project to become familiar with the questions and supporting pages.

5. A sample solution is shown in the teaching notes, it includes step-by-step building instructions, a program, and a video of the model in motion. Build the sample solution, then download and run the program to see how far the model moves.

6. Choose a lesson planning route that suits your needs. See "Suggested Lesson Planning Routes" later in this introduction.

7. Ensure that each student's computer has a preinstalled student version of the LEGO MINDSTORMS Education EV3 Design Engineering Projects. Refer to the **readme.txt** file for installation instructions. In order to find out which version is installed, look in the top bar of the Software.

8. Ensure that each EV3 Brick has the latest firmware and is fully charged.

Firmware Update

9. It is very important for students to understand the relevance of the elements in the brick set. Run through the naming and basic functionality of the key hardware components and establish a set of brick management rules.

The User Guide is your source for everything relating to the LEGO MINDSTORMS EV3 hardware.
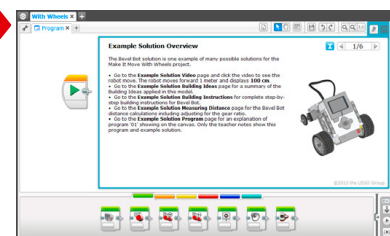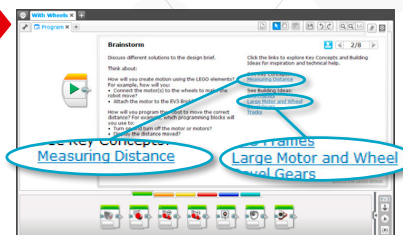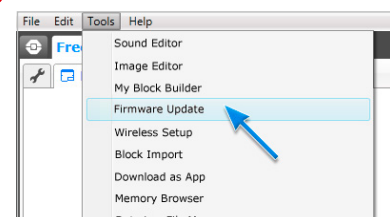
Classroom Management Tips

How Much Time Do I Need?
The time taken to complete each of the Projects depends on a number of factors, including the level of complexity, the age of the student, the student's experience with LEGO® MINDSTORMS®, and their familiarity with the concepts covered in the Project.

There are three Categories of Projects, with five Projects in each Category. The Categories are designed to progress from simple to more complex. Open-ended design is encouraged. The following estimates will give you an idea of the amount of time needed for an average student to complete the building and programming of a Project in each of the Categories.

Project Category	Suggested Completion Time (in minutes)
Make It Move	45 - 120
Make It Smarter	90 - 120
Make a System	120 - 180

If you do not have double-block class time, students can use the digital tools to document their work and then pick up where they left off during the next class period. Documenting the process may encourage students to share their work and consider other design ideas. Allow your students to see and evaluate a variety of ideas and solutions by having each student group present and discuss their projects among a larger group or the whole class.

One of the most important lessons of these Projects is that there is no one perfect solution. There are benefits and drawbacks to every design. More creative solutions may emerge as students share their work. You can also modify the design brief so students have easier or more difficult criteria for satisfactorily completing the Project.

See "Suggested Lesson Planning Routes" in this guide for three units of study: engineering, applied mathematics, and science.

Classroom Management Tips

How Do I Use the Robot Educator Tutorials with the Design Engineering Projects?
The EV3 Software includes forty-eight Robot Educator tutorials. Your students do not need to do all of these tutorials before beginning the Design Engineering Projects.

Some teachers like to have the students work through a few tutorials before beginning the Design Engineering Projects. Others prefer to have students learn hands-on about the EV3 Software and hardware as they design their own robots. Either method can be successful.

Links to useful Robot Educator tutorials are included on the pages of the Design Engineering Projects. You may wish to highlight the Robot Educator menus so that students are familiar with the overall structure and content of the tutorials and how to find information.

If you prefer to start students with the tutorials before beginning the Design Engineering Projects, refer to Robot Educator – Introduction to Robotics Lesson Plan. For most middle school students beginning a robotics course, the Introduction to Robotics Lesson Plan route is a good start. Students completing this route will be familiar with the main EV3 building and programming features, and will be ready for a design challenge.

Introduction to Robotics Lesson Plan
Please see next page.

Introduction to Robotics Lesson Plan

Quick Start Videos	Basics	Beyond Basics	Hardware	Data Logging	Tools
User Guide	Configuring Blocks	Multitasking	Brick Sound	Oscilloscope	Sound Editor
Programming	Straight Move	Loop	Brick Status Light	Live Data Logging	My Blocks
Programming Overview	Curved Move	Switch	Brick Display	Remote Data Logging	Image Editor
Data Logging	Tank Move	Multiple Switch	Brick Buttons	Brick Data Logging	
Data Logging Overview	Move Object	Data Wires	Large Motor	Autonomous Data Logging	
Content Editor	Stop at Line	Random	Medium Motor	Dataset Calculation	
Content Editor Teacher	Stop at Angle	Sensor Blocks	Touch Sensor	Graph Programming	
	Stop at Object	Text	Gyro Sensor		
	Brick Programming	Range	Color Sensor – Color		
		Math – Basic	Color Sensor – Light		
		Gyro Rate	Ultrasonic Sensor		
		Compare			
		Variables			
		Color Sensor – Calibrate			
		Messaging			
		Logic			
		Math – Advanced			
		Arrays			

Classroom Management Tips

Use the Content Editor to Create Customized Tutorials

The integrated Content Editor gives you the ability to customize the project files supplied with the Design Engineering Projects to create your own set of differentiated lessons.

Here are a few ways to customize the Projects:

• Rephrase the text to better match the reading ability of your students
• Add images that are more relevant to your students
• Adjust the design brief criteria to increase or decrease the level of difficulty
• Change the design brief to widen or narrow the scope of possible solutions
• Make your own design briefs
• Modify the supplied rubrics or add your own assessment tools

To ensure that you do not overwrite the files, any changes you make will be saved as a new project. All of the files included with the original project will also be included in the new project file, which you are then free to share with your students (for example, on a network shared drive).

Use the Content Editor as a Student Documentation Tool

The Content Editor also allows students to document their progress and findings as they work through each Project.

The Content Editor allows them to:

• Write descriptions of their group discussions, working procedures, observations, results, and reflections
• Record their data in table form
• Post audio recordings of their work in progress, discussions, and robot's behavior
• Insert their own pages
• Add images and videos of their robot in action
• Evaluate their work using the supplied rubrics
• Share their unique project with other students

For more information on the Content Editor, watch the Quick Start Videos.
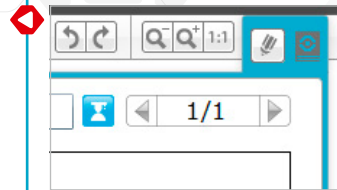
Suggested Lesson Planning Routes

There are many ways to use the Design Engineering Projects in your classroom. There are three lesson planning routes on the following pages, choose the one that best suits your needs.

Introduction to Design Engineering

The aim of this route is to introduce students to problem solving in an engineering context. These lessons assume a 90-minute class period. Adjust the time for discussion, building and programming, group presentations, and feedback as your class requires.

Lesson 1. What Is a Robot and What Do They Do?
a. In the **Robots In Action** Category, real robots from seven industries are represented in videos. Watch one or more of the clips in small groups or as a class.
b. Discuss the questions included in the video projects and draw conclusions about where robots are found now, and where they may be found in the future.
c. Distribute building sets to each team. Challenge students to use the Robot Educator tutorials to control a motor, EV3 Brick Display, and EV3 Brick Status Lights. By the end of the lesson, students should know how to build with a motor, how to create and download a program, and how to run it on the EV3 Brick.
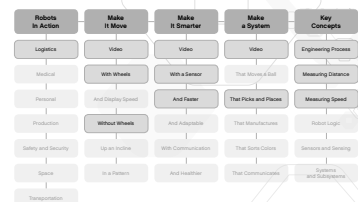
Lesson 2. Working as Engineers
a. Review the **Key Concepts Engineering Process** Project to help students become familiar with the language and process of engineering.
b. Challenge students to design, build, and program a robot using the **Make It Move With Wheels** Project.
c. During the students' brainstorming process, try the **Key Concepts Measuring Distance** Project. You may wish to work with the building and programming tools as a class or have students work with the tools on their own. This Project uses a motorized wheel and a program with the EV3 Brick to convert motor rotations to distance (in centimeters).

Lesson 3. Make It Move Without Wheels
a. Challenge students to design, build, and program a robot using the **Make It Move Without Wheels** Project. This is a creative design challenge. Moving without using wheels demands experimenting with other kinds of mechanisms.
b. Use the **Make It Move Video** and discussion questions for inspiration and support in finding ways that robots can move without wheels.

Introduction to Design Engineering
Please see page 12.

Robots In Action	Make It Move	Make It Smarter	Make a System	Key Concepts
Logistics	Video	Video	Video	Engineering Process
Medical	With Wheels	With a Sensor	That Moves a Ball	Measuring Distance
Personal	And Display Speed	And Faster	That Picks and Places	Measuring Speed
Production	Without Wheels	And Adaptable	That Manufactures	Robot Logic
Safety and Security	Up an Incline	With Communication	That Sorts Colors	Sensors and Sensing
Space	In a Pattern	And Healthier	That Communicates	Systems and Subsystems
Transportation				

Lesson 4. Using Sensors

a. Challenge students to explore sensor feedback and control the display, lights, and sounds of their robot with the **Make It Smarter With a Sensor** Project.
b. During the students' Brainstorming process, refer to the **Key Concepts Sensors and Sensing** Project. You may wish to take some class time to discuss each sensor and how it can be used.

Lessons 5 and 6. Sensors and Motors

a. Challenge students to control robot behavior using motors and sensor feedback with the **Make It Smarter and Faster** Project.
b. Use the **Make It Smarter Video** and discussion questions for inspiration and support in finding other ways robots move as they react to sensors and the environment.

Lessons 7 and 8. Systems Thinking

a. Review the **Key Concepts Systems and Subsystems** Project to help students become familiar with the language, and conceptual and practical thinking about a robot as a larger system of subsystems.
b. Challenge students to design a robotic system with the **Make a System That Picks and Places** Project.
c. For a more elaborate final project, you could challenge the students to combine their robotic systems into a large system that moves the Cuboid from one robot to another around the room.

For additional lessons, refer to the other Projects available in the **Make It Move**, **Make It Smarter**, and **Make a System** Categories. You may wish to let the students choose what interests them, or create their own design challenge.

Introduction to Design Engineering

Robots In Action	Make It Move	Make It Smarter	Make a System	Key Concepts
Logistics	Video	Video	Video	Engineering Process
Medical	With Wheels	With a Sensor	That Moves a Ball	Measuring Distance
Personal	And Display Speed	And Faster	That Picks and Places	Measuring Speed
Production	Without Wheels	And Adaptable	That Manufactures	Robot Logic
Safety and Security	Up an Incline	With Communication	That Sorts Colors	Sensors and Sensing
Space	In a Pattern	And Healthier	That Communicates	Systems and Subsystems
Transportation				

Engineering and Applied Mathematics
This lesson planning route shows students how mathematics can be applied to a wide range of robot tasks and behaviors. These lessons assume a 90-minute class period. Adjust the time for discussion, building and programming, group presentations, and feedback as your class requires.

Lesson 1. What Is a Robot and What Do They Do?
a. The **Robots In Action** Category features videos of real robots from seven industries. Watch one or more of the videos in small groups or as a class.
b. Discuss the questions included in the video projects and draw conclusions about where robots are found now, and where they may be found in the future.
c. Distribute building sets to each team. Challenge students to use the Robot Educator tutorials to control a motor, EV3 Brick Display, and EV3 Brick Status Lights. By the end of the lesson, students should know how to build with a motor, how to create and download a program, and how to run it on the EV3 Brick.

Lesson 2. Working as Engineers
a. Review the **Key Concepts Engineering Process** Project to help students become familiar with the language and process of engineering.
b. Challenge students to design, build, and program a robot using the **Make It Move With Wheels** Project.
c. During the students' brainstorming process, try the **Key Concepts Measuring Distance** Project. You may wish to work with the building and programming tools as a class or have students work with the tools on their own. This Project uses a motorized wheel and a program with the EV3 Brick to convert motor rotations to distance (in centimeters).

Lessons 3 and 4. Make It Move Up an Incline
a. Challenge students to design a robot for the **Make It Move Up an Incline** Project. Students working with this challenge are encouraged to explore gear ratios to move robots up a steep incline ramp.
b. During their brainstorming process, students can try the **Building Idea Gear Down** Project with the **Key Concepts Measuring Distance** and **Measuring Speed** Projects. This will show them how changing gears affects motor rotations, and how to adapt the measuring distance program to adjust for gear ratio.

Lessons 5 and 6. Make It Move In a Pattern
a. Challenge students to design a robot for the **Make It Move In a Pattern** Project. Students working with this challenge are encouraged to explore how two motors can be used to move robots forward, backward, and turn to move in geometric patterns.
b. The sample solution for this Project shows how to add the **Pen Holder** from the **Building Ideas** Category so the robot draws as it moves. You may wish to create this robot and demonstrate the robot drawing shapes on paper.
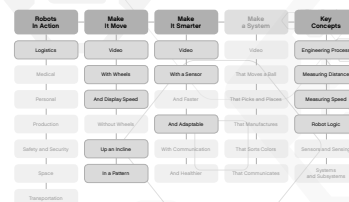
Lesson 7. Using Sensors

a. Challenge students to explore sensor feedback and how to control the display, lights, and sounds of their robot for the **Make It Smarter With a Sensor** Project.

b. During the students' brainstorming process, refer to the **Key Concepts Sensors and Sensing** Project. You may wish to take some class time to discuss each sensor and how it can be used.

Lesson 8. Robot Behavior

a. Challenge students to design a robot that changes behavior in response to light and darkness in the **Make It Smarter and Adaptable** Project.

b. Use the **Make It Smarter Video** and discussion questions for inspiration and support in finding other ways that robots move as they react to sensors and the environment.

For additional lessons, refer to the other Projects such as **Make It Smarter and Healthier** to program a timed system. Working on solutions for the **Make a System That Picks and Places** and **Make a System That Manufactures** Projects will introduce concepts such as accuracy, precision, efficiency, and repeatability.

Engineering and Applied Mathematics

Robots In Action	Make It Move	Make It Smarter	Make a System	Key Concepts
Logistics	Video	Video	Video	Engineering Process
Medical	With Wheels	With a Sensor	That Moves a Ball	Measuring Distance
Personal	And Display Speed	And Faster	That Picks and Places	Measuring Speed
Production	Without Wheels	And Adaptable	That Manufactures	Robot Logic
Safety and Security	Up an Incline	With Communication	That Sorts Colors	Sensors and Sensing
Space	In a Pattern	And Healthier	That Communicates	Systems and Subsystems
Transportation				

Science and Engineering

The aim of this lesson planning route is to introduce students to scientific concepts and design engineering processes in a hands-on approach. These lessons assume a 90-minute class period. Adjust the time for discussion, building and programming, group presentations, and feedback as your class requires.

Lesson 1. What Is a Robot and What Do They Do?
a. The **Robots In Action** Category features videos of real robots from seven industries. Watch one or more of the videos in small groups or as a class.
b. Discuss the questions included in the video projects and draw conclusions about where robots are found now, and where they may be found in the future.
c. Distribute building sets to each team. Challenge students to use the Robot Educator tutorials to control a motor, EV3 Brick Display, and EV3 Brick Status Lights. By the end of the lesson, students should know how to build with a motor, how to create and download a program, and how to run it on the EV3 Brick.

Lesson 2. Working as Engineers
a. Review the **Key Concepts Engineering Process** Project to help students become familiar with the language and process of engineering.
b. Challenge students to design, build, and program a robot using the **Make It Move With Wheels** Project.
c. During the students' brainstorming process, try the **Key Concepts Measuring Distance** Project. You may wish to work with the building and programming tools as a class or have students work with the tools on their own. This Project uses a motorized wheel and a program with the EV3 Brick to convert motor rotations to distance (in centimeters).

Lesson 3. Make It Move and Display Speed
a. Challenge students to design, build, and program a robot using the **Make It Move and Display Speed** Project.
b. During the students' brainstorming process, try the **Key Concepts Measuring Speed** Project. You may wish to work with the building and programming tools as a class or have students work with the tools on their own. This Project uses a motorized wheel and a program with the EV3 Brick to convert motor rotations to speed by dividing distance (in centimeters) by the elapsed time.

Lessons 4. Make It Move Up an Incline
Since students are familiar with measuring distance and speed, working with this Project will take less time than in other lesson planning routes.
a. Challenge students to design a robot and **Make It Move Up an Incline**. Students working with this challenge are encouraged to explore gear ratios to move robots up a steep incline ramp.
b. During their brainstorming process, students can try the **Building Idea Gear Down** Project with the Projects called **Key Concepts Measuring Distance** and **Measuring Speed** to see how changing gears affects motor rotations. The Projects also show how to adapt the measuring distance program to adjust for gear ratio.

Science and Engineering
Please see page 18.
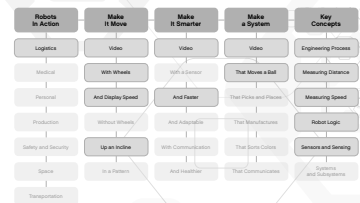
Lessons 5 and 6. Sensors and Motors
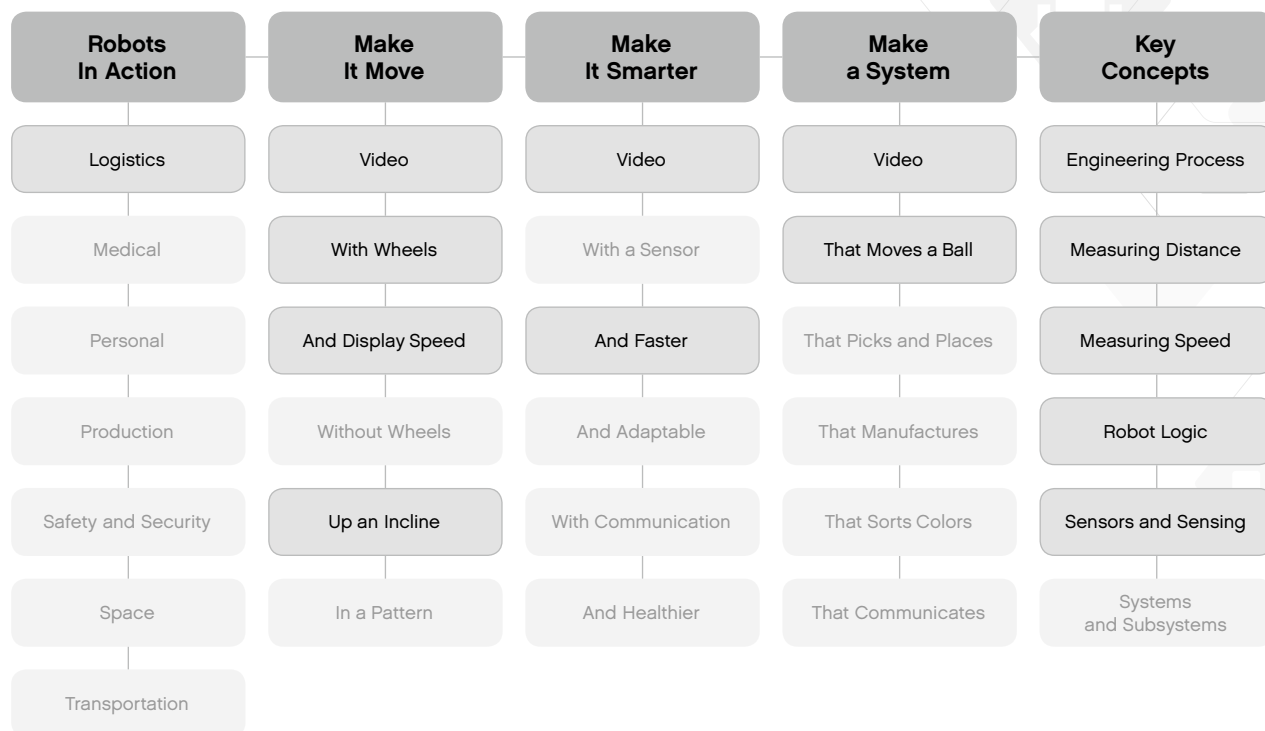a. Challenge students to control robot behavior using motors and sensor feedback for the **Make It Smarter and Faster** Project.
b. Use the **Make It Smarter Video** and discussion questions for inspiration and support in finding other ways that robots move as they react to sensors and the environment.
c. During the students' brainstorming process, refer to the **Key Concepts Sensors and Sensing** Project. You may wish to take some class time to discuss each sensor and how it can be used.

Lessons 7 and 8. Systems Thinking
a. Review the **Key Concepts Systems and Subsystems** Project to help students become familiar with the language, and conceptual and practical thinking about a robot as a larger system of subsystems.
b. Challenge students to design a robotic system with the **Make a System That Moves a Ball** Project.
c. For a more elaborate final project, you could challenge the students to combine their robotic systems into a large system that moves the ball from one robot to another around the room.

For additional lessons, refer to the other Projects in the **Make It Smarter** Category to introduce concepts such as adaptation, communication, and more opportunities for data collection and analysis. See also the **Make a System That Picks and Places** and **Make a System That Manufactures** Projects to introduce concepts such as accuracy and precision.

Science and Engineering

Robots In Action	Make It Move	Make It Smarter	Make a System	Key Concepts
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Safety and Security	Up an Incline	With Communication	That Sorts Colors	Sensors and Sensing
Space	In a Pattern	And Healthier	That Communicates	Systems and Subsystems
Transportation				

Design Engineering Projects Overview

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