Introduction

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

Who Is It For?

Using the Design Engineering Projects, educators can immerse their students in physical science, technology, and mathematics concepts. Students can apply those concepts in creative problem-solving projects supported by digital documentation tools integrated with a software programming environment. Educators can also emphasize technical writing as well as oral and written communication skills and teamwork. No prior knowledge of LEGO building, MINDSTORMS® programming concepts, or data logging is required before using this material.

What Is It For?

As they work on Design Engineering Projects, students are the engineers. Each student is a member of a small team: students brainstorm ideas for solving a design challenge, and then 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 mathematics skills and developing technical language and other communication skills working with their team.

What Is In The Pack?

2005544 – LEGO® MINDSTORMS® Education EV3 Design Engineering Projects
The fifteen projects in Design Engineering Projects include student and teacher materials in the multimedia content environment. Each project is framed using the engineering process. Other student supporting materials include building ideas and key concepts projects that include background information and vocabulary and programming tools. Teacher materials include example solutions with videos of a working model, 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 in the LEGO MINDSTORMS Content Editor with features for multimedia presentation, interaction, and documentation, including:

- Robots In Action videos – these real life-robots provide inspiration, examples of mechanisms, and programmed behaviors and discussion questions;
- Building Ideas to support brainstorming and generating creative ideas;
- Tables to encourage organizing test data and observations;
- Graphs and other data logging tools to enable analyzing sensor data;
- Software buttons to easily add video clips, photographs, and other images, text, audio recordings, and weblinks.

Each student project includes pages related to the engineering process as follows:

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

Design Engineering Projects Overview
Please see page 18.

Building Ideas and Key Concepts projects provide information and "tools-to-think-with" as students work on their projects.
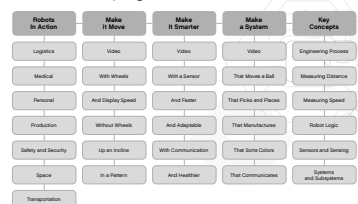
Teacher notes are part of each design project. Teacher notes include Objectives, Materials Needed, Vocabulary, and other practical suggestions. Also included is an Example Solution with a robot video, step-by-step building instructions, and a downloadable program or graph data.

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

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 teacher notes.

An Example Solution for the design brief is also included. Each Example Solution has these pages:

- Overview summarizing the example
- Video showing the robot moving and responding, demonstrating a solution to the design brief
- Step-by-step building instructions
- Downloadable program or graph data

See the "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.

How Do I Get Started?

If you are new to LEGO MINDSTORMS Education EV3 software, go to the Robot Educator Teacher's Guide and click on Robot Educator – Introduction 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. Click on one of the Building Ideas links on the page to open the project and see the building steps. Notice that these are ideas to help the student brainstorm. They are not complete solutions.

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

4. Now skim through the rest of the Make It Move With Wheels project to become familiar with the questions and supporting pages.

5. An example solution is shown in the Teacher Notes. Building instructions and a program are included. You can build the example solution using the step-by-step instructions. Then download and run the program to see how far the model moves. You can also watch the video of the model.

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 LEGO MINDSTORMS Education EV3 Design Engineering Projects. Refer to the **readme.txt** file for installation instructions. You can see which version is installed in the top bar of the software.

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

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.
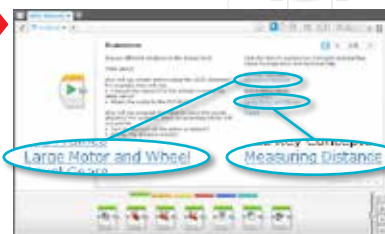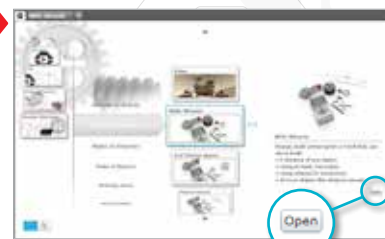
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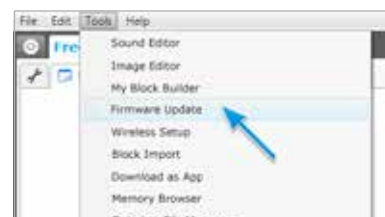
Classroom Management Tips

How Much Time Do I Need?

Projects
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, and the student's experience with LEGO MINDSTORMS and the concepts covered in the relevant project.

There are three categories, with five projects in each category. The categories are designed to progress from easier to harder. Open-ended design is encouraged. There is no one example that can be timed. However, the following estimates provide a range of time that would be needed for an average student to complete the building and programming of a project in each of the following categories:

Projects in category	Suggested completion time (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. You may, for example, have each student group present and discuss their projects among a larger group or the whole class. That way, the variety of ideas and solutions can be seen and evaluated.

One of the important lessons for Design Engineering is that there is no one perfect solution: there are benefits and drawbacks to any design. More creative solutions may emerge as students consider other design ideas and share their work. You can also modify the design brief so the students have less- or more-demanding 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 Robot Educator Tutorials with the Design Engineering Projects?

EV3 software includes forty-eight Robot Educator tutorials. Your students do not need to do all of these tutorials before beginning with 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 about the software and hardware materials 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 in the tutorials before beginning the Design Engineering Projects, see the Robot Educator – Introduction Lesson-Planning Routes. For most middle school students beginning a robotics course, the Basics of Robotics 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.

Basics of Robotics
Please see next page.

Basics of Robotics

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

Content Editor

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;
• Add your own rubrics or other assessment tools.

To ensure that you do not overwrite the files supplied in Design Engineering Projects, any changes you make will be saved as a new project. All 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).

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 or graph form;
• Post audio recordings of their work in progress, discussions, and robot behavior;
• Insert their own pages;
• Add images and videos of their robot in action;
• Share their unique project with other students.

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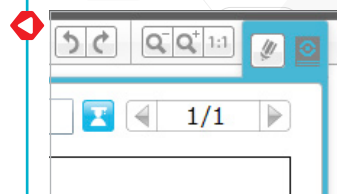
Suggested Lesson Planning Routes

There are many ways to use the Design Engineering Projects in your classroom. On the following pages are three lesson planning routes. Choose the one that 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 make conclusions about where robots are found now and may be found in the future.
c. Hand out the building sets for 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 **Make It Move With Wheels**.
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. **Measuring Distance** 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 **Make It Move Without Wheels**. 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 other ways that robots can move without wheels.

Introduction to Design Engineering
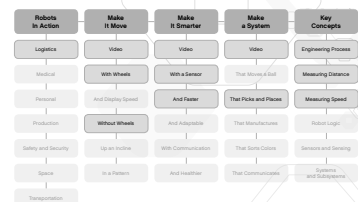
Lesson 4. Using Sensors
a. Challenge students to explore sensor feedback and control the display, lights, and sounds of their robot for **Make It Smarter With a Sensor**.
b. During the students' Brainstorming process, refer to the **Key Concepts Sensors and Sensing** project. You may wish to take some class time to discuss each sensor and how it can be used.
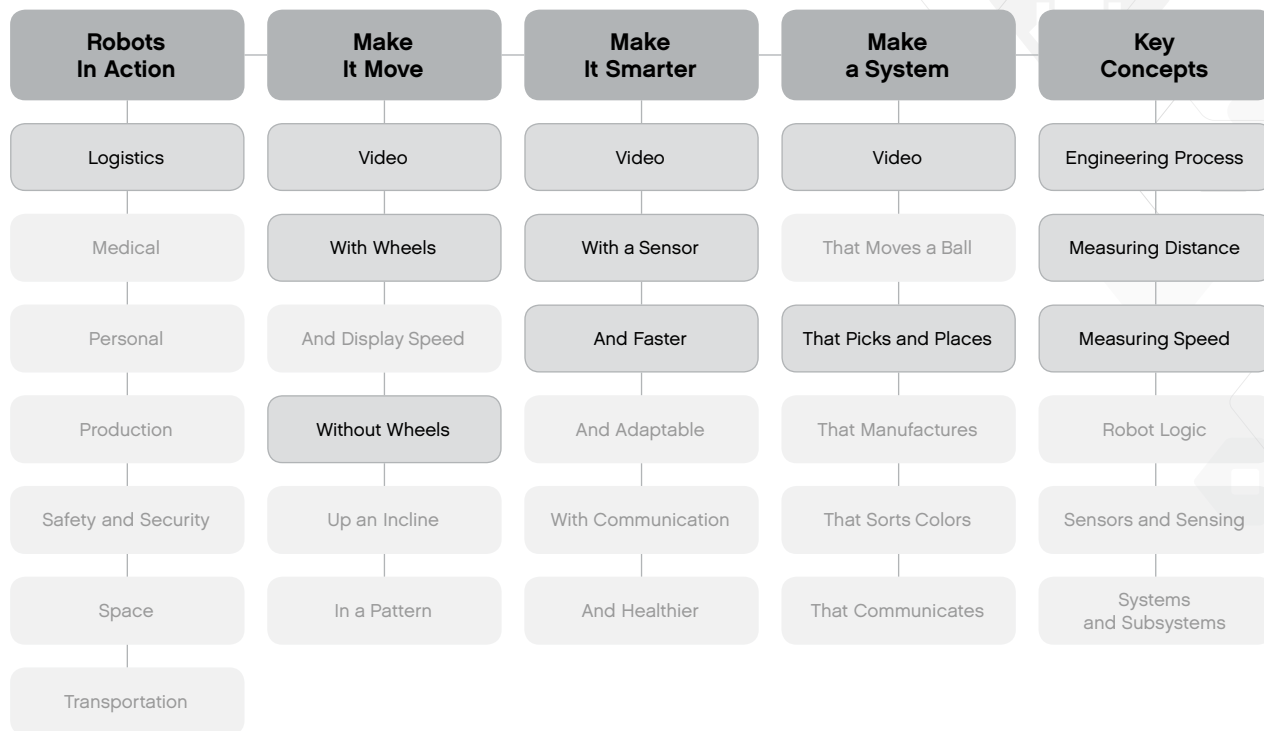
Lessons 5 and 6. Sensors and Motors
a. Challenge students to control robot behavior using motors and sensor feedback for **Make It Smarter and Faster**.
b. Use the **Make It Smarter Video** and discussion questions for inspiration and support in finding other ways robots move as they react to sensors 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 the conceptual and practical thinking about a robot as a larger system of subsystems.
b. Challenge students to design a robotic system with **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 Make It Move, Make It Smarter, and Make a System. 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 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. 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 make conclusions about where robots are found now and may be found in the future.
c. Hand out the building sets for 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. Measuring Distance 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 to see how changing gears affects the motor rotations. The projects also show 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 and **Make It Move In a Pattern**. Students working with this challenge are encouraged to explore how two-motor robots can be used to move robots forward, backward, and turn to move in geometric patterns.
b. The Example Solution for this project shows how to add the **Pen Holder** from **Building Ideas** so the robot draws as it moves. You may wish to create this robot and demonstrate the robot drawing shapes on paper.

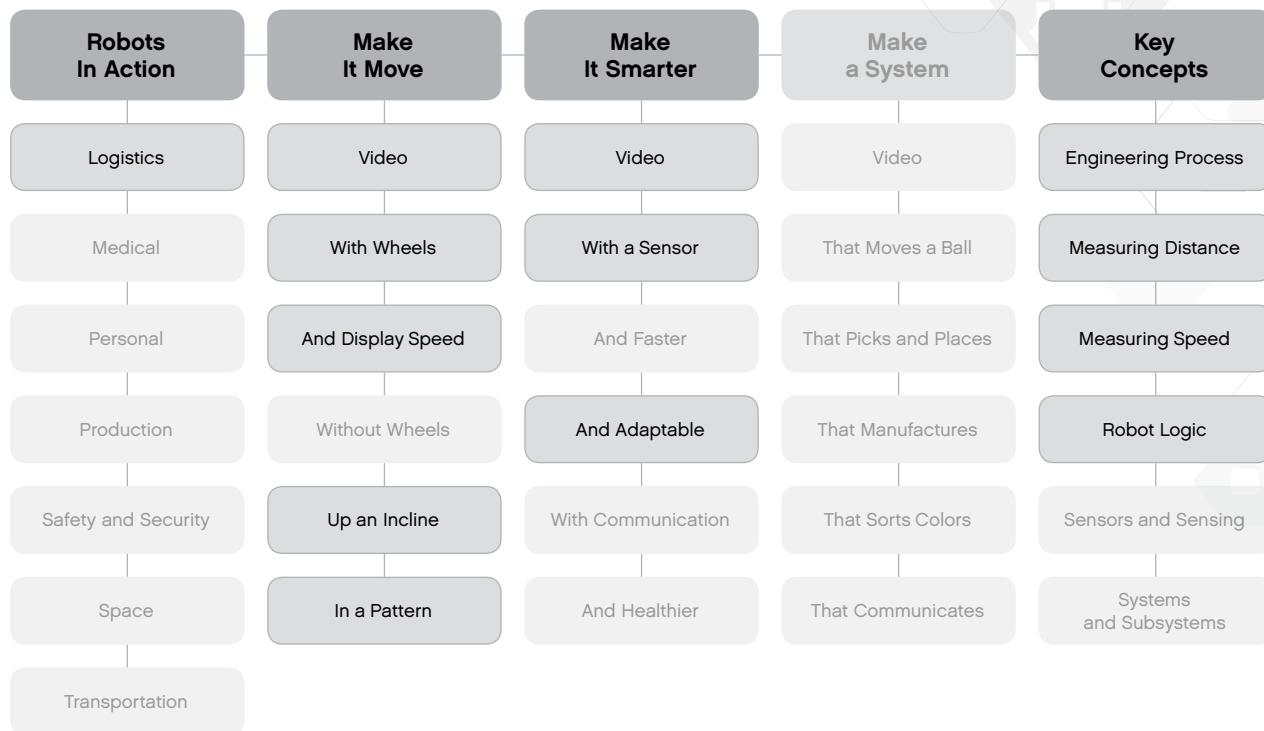**Engineering and Applied Mathematics**
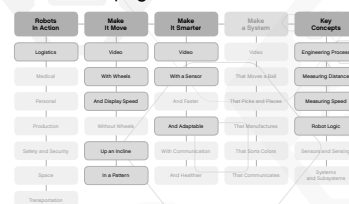
Lesson 7. Using Sensors
a. Challenge students to explore sensor feedback and controlling the display, lights, and sounds of their robot for the **Make It Smarter With a Sensor** project. The Experiment graph set up in the project shows the *Y*-axis for each sensor and indicates the units of measure for each type of sensor.
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. Graphing and 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 **Make a System That Picks** and Places and **Make a System That Manufactures** will add 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				

Middle School Science

The aim of this 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.

Science and Engineering
Please see page 17.

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 make conclusions about where robots are found now and may be found in the future.
c. Hand out the building sets for 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 **Make It Move With Wheels**.
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. Measuring Distance 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 **Make It Move and Display Speed.**
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. Measuring Speed uses a motorized wheel and a program with the EV3 Brick to convert motor rotations to distance in centimeters divided 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 the motor rotations. The projects also show how to adapt the measuring distance program to adjust for gear ratio.
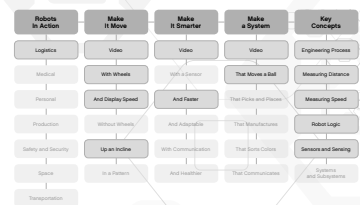
Lessons 5 and 6. Sensors and Motors

a. Challenge students to control robot behavior using motors and sensor feedback for **Make It Smarter and Faster**.
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 the conceptual and practical thinking about a robot as a larger system of subsystems.
b. Challenge students to design a robotic system with **Make a System That Moves a Ball**.
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 Make It Smarter to add concepts such as adaptation, communication, and more opportunities for data collection and analysis. See also **Make a System That Picks and Places** and **Make a System That Manufactures** to add concepts such as accuracy and precision.

Science and 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				

Design Engineering Overview

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				