

## How Robotics Achieves Outcomes

### Information Addressing how this Robotics Curriculum Addresses Content Standards

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You will find information regarding how this curriculum addresses aspects of the various standards on the following pages:

Science Standards – *Page 2*

Mathematics Standards – *Page 6*

Technology Standards – *Page 9*

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### How to Use this Document

This document is designed to link standards to the ways in which a robotics curriculum address those standards. Each standard or organizer is broken up into two sections, following the format below. The robotics link may refer to specific Activities and Investigations within the product, or it may refer to overarching ideas and general principles that are covered.

### Standard Title or Description

Standard	Robotics Link
<i>On the left</i> is a description of the standard or particular point of the standard that is addressed through robotics.	<i>On the right</i> is a description of how robotics in general and this curriculum in particular addresses this standard.

## Science Standards Addressed

From the National Science Education Standards (NSES)

### Systems, Order and Organization

The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once.

A system is an organized group of related objects or components that form a whole.

The goal of this standard is to think and analyze in terms of systems.

Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable.

Prediction is the use of knowledge to identify and explain observation, or changes, in advance. The use of mathematics allows for greater or lesser certainty of predictions.

Order is the behavior of units of matter, objects, organisms or events in the universe – can be described mathematically.

Types and levels of organization provide useful ways of thinking about the world

Robots are excellent examples of systems, with many heterogeneous components interacting in organized, methodical ways to achieve results as a whole that they could not have achieved separately.

Examples include:

- Navigation systems (e.g. sensor tells the robot where it is, programmable controller tells the robot how to interpret this information, motors move in order to achieve the desired result)
- Sensing systems (electrical, mechanical, and programming elements of a sensor)
- Power & transmission systems (motor, axle, gear, wheel)
- Manipulator systems
- Lifting systems, vision systems, etc.

Each system can be broken down into subsystems.

Robotics technology is built upon a series of behaviors that can be measured mathematically and are understandable and predictable.

There are many examples that are easy for students to manipulate and understand:

- Gears and mechanical advantage
- Sensors and electronic control
- Wheel diameter and its effect on distance traveled
- Rotation sensor readings and robot path planning

### Evidence, Models and Explanation

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows

The investigations included in this curriculum allow students to collect evidence to investigate scientific principles. Robots

individuals to predict changes in natural and designed systems.

Models are tentative schemes or structures that correspond to real objects, events, or classes of events that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence into logical statements. Terms like “hypothesis,” “model,” “law,” “theory,” and “paradigm” are used to describe various scientific explanations.

physically demonstrate many scientific concepts to make them more clear and understandable.

Examples include:

- Electronics and basic circuitry, which can be demonstrated using touch sensors and the NXT power supply
- Gear trains, which demonstrate the ability to mathematically predict mechanical advantage and speed.
- Light sensors, which can detect infrared as well as visible light

## Constancy, Change and Measurement

Although most things are in the process of becoming different – changing – some properties of objects and processes are characterized by constancy; the speed of light, the charge of an electron, the total mass plus energy of the universe.

Energy can be transmitted and matter can be changed. Nevertheless, when measured, the sum of energy and matter in the system, and, by extension, the universe, remains the same.

Mathematics is essential for accurately measuring change.

Different systems of measurement are used for different purposes.

Scale includes understanding that different characteristics, properties, or relationships with a system might change as its dimensions are increased or decreased.

Rate involves comparing one measured quantity with another measured quantity, for example, 60 meters per second.

Robots rely on the use of many innate constants in their basic operation. Ultrasonic sensors, for instance, calculate distance based around an assumed value for the speed of sound.

In calculating the distance a robot travels per spin of its motor, fundamental mathematical relationships govern the elements of change and constancy between the different factors involved. For example, the ratio between the diameter and circumference of the wheel is constant ( $C=\pi d$ ). On the other hand, a robot doesn't always need to use the same wheels – they can change – yet, no matter what the size of the wheel, the distance traveled per turn of the wheel remains proportional.

Measurement is fundamental to all aspects of robotics, from matching dimensions of parts to ensure that they can connect properly, to measuring how far your robot went, to measuring how well a prediction matched a result.

## Evolution and Equilibrium

Evolution is a series of changes, sometimes gradual and sporadic, that accounts for the present form and function of objects, natural systems and designed systems. The general idea of evolution is that the present arises from materials and forms of the past.

Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions. For example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates.

Every robot design has a story. As they build and modify their robot designs, students can trace the evolution of their creation as they adapt it in different ways that allow it to complete different tasks, building upon lessons learned from their previous designs.

Equilibrium appears in many different forms as a design factor that students will encounter in designing their robots. For example, a robot's top speed is an equilibrium point between the physical force of friction and the force generated by the motor.

## Form and Function

Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world.

When designing robots, form always follows function.

Whether the design decision involves using large versus small wheels, making the motor power high versus low, or selecting the sensing device the robot will use, all decisions are based on what the robot is expected to do: its function. All of these decisions will affect the final shape of the robot: its form.

## Science as Inquiry – Content Standard “A”

As a result of activities in all grades, all students should develop:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Students should be engaged in activities that:

- Begin with a question
- Allow them to perform an investigation
- Gather evidence
- Formulate an answer to the original question
- Communicate the investigative process and results

The guided investigations in Robotics Engineering are targeted at specific relevant questions about robotics technologies and concepts that lead to rich exploratory experiences.

Some investigations focus on specific portions of the inquiry process, such as evidence-gathering or hypothesis evaluation. Others begin with a question and seek an answer using general inquiry processes.

Explanation and evaluation are primary abilities applied in answering questions, not simply calculations or summarization.

## Physical Science – Content Standard “B”

As a result of activities in the middle grades, all students should develop an understanding of:

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects.

Understanding of energy will include light, heat, sound, electricity, magnetism, and the motion of objects.

Robotics is able to demonstrate many applied physical concepts. Here are a few examples:

- Mechanical advantage (gears)
- Basic circuitry (sensor operation)
- Digital and analog electronics (sensors)
- Light (lamp, light sensor)
- Sound (ultrasonic, sound sensors)
- Speed (motors)
- Friction (robot movement)

Quantitative measurement is a staple of all investigations.

## Science and Technology – Content Standard “E”

As a result of activities in all grades, all students should develop:

- Abilities in technological design
- Understandings about science and technology

Students should begin to differentiate between science and technology.

In the middle school years, scientific investigations can be completed by activities in which the purpose is to meet a human need, solve a problem, or develop a product rather than explore ideas about the natural world.

Robotics is the premier example of the marriage of science and technology, especially as related to the solving of problems or human needs.

Every investigation students conduct with the robot is motivated by the need to advance the performance of the robot in order to meet performance criteria, connecting the “need to know” with the “ability to do”.

## Mathematics Standards Addressed

From the National Council of Teachers of Mathematics (NCTM) Standards

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### Numbers and Operations

- Understand numbers, ways of representing number, relationships among numbers and number systems.
- Understand meaning of operations and how they relate to one another.
- Compute fluently and make reasonable estimates.

Robotics uses numbers and operations in nearly all lessons, for example:

- Calculating distance with rotational sensors (equations, equalities)
- Gears, gear ratios and speed (ratios and proportions)
- Light sensors and threshold (inequalities)
- Wheel circumference, radius and diameter (geometric relationships)

### Algebra

- Represent and analyze mathematical situations and structures using algebraic symbols.
- Use mathematical models to represent and understand qualitative relationships.
- Analyze change in various contexts.

Robotics lessons that involve algebra include the following:

- Switch blocks (inequalities)
- Programming sensors and thresholds (inequalities)
- Measuring turns (equalities, solving equations)
- Gears and speed (ratios, direct and indirect proportionality)

### Geometry

- Precisely describe, classify, and understand relationships among types of two and three-dimensional objects using their defining properties.
- Specify location and describe spatial relationships using coordinate geometry and other representational systems.

Robotics situations involving geometry include:

- Wheel rotations and circumference (diameter, circumference)
- Identifying locations in order to program a robot to move from point to point (connected path segments)
- Interlocking gears and gear ratios (discrete combinations of radii)

## Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement.
- Apply appropriate techniques, tools and formulas to determine measurements.

Understanding the significance and meaning of measurements are central to the understanding of robotics:

- Distance the robot travels (linear measurement, meter stick)
- Amount a motor turns (angular measurement)
- Directional change of the robot (angular measurement, protractor)
- Speed of the robot (rate measurement, meter stick, built-in timer)
- Physical quantities measured by sensors (touch, sound, light, distance)
- Detectable region of a sensor (ultrasonic sensor, meter stick, 2D graph paper)

## Problem Solving

- Build new mathematical knowledge through problem solving.
- Solve problems that arise in mathematics and other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Monitor and reflect on the process of problem solving.

In the lessons, there are both guided and open-ended design problems that involve designing, building, and programming needed to create autonomous robots.

- How do I get a robot to move a certain distance? (solved through measurement and the verification and use of a proportionality relationship)
- What does the sound sensor measure? (solved by graphing the sensor readings with tones of varying volume and pitch, then seeing which one indicated an orderly relationship)

## Reasoning and Proof

- Recognize reasoning and proof as fundamental aspects of mathematics.
- Make and investigate mathematical conjectures.
- Develop and evaluate mathematical arguments and proofs.
- Select and use various types of reasoning and methods of proof.

Reasoning in robotics comes in many different forms, including the following:

- Experimental reasoning, proof using measurements and physical evidence (Wheels and Distance)
- Reasoning using equations, proof by solving (Measured Turns)
- Reasoning about graphs, proof by observing trends (Frequency and Amplitude)



## Communications

- Organize and consolidate their mathematical thinking through communications.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Use the language of mathematics to express mathematical ideas precisely.

Each Activity and Investigation includes worksheet questions that require the student to reflect on what they have accomplished or experienced, and describe it or some aspect of it in their own words to someone else. Emphasis is placed upon explaining reasoning in addition to showing calculations.

The End of Project Activities also include opportunities for students to communicate with their peers and teachers what they have learned and accomplished.

## Connections

- Recognize and use connections among mathematical ideas.
- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
- Recognize and apply mathematics in contexts outside of mathematics.

One of the strongest features of using robotics to teach math, science, engineering, technology and communications is its ability to make links between multiple disciplines. Students are able to take what they know and connect it to what they are learning, synthesizing new knowledge as they continue.



## Technology Standards Addressed

From the International Technology Education Association (ITEA) Standards

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### The Nature of Technology

1. Students will develop an understanding of the characteristics and scope of technology.
2. Students will develop an understanding of the core concepts of technology.
3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

All robotics activities provide excellent hands-on exposure to technology in use and development.

- “Connect” activities feature linkages to real-world robots that allow students to connect their designs to real-world needs and solutions
- Successful robot operation revolves around the application of systems concepts to make sensors, actuators, and other components work together
- Design processes take into account goals, resources, and trade-off factors to achieve optimal results
- Technology exists in proper context alongside applications in science, math, and engineering
- Several different technologies (e.g. desktop computer, USB/Bluetooth peripheral interface, mobile robotics controller, electromechanical sensors and actuators) are routinely used together in the operation of the NXT robot system, and all are necessary for it to work

## Technology and Society

6. Students will develop an understanding of the role of society in the development and use of technology.

Activities are linked to real world robots that use similar technologies to accomplish tasks that fulfill a social and/or economic need in the real world. For example:

- Follow the Guidelines (robot follows a line on the table; linked to AMTS real-world robot, which follows a pattern on a warehouse floor to transport materials autonomously)

Some activities focus specifically on Human-Robot Interaction (HRI), an emerging field dealing specifically with psychological and design issues relating to the use of robots in human environments.

- Hello! My Name Is... (students use sound and graphical elements to make the robot communicate with people)
- Full Stop (emergency stop functionality for a runaway mobile robot)

## Design

8. Students will develop an understanding of the attributes of design
9. Students will develop and understanding of engineering design
10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem-solving.

Students gain first-hand experience with developing a functional robotic system in many activities, including:

- Hello! My Name Is...(iterative – students design a robot to convey an emotion, then test their program with real users to see if they can correctly interpret the robot's actions)
- Follow the Guidelines and Faster Line Tracking (guided – students first build a functional line-following robot, then improve its performance by modifying the design)
- End of Project Housekeeping Challenge (goal-based open ended challenge – students in teams will develop their own robotic solutions to a board-based challenge)

## Abilities for a Technological World

11. Students will develop the ability to apply the design process
12. Students will develop the ability to use and maintain technological products and systems

Students will apply design processes continually while working with and developing the robot. Here are some basic examples:

- Full Speed Ahead (students learn the basics of making the robot move)
- Obstacle Detection (students add a touch sensor and an ultrasonic rangefinder to help the robot avoid collisions)
- Get in Gear (students adapt the robot's drive mechanism to make it faster or slower, weaker or stronger)

In the course of working with the robot, students will be responsible for the maintenance of their robots:

- Mechanical soundness (the robot needs to be kept in good enough condition to perform its tasks daily)
- Organizing information (students must keep good enough records to know how to use systems they initially designed days or weeks earlier)
- Troubleshooting (robots have problems—often—and students must be able to identify and solve these issues as they arise)

Students will work with many important technologies as part of the operation of the NXT system:

- Electronic microcontrollers (NXT)
- Desktop/laptop computer and software (NXT Programming Software, word processor for writeups, spreadsheets for data graphs)
- Peripheral interfaces (USB or Bluetooth wireless)
- Electromechanical systems (touch, light, rotation, sound, ultrasonic sensors)
- Electromechanical actuators (Interactive Servo Motors)

## The Designed World

16. Students will develop an understanding of and be able to select and use energy and power technologies
17. Students will develop an understanding of and be able to select and use information and communications technologies
18. Students will develop an understanding of and be able to select and use transportation technologies
19. Students will develop an understanding of and be able to select and use manufacturing technologies

The NXT robot itself is an excellent example and integrator of many different designed technologies working together as a coordinated system.

- Power sources (battery technologies – rechargeable Lithium-Ion vs. disposable alkaline)
- Vehicle systems (all the robot's systems must work together in order to make it mobile, a viable platform for transportation of goods or as a platform to perform other work)
- Manufacturing and prototyping (robot must be built and modified using appropriate materials, plans and tools)
- Structural soundness and stability concepts are integral to the design of the robot's physical form.
- Communication between system components (desktop to NXT, sensors to NXT, NXT to motors, NXT to NXT)
- Communication technologies (USB vs. Bluetooth)