



TryEngineering

# Cracking the Code



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## Lesson Focus

Lesson focuses on how computerized barcodes have improved efficiency in product distribution; explores the barcoding process and engineering design.

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## Lesson Synopsis

The Cracking the Code activity explores the concept of how computerized barcoding has simplified distributing and pricing of products. Students learn about encoding and decoding, the barcoding system, and how a mathematical formula is embedded in barcoding to safeguard against errors. Students use websites to identify product barcodes, test codes from everyday product, and work as an "engineering team" to come up with the next generation of information embedding systems.

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## Age Levels

8-18.

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## Objectives

- ✦ Learn about encoding systems -- specifically barcodes -- and decoding technology.
- ✦ Learn about how barcodes interface with computer systems.
- ✦ Learn about how barcodes have improved distribution efficiency and pricing accuracy of manufactured products.
- ✦ Learn how the development of barcodes has impacted everyday life.
- ✦ Learn about teamwork and engineering problem solving in groups.

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## Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- ✦ computerized encoding and decoding systems (barcodes)
- ✦ impact of engineering and technology on society
- ✦ engineering problem solving
- ✦ teamwork

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## Lesson Activities

Students learn about how computer coding systems have impacted everyday life, including distribution of products, management of inventory, and pricing at retail outlets and online websites. Topics examined include barcodes, and the impact of computerized scanning/pricing/inventory systems. Students work in teams to design an improved information embedding system, learn how the computer coding/decoding works, and solve underlying mathematical formulas to check barcodes.

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## Resources/Materials

- ✦ Teacher Resource Documents (attached)
- ✦ Student Resource Sheet (attached)
- ✦ Student Worksheets (attached)

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## Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

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## Internet Connections

- ✦ TryEngineering ([www.tryengineering.org](http://www.tryengineering.org))
- ✦ American Mathematical Association: The Digital Revolution - Barcodes ([www.ams.org/featurecolumn/archive/barcodes1.html](http://www.ams.org/featurecolumn/archive/barcodes1.html))
- ✦ Internet UPC Database ([www.upcdatabase.com](http://www.upcdatabase.com))
- ✦ ITEA Standards for Technological Literacy: Content for the Study of Technology ([www.iteaconnect.org/TAA](http://www.iteaconnect.org/TAA))
- ✦ NSTA National Science Education Standards ([www.nsta.org/publications/nse.aspx](http://www.nsta.org/publications/nse.aspx))
- ✦ NCTM Principles and Standards for School Mathematics (<http://standards.nctm.org>)

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## Recommended Reading

- ✦ Revolution at the Checkout Counter: The Explosion of the Barcode (ISBN: 0674767209)
- ✦ Code: The Hidden Language of Computer Hardware and Software, by Charles Petzold (ISBN: 0735611319)
- ✦ Raising the Bar [Code]: The Value of Auto-ID Technology (ISBN: 0324300786)

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## Optional Writing Activities

- ✦ **Younger Students:** Write an essay or a paragraph describing whether or not you think there were more errors in charging for items at a grocery store before or after the implementation of the computer scanned barcode system.
- ✦ **Older Students:** Write an essay or a paragraph describing how running a grocery store would be different if there were no barcodes? Explain what it might have been like to conduct an inventory listing in 1960. How has computer engineering changed the shopping experience?

# Cracking the Code



## For Teachers: Teacher Resources

### ◆ Lesson Goal

Explore the impact of coding and decoding systems on society by demonstrating how barcodes work. Students learn about barcodes, test product codes on websites, evaluate the impact the technology has had on society, learn about the mathematical relationship between barcode numbers, and develop their own encoding systems.

### ◆ Lesson Objectives

- ✦ Students learn about encoding systems -- specifically barcodes -- and decoding technology.
- ✦ Students learn about how barcodes interface with computer systems.
- ✦ Students learn about how barcodes have improved efficiency in distribution of manufactured products.
- ✦ Students learn how the development of barcodes has impacted everyday life.
- ✦ Students learn about teamwork and problem solving in groups.

### ◆ Materials

- Student Resource Sheet
- Student Worksheets
- Internet Access (if possible)
- One set of materials for each group of students:
  - Barcodes from five different products
  - Access to Internet



### ◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class or provided as reading material for the prior night's homework. They may also be directed to bring in several barcodes from food or other items from their homes.
2. Divide students into groups of 3-4 students; provide one set of materials per group.
3. Ask students to visit the Internet UPC Database ([www.upcdatabase.com](http://www.upcdatabase.com)) and type in several barcodes to help identify the products.
4. Students should also be directed to search for and print out barcodes for items they would potentially like to buy.
5. Students perform mathematical check on barcodes to determine accuracy and understanding of the numerical relationships of bar coding systems.
6. Students work in teams as "engineers" to develop a new coding system, or way of embedding information in manufactured products.
7. Student then complete student worksheets addressing the impact of computer engineering and technology on society.
8. Each student group presents the vision for new coding systems and their views on societal impact of engineering to the class.

### ◆ Time Needed

One to two 45 minute sessions.

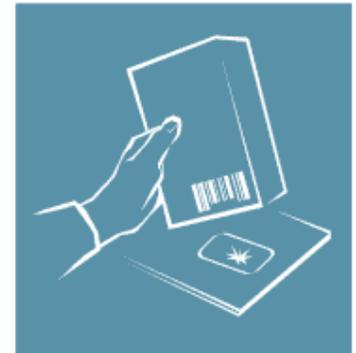
# Cracking the Code



## Student Resource: What are Barcodes?

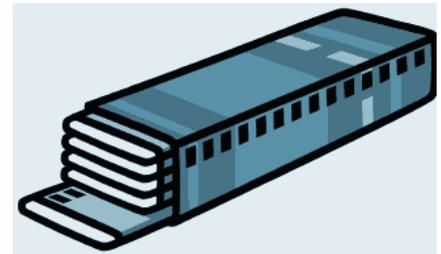
### ◆ Computer Barcodes

Thirty years ago marked the launch of the Universal Product Code (UPC) -- or the "barcode. At the time, food distribution and sales systems lead the way encouraged by potential savings in having to affix pricing labels to every product in every grocery store. It took cooperation between food manufacturers and grocery chains to support the required engineering and technology to develop an automated check-out system. The results were amazing! In addition to automatically ensuring that no pricing errors were made by clerks, automated check-out counters have now completely eliminated the need for humans to check out at some grocery, home goods, and home improvement stores. The barcode has had a huge impact on retail, manufacturing systems, and distribution of products all over the world. In addition, the little black and white lines have established a computerized database tracking buying habits, sales preferences, and pricing preferences for consumers everywhere. The barcode has boosted the odds that a new product will meet the needs of society, and dramatically increased the accuracy of inventories.



### ◆ History

The first barcodes were used at a supermarket in Troy, OH, in 1974, and the scanners that read the barcode were considered large, loud, and clumsy. The very first item scanned was a pack of Wrigley's Juicy Fruit chewing gum. This was simply by chance, as the first customer (whose name now lost to history...) pulled a pack of Juicy Fruit from the rack! That historic pack of now very stale gum can be viewed on display at the Smithsonian Institution's National Museum of American History in Washington DC!



Now scanners are small, hand held, unobtrusive, quiet, and quick; they are used everywhere from stores and post offices -- to hospitals -- and by researchers and engineers in remote locations all over the world.

### ◆ What's New?

Recently, advances have been made in providing medicine instructions and blood transfusion accuracy by attaching bar coding systems to these items as well. Dry cleaners are applying barcodes to make sure that clothing is returned to the right customer, and banking system codes allow customers to "swipe and go" --- purchasing gasoline, food, and even meals at restaurants at lightning speed.



## ◆ How Does it Work?

Most product UPC codes have twelve digits. The first six numbers define the manufacturer or vendor of the product. Every product that the vendor sells will have the same first six numbers. The next five digits are specific to the product itself. And, the last number is a special digit called the "check digit" that is a double check to make sure that the UPC for the code is correct. This "check digit" has a mathematical formula it follows to confirm that the product is accurately checked. Here's how it works:

Let's use the UPC code for Heinz 57 Ketchup Tomato (14 oz).  
The code is 013000001243.



Step One: Add the digits in the odd positions together:

$$0 + 3 + 0 + 0 + 1 + 4 = 8$$

Step Two: Multiply the answer in Step One by 3:

$$8 \times 3 = 24$$

Step Three: Add the digits in the even positions (except for the 12th digit):

$$1 + 0 + 0 + 0 + 2 = 3$$

Step Four: Add the answer from Step Three to the answer from Step Two:

$$3 + 24 = 27$$

Step Five: Add the check digit (in this case 3) to the answer from Step Four (27):

$$3 + 27 = 30$$

Step Six: This check digit must be a multiple of ten to be accurate, and the first digit of the answer (a multiple of ten) is used as the check digit.

Each time that a UPC is read by a barcode scanner, this calculation is automatically performed. If the check digit is different than the one that is calculated, then the computer knows that there is something wrong with the UPC.

## ◆ How Do Barcode Readers Work?

Because computers cannot read barcodes, they require an adapter called a "Barcode Reader" kit to scan products. The kit usually consists of a scanner, a decoder, and a cable that connects to a computer, cash register, or other computer embedded product. The scanner "reads" the barcodes -- looking at both the black lines and the size and spacing of blank space between bars. The decoder checks the number through the method above, and transmits the corresponding information about the item to the computer in text format. Depending upon the application, the information might be the price of a product, the expiration date of medicine, or blood types for a transfusion.

## ◆ How Are Engineers Involved?

Products, such as barcode readers, are originally designed and then continually improved by computer engineers, software engineers, electrical engineers, and others who work in teams to solve problems through engineered products. Products often go through a redesign process after launch to meet consumer needs. For example, barcode readers are now available in pen form, wireless forms, and can be built to withstand harsh environments -- the original designs were engineered for use in climate controlled grocery stores.

# Cracking the Code



## Student Worksheet: What's Next?

Engineers are currently working on improvements to the barcode system. For example, Electrical Engineers at the University of Pittsburgh and Oregon State University have been working together to develop a new product ID system called the "Peni-Tag" (Product Emitting Number Identification Tag). These would be embedded in all products, perhaps in place of labels in clothing, and if the design is successful, would eliminate the need for barcodes.



When engineers work in teams to solve a problem they usually look at the problems that are associated with a current product or way of doing something.

### You are the Engineering Team!

Your challenge is to work as a team to identify problems associated with the current barcode system and propose a new product or system to improve the current system.

### State the Problems:

1. Identify three shortcomings of the current barcode system (for example, sometimes the barcode is scratched and the computer can't pick it up, or sometimes the check-out person has to run it across two or three times before the computer picks it up).
2. As a team, develop on paper a new product or system that would solve these problems and also add new benefits to embedded information (for example, an entire product manual could be embedded in a chip that could tell a futuristic washing machine what temperature to set the water to safely wash a load of similar shirts).
3. Present your ideas to the class in three forms:
  - describe how your product works, technically, in words.
  - draw an illustration of either your final product, or a situation where it is being used.
  - write an advertisement for the new product stating its top three features.

# Cracking the Code



## Student Worksheet: Checking the Code

Most product UPC codes have twelve digits. The first six numbers define the manufacturer or vendor of the product. Every product that the vendor sells will have the same first six numbers. The next five digits are specific to the product itself. And, the last number is a special digit called the "check digit" that is a double check to make sure that the UPC for the code is correct. This "check digit" has a mathematical formula it follows to confirm that the product is accurately checked. Here's how it works, using the UPC code for Heinz 57 Ketchup Tomato (14 oz). The code is 013000001243.



Step One: Add the digits in the odd positions together:

$$0 + 3 + 0 + 0 + 1 + 4 = 8$$

Step Two: Multiply the answer in Step One by 3:

$$8 \times 3 = 24$$

Step Three: Add the digits in the even positions (except for the 12th digit):

$$1 + 0 + 0 + 0 + 2 = 3$$

Step Four: Add the answer from Step Three to the answer from Step Two:

$$3 + 24 = 27$$

Step Five: Add the check digit (in this case 3) to the answer from Step Four (27):

$$3 + 27 = 30$$

Step Six: This check digit must be a multiple of ten to be accurate, and the first digit of the answer (a multiple of ten) is used at the check digit.

Each time that a UPC is read by a barcode scanner, this calculation is automatically performed. If the check digit is different than the one that is calculated, then the computer knows that there is something wrong with the UPC.

### Your Turn:

Compute the formulas for four different barcodes and see if your calculations result in a "check digit" that is a multiple of ten.


# Cracking the Code



## Student Worksheet:

Read the following press release and answer the following questions regarding the impact that bar coding technology and software engineering has had on society:

### HHS Announces New Requirements for Barcodes on Drugs and Blood to Reduce Risk of Medication Errors



HHS Secretary Tommy G. Thompson has announced that the Food and Drug Administration is issuing a final rule requiring barcodes on the labels of thousands of human drugs and biological products. The measure will help protect patients from preventable medication errors and reduce the cost of health care and represents a major step forward in the department's efforts to harness information technology to promote higher quality care.

"Barcodes can help doctors, nurses and hospitals make sure that they give their patients the right drugs at the appropriate dosage," Secretary Thompson said. "By giving health care providers a way to check medications and dosages quickly, we create an opportunity to reduce the risks of medication errors that can seriously harm patients."

"We're encouraging widespread use of technologies that can help health care providers avoid hundreds of thousands of medication errors," FDA Commissioner Mark B. McClellan, M.D., Ph.D., said. "Bar coding systems have proved their dependability and effectiveness by ensuring the accuracy of a myriad of actions in commerce and industry. We're now advancing the adoption of these systems in settings where they can help save lives."

The FDA rule calls for the inclusion of linear barcodes -- such as are used on millions of packages of consumer goods -- on most prescription drugs and on certain over-the-counter drugs that are commonly used in hospitals and dispensed pursuant to an order. Each barcode for a drug will have to contain, at a minimum, the drug's National Drug Code number. This information will be encoded within the barcode on the label of the product. Companies also may include information about lot number and product expiration dates.

In addition, the rule requires the use of machine-readable information on container labels of blood and blood components intended for transfusion. These labels, which are already used by most blood establishments, contain FDA-approved, machine-readable symbols identifying the collecting facility, the lot number relating to the donor, the product code and the donor's blood group and type.

The barcode rule is designed to support and encourage widespread adoption of advanced information systems that, in some hospitals, have reduced medication error rates by as much as 85 percent. In these institutions, patients are provided with identification bracelets that bear a barcode, which identifies the patient. The health care professional then scans the patient's barcode and scans the drug's barcode. The information system then compares the patient's drug regimen information to the drug to verify that the right patient is getting the right drug, at the right time, and at the right dose and route of administration. In a study conducted at a Veterans Affairs Medical Center employing such a barcode scanning system, 5.7 million doses of medication were administered to patients with no medication errors.

FDA estimates that the barcode rule, when fully implemented, will help prevent nearly 500,000 adverse events and transfusion errors over 20 years. The economic benefit of reducing health care costs, reducing patient pain and suffering, and reducing lost work time due to adverse events is estimated to be \$93 billion over the same period.

FDA first proposed barcode requirements in March 2003. Comments from hospitals, health care professionals, trade and professional associations and others showed widespread support for the approach to improving patient safety and promoting higher quality care.

The final rule applies to most drug manufacturers, repackers, relabelers, private label distributors and blood establishments. New medications covered by the rule will have to include barcodes within 60 days of their approval; most previously approved medicines and all blood and blood products will have to comply with the new requirements within two years.

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### Questions:

1. How do you think technology, and the introduction of barcodes have impacted the day to day life of check-out personnel at grocery stores? What's easier? What's harder?
2. Barcodes on medicine bottles or tubes help alert people to side effects and guidelines for taking their medication. How do you think this impacts society?
3. What ethical considerations would engineers discuss about barcoding blood donations?
4. What computer errors could negatively impact society through the barcode system? Give examples?
4. How could a computer or software engineer help prevent errors in the barcode system?
5. What other applications can you think of where engineers could develop equipment to embed important information? More ethical implications?



## For Teachers:

### Alignment to Curriculum Frameworks

**Note:** Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards ([http://www.nap.edu/catalog.php?record\\_id=4962](http://www.nap.edu/catalog.php?record_id=4962))
- U.S. Next Generation Science Standards (<http://www.nextgenscience.org/>)
- International Technology Education Association's Standards for Technological Literacy (<http://www.iteea.org/TAA/PDFs/xstnd.pdf>)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (<http://www.nctm.org/standards/content.aspx?id=16909>)
- U.S. Common Core State Standards for Mathematics (<http://www.corestandards.org/Math>)
- Computer Science Teachers Association K-12 Computer Science Standards (<http://csta.acm.org/Curriculum/sub/K12Standards.html>)

#### ◆ National Science Education Standards Grades K-4 (ages 4-9)

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

##### **CONTENT STANDARD G: History and Nature of Science**

As a result of activities, all students should develop understanding of

- ✦ History of science

#### ◆ National Science Education Standards Grades 5-8 (ages 10-14)

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ✦ Personal health
- ✦ Risks and benefits
- ✦ Science and technology in society

##### **CONTENT STANDARD G: History and Nature of Science**

As a result of activities, all students should develop understanding of

- ✦ Nature of science
- ✦ History of science

#### ◆ National Science Education Standards Grades 9-12 (ages 14-18)

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ✦ Personal and community health
- ✦ Science and technology in local, national, and global challenges



## For Teachers:

### Alignment to Curriculum Frameworks (continued)

#### ◆ National Science Education Standards Grades 9-12 (ages 14-18)

##### **CONTENT STANDARD G: History and Nature of Science**

As a result of activities, all students should develop understanding of

- ✦ Nature of scientific knowledge
- ✦ Historical perspectives

#### ◆ Next Generation Science Standards Grades 3-5 (Ages 8-11)

##### **Waves and Their Applications in Technologies for Information Transfer**

Students who demonstrate understanding can:

- ✦ 4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

##### **Engineering Design**

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

#### ◆ Principles and Standards for School Mathematics

##### **Understand meanings of operations and how they relate to one another**

- ✦ understand the effects of multiplying and dividing whole numbers;
- ✦ identify and use relationships between operations

##### **Data Analysis and Probability Standard**

- ✦ select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots

##### **Problem Solving**

- ✦ Solve problems that arise in mathematics and in other contexts

##### **Connections**

- ✦ Recognize and apply mathematics in contexts outside of mathematics

#### ◆ Common Core State Standards for School Mathematics Grades 3-8 (ages 8-14)

##### **Operations & Algebraic Thinking**

- Multiply and divide within 100.
  - ✦ CCSS.Math.Content.3.OA.C.7 Fluently multiply and divide within 100, using strategies such as the relationship between multiplication and division (e.g., knowing that  $8 \times 5 = 40$ , one knows  $40 \div 5 = 8$ ) or properties of operations. By the end of Grade 3, know from memory all products of two one-digit numbers.
- Gain familiarity with factors and multiples.
  - ✦ CCSS.Math.Content.4.OA.B.4 Find all factor pairs for a whole number in the range 1–100. Recognize that a whole number is a multiple of each of its factors. Determine whether a given whole number in the range 1–100 is a multiple of a given one-digit number. Determine whether a given whole number in the range 1–100 is prime or composite.

# Cracking the Code



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## For Teachers: Alignment to Curriculum Frameworks (continued)

### ◆Common Core State Standards for School Mathematics Grades 3-8 (ages 8-14)

#### **Operations & Algebraic Thinking**

- Generate and analyze patterns.
  - ✦ CCSS.Math.Content.4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself. For example, given the rule “Add 3” and the starting number 1, generate terms in the resulting sequence and observe that the terms appear to alternate between odd and even numbers. Explain informally why the numbers will continue to alternate in this way.

### ◆Standards for Technological Literacy - All Ages

#### **The Nature of Technology**

- ✦ Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- ✦ Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

#### **Technology and Society**

- ✦ Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- ✦ Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- ✦ Standard 7: Students will develop an understanding of the influence of technology on history.

#### **Design**

- ✦ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

#### **Abilities for a Technological World**

- ✦ Standard 13: Students will develop abilities to assess the impact of products and systems.

#### **The Designed World**

- ✦ Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.