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Notes: The numbering in the Student Notebook matches the corresponding numbers used in the Teacher’s Presentation.

If time allows, and students are interested, incorporate time during or after each lesson to lead students through solving stages of the Rubik’s Cube until completed.

Keep in mind that the vocabulary lists are suggested vocabulary and can be modified for grade level.

“All logos, images and artwork are property of the respective owners, including but not limited to affiliates, partners and subcontractors of Rubik’s Brand Ltd. & STEM.org™ 2016”
This module explores project-based learning and game theory in education, starting with the Rubik’s® Cube and other games and using these as entry points to explore a wide variety of topics in STEM, including history and archaeology; biology and ecological diversity; architecture and design; physics; engineering and construction; materials science; psychology and neuroscience; and technology and communication. Lessons are made to be adaptable to teacher needs depending on the age, level, and interests of students, and can be taught in any order after the introduction. The students themselves will play a role in shaping the order of topics, and engage in self-directed learning throughout the course.
INTRODUCTION: ANCIENT GAMES AND PUZZLES AROUND THE WORLD

Suggested Time: 120 minutes

Overview
Students will explore the history of the Rubik’s Cube, then discuss the importance of games and evaluate how early evidence of gaming appears in the archaeological record. They will practice playing ancient Old World games, exploring the connections between these and modern variations. Then they will learn about how archaeological evidence has unearthed the importance of games among Native American cultures, and practice some of the games themselves. Finally, students will work together to provide input on the structure of the course and order of topics related to gaming.

Vocabulary
• Games
• Puzzles
• Archaeology
• Archaeological record
• History
• Native American
• Lacrosse

Objectives
• Students will gain a cross-cultural understanding of the history of gaming.
• Students will connect history with the archaeological record, and learn about archaeology.
• Students will come up with their own interpretations of archaeological finds.

Next Generation Science Standards
Planning and Carrying Out Investigations
• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
• Make observations (firsthand or from media) to collect data which can be used to make comparisons. (2-LS4-1)
• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-1)
• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2)
• Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
• Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)
Cause and Effect
• Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)

Science Knowledge Is Based on Empirical Evidence
• Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)
• Construct an argument with evidence, data, and/or a model. (4-LS1-1)

Project Materials
• Several Rubik’s Cubes (ideally enough for each student). Available from www.YouCanDoTheCube.com. Teachers may borrow up to 36 cubes at no cost or purchase cubes as a long-term resource
• Robust art paper and paints, color pencils, and/or pens
• Classic games with ancient roots, which may include Go, Dominos, regular playing cards, Mahjong, Mancala, Chess, Checkers, Backgammon, and Chutes and Ladders (or the variation Snakes and Ladders)
• The ancient Egyptian game Senet, such as WE Games Wood Senet Game (modern interpretation). Available through major distributors.
• The ancient Game of Ur, such as Wood Expressions version (modern interpretation). Available through major distributors.
• Various “found” materials, balls, sticks, etc. (review Native American Games and Stories for ideas)
• World map

Resources
• The History of the Rubik’s Cube: https://www.rubiks.com/about/the-history-of-the-rubiks-cube
• Native American Games and Stories. Joseph Bruchac, et.al.
**Before the Lesson/ Background Information**

- Read through the books and scientific articles to acquaint yourself with the subject matter in archaeology.
- Select homework and readings from Native American Games and Stories, and identify readings and assignments appropriate for class.
- Print out “The History of the Rubik’s Cube.”

**The Lesson**

**Part 1: Rubik’s Cube History (40 mins)**

1. Depending on the age of the students, the teacher can pre-read the article “The History of the Rubik’s Cube” and summarize the content to students or hand out copies of the article for the students to read.

2. Using the timeline of the history of the Rubik’s Cube website as a starting point, work with the class to build a large timeline to hang up in class. To do this, separate students into small groups. Each group will take a different section of the timeline and illustrate it on a page.

3. Tape the pages together and hang up the timeline in class.

4. Using a computer, show the chosen videos from “Official Videos of the Rubik Cube World Championships 2015.”

5. Allow the students to explore the Rubik’s Cube by attempting to solve the white corners or white cross, create a multi-colored face, or for first-time users, just explore how a Rubik’s Cube works. (Integrate with Rubik’s Cube mathematical or design exercises, solving exercises available on the Rubik’s website, or with the Additional Resources listed at the end of this module.)

**Part 2: The History of Games (20 mins)**

1. Ask students why they play games. Who else plays games? Why do people play games? *Fun is an obvious answer, but from here you can explore some of the benefits of games, including learning, physical activity, and mental stimulation.*

2. Ask students how old they think games are. Take guesses from the classroom. Use the archaeological evidence you’ve reviewed to discuss the ancient history of games around the world.
3. Relate popular modern games to their ancient histories. For example, ancient versions of Mancala have been found in Africa and Arabia. Ancient Egyptian games are thought to be the ancestor of the modern game Backgammon. Playing cards were invented in Ancient China. And Chess and Checkers are among the oldest games known. Allow some time for students to explore and play these games, if possible. You can also separate the students into groups and have them report back on the games they played.

4. Define history and archaeology with the students. Why is it important for archaeologists to consider the games people played? What are some of the items and structures they’ve found that might have been games?

5. Explain that the class will be exploring games from various parts of the world, such as ancient Egypt and Mesopotamia, and North America. (You can add other regions, such as China, depending on how much time and how many class sessions you have.)

6. Follow with the optional activities below, and wrap up the last session with Part 5, to determine the order and structure of the class sessions to follow.

**Part 3: Ancient Egyptian and Mesopotamian Games (50 mins)**

1. Students will play Senet and the Game of Ur (known in its ancient form as the Game of Twenty Squares).

2. Have the students identify the games’ origins on the world map.

3. After playing the games, ask the students who might have played the games and why. What do students think about what these ancient peoples might have believed?

4. Use the internet or other resources to explore Egyptian and Mesopotamian archaeology with the students. Have the students list the 3 important points they found about Egyptian and Mesopotamian archaeology based on their research.

5. Assign readings from Native American Games and Stories.

**Part 4: Ancient American Games (50 mins)**

1. Read excerpts from Native American Games and Stories with the students. Have the students list 3–5 important points in their Student Notebook.

2. Allow students to recreate Native American games using the supplies you have available. This lesson is great for outdoor activity as well.
3. After playing the games, what do students think about what these ancient peoples might have believed? Who might have played the games and why? How are these games still carried on by Native peoples, and other Americans, today? *Lacrosse is a good example of this.*

4. Have students use the internet or other resources to list 3 things they learned that were surprising or unusual about American archaeology.

**PART 5: ORGANIZING THE CLASS STRUCTURE (10 MINS)**

1. Review some of the important benefits and reasons for games. Tell the class that together, you will be exploring some of the important aspects of gaming and exploring how games are related to STEM subjects, as well as daily life. The class will then vote on the order of subjects based on their own interests.

   **Subjects may include:**
   - Animals and Biology: How Animals Learn Through Play
   - Architecture and Design: Building Blocks*
   - Educational Games: a Classroom Study
   - Engineering and Construction: Solving Real-World Problems*
   - Materials Science: How Things Are Made
   - Physics: May the Force Be With You
   - The Science of Memory and Learning: Brain Games
   - Technology and Communication: Build Your Own Game!

2. If you don’t want to hold a vote, or class interests are not evident yet, you can also use a lottery method. Write out the subjects and put them on slips of paper and attach them to the underside of dominoes with double-sided tape. Then allow each student to pick a domino! The order of dominoes picked will determine the sequence of the class.

3. Assign activities from Archaeology for Kids book and/or game/research activities on the Archaeology for Kids Games and Activities website. You can incorporate activities from these sources in the classroom or as homework throughout the course.

*Architecture and Design: Building Blocks and Engineering and Construction: Solving Real-World Problems cover some of the same basic concepts at the Elementary level. If you are doing both lessons, you should combine them for maximum impact and exposure.*
Optional Resources and Additional Reading:

- The Game of Ur (Game of Twenty Squares) online at the British Museum: http://www.yourturnmyturn.com/java/ur/index.php
- The Game of Ur online guide: http://www.tradgames.org.uk/games/Royal-Game-Ur.htm
- Additional links and resources at Board Game Geek: http://boardgamegeek.com/geeklist/192645/game-twenty-squares
- Archaeology for Kids Games and Activities: http://archaeology.mrdonn.org/games.html
ANIMALS AND BIOLOGY: HOW ANIMALS LEARN THROUGH PLAY

Suggested Time: 60-120 minutes

Overview
Students will observe differences between plants and animals, identify different types of organisms, and think about types of intelligence. Focusing on cephalopods (octopi), they will learn how games are used to study animal intelligence and relate game-playing to childhood development for both human and non-human animals. Ideally, they will take a field trip to a laboratory, aquarium, zoo, or other animal research facility where humane experiments take place, and witness them in person.

Vocabulary
- Biology
- Organism
- Plant
- Animal
- Human and non-human animal
- Intelligence
- Development (physical and psychological)
- Invertebrate
- Vertebrate
- DNA
- Genome
- Octopus
- Cephalopod

Objectives
- Students will learn how to identify the differences between plants and animals through direct observation.
- Students will consider whether they themselves are animals.
- Students will think about the connections between childhood play, games, and critical physical and psychological development.

Next Generation Science Standards
LS1.A: Structure and Function
- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

LS4.D: Biodiversity and Humans
- There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)
- Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)
ESS3.C: Human Impacts on Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)

Planning and Carrying Out Investigations

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
- Make observations (firsthand or from media) to collect data which can be used to make comparisons. (2-LS4-1)
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-1)
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2)
- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)

Science Knowledge Is Based on Empirical Evidence

- Scientists look for patterns and order when making observations about the world. (2-LS4-1)
- Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)
- Construct an argument with evidence, data, and/or a model. (4-LS1-1)

Project Materials

- Space where students can observe plant and animal life (optional)
- Examples of toys used to further childhood development (optional)
- DNA model (optional)

Resources

- “Crafty Octopus opens container to find food.” https://www.youtube.com/watch?v=rGHGQdA7yq0
THE LESSON

Part 1: Rubik’s for Animals (20 mins)

1. Can animals solve the Rubik’s Cube? Read “Ursula the Octopus has Surprising Knack for Solving Puzzles” with the class. Octopi can solve simpler puzzles, but they enjoy the Rubik’s Cube as a toy, and they can move its parts. Research how scientists used the Rubik’s Cube to study whether octopi demonstrate “handedness” — that is, if they favor certain limbs for playing with toys and exploring objects. Ask the students: What do you think the findings are? Then, watch the videos “Pull or Push? Octopuses Solve a Puzzle Problem” and “Crafty Octopus opens container to find food.”

2. Come up with a list of animals that could possibly handle a Rubik’s Cube. Think about animals with hands or limbs, and excellent vision. Obvious ones are monkeys, apes, and tentacled creatures.

3. Break the students up into small groups. Each group will come up with a different idea for how to use the Rubik’s Cube to explore something about an animal, such as handedness. After five to ten minutes, have the groups share their ideas in class.
Part 2: Animal Intelligence (40-80 mins)

1. Have the students go outside and spend ten minutes observing organisms. If this is not possible, have them think of a park or other outdoor area they have visited and come up with examples. Which organisms are plants? Which ones are animals? Have them identify the differences between the organisms they observe/think of and themselves.

2. Ask the students to think about whether they themselves are plants or animals. Why? For older students, use the terms human and non-human animals.

3. How do plants think and feel? What about animals? What are the differences?

4. Work with the class to discuss types of intelligence. Show any videos you found that depict how animals are tested with puzzles to explore animal intelligence. Read the octopus articles with the class, and show “Why the Octopus Brain is So Extraordinary.”

5. Show the “Octopus Intelligence” video for older or advanced students and address vocabulary including genome and DNA. If you do this, pass around a model of DNA, explaining that this is the common building block of life, including plants.

6. Show excerpt(s) from SuperSmart Animals.

7. Why do people test animals with puzzles? How do young animals learn? Relate this to toys that help human children to develop spatial concepts, learn colors, etc.

8. Do human children play? What about infant non-human animals? Discuss why play is important. For example, cats and other predators are known to play-hunt when young, and in so doing, learn skills that will help them later in life. But what about when baby goats play? They may acquire agility and other skills; but what is their motivation? Have the students think through why they themselves like to play. What is the motivation? What does regular play help them learn that will be beneficial later in life? (Items might include physical strength and agility, the ability to work on a team, critical thinking or “smarts”, language ability, visual ability, etc.)

9. Depending on the age of your students, you might relate this to motivation built into games. Why are games rewarding? Why do you want to keep playing them? Have the students identify specific rewards built into games.

10. Show the Animal Planet videos of baby animals playing.

11. Conduct a classroom activity or two from Einstein Never Used Flashcards: How Our Children Really
Learn.

12. If possible, supplement these activities with a field trip where students may observe dolphins, octopi, rats, or other intelligent animals playing games and learning things for research.

Optional Resources and Additional Reading

- “Octopus Intelligence and Genome Research at the University of Chicago.” The University of Chicago (7:25) https://youtu.be/7QaPmCRhr80 (for upper grades/ advanced students)
- “Pharrell Williams - Happy - Happy Animals” Video (3:07) https://youtu.be/EgAn8CP6d_g
- “Animals Playing Soccer - When animals love football too” Video (4:45) https://youtu.be/-m39h6blOzE
DNA MODEL

(A) adenine
(C) cytosine
(G) guanine
(T) thymine
ARCHITECTURE AND DESIGN: BUILDING BLOCKS

Suggested Time: 60-120 minutes

Overview*
This lesson covers some of the same concepts as Engineering and Construction: Solving Real-World Problems, but from an architecture/design perspective. After considering the math and design concepts related to the shape and proportions of the Rubik’s Cube, students will practice similar concepts by exploring architecture and design. Students will apply the same mathematical principles to building a larger cube-shaped house, then apply the same principles to actual rooms.

Vocabulary
• Shape
• Cube
• Square
• Rectangle
• Circle
• Sphere
• Ovoid
• Two-dimensional
• Three-dimensional
• Architecture
• Construction
• Design
• Planning
• Project management
• Physics
• Mathematics
• Aesthetics
• Length
• Width
• Height
• Symmetry
• Perimeter
• Area
• Surface area
• Volume
• Proportions
• Ratio

Objectives
• Students will relate concepts in physics, mathematics, and aesthetics to architecture.
• Students will build models.

Next Generation Science Standards
Obtaining, Evaluating, and Communicating Information
• Obtain and combine information from books and other reliable media to explain phenomena. (4-ESS3-1)

Interdependence of Science, Engineering, and Technology
• Knowledge of relevant scientific concepts and research findings is important in engineering. (4-ESS3-1)
Project Materials

- Six-sided dice (enough for each student to have or share one with a partner)
- Marbles
- Tape measure
- Tape and glue
- Scissors
- Large slabs of cardboard, or a couple of basic large refrigerator boxes or similar
- Wrapping paper
- Paints and brushes

Resources


Before the Lesson/ Background Information

- Prepare math and geometry problems appropriate to the grade level of your students. The problems should be solved by interacting with the Rubik’s Cube and solving problems in a hands-on manner. You can use the provided Rubik’s Cube Math Worksheet, and add to it/ modify it as necessary.
- Select appropriate activities (which students may do on their own) from Archidoodle: The Architect’s Activity Book.

The Lesson

Part 1: The Geometry and Design of the Rubik’s Cube (60 mins)

1. Read Mummy Math: an Adventure in Geometry with the students. Inform them that they will go on a similar adventure by exploring the Rubik’s Cubes.

2. Pass around Rubik’s Cubes. Have the students identify the shape “cube.” What makes it a cube? six faces Define two- and three-dimensional object and give an example of each.

3. Ask: why is the Rubik’s Cube a cube? How is the shape related to how we solve the puzzle? (For example: the puzzle would not work if the sides were asymmetrical.)

4. Work with the students to identify other 2D and 3D shapes in the room. For advanced students, this is an opportunity to explore the types of three-dimensional rectangles (right-angled parallelepiped, cuboid, etc.)
5. Note that all buildings are made from a combination of shapes (relating mathematical concepts to architecture).
   • What shapes do you see?

6. What are the properties of a cube? Here is where you can discuss stability and its relationship to architecture. Have the students stack Rubik’s Cubes (or blocks, if you prefer). Let them explore other shapes as well, so that they get a hands-on feel for different shapes and how they take up space.
   • What happens if they try to stack marbles?
   • Is there a way to make the marbles more stable? If so — how? (Hint: marbles can be arranged together in certain shapes that make them less likely to roll. They can also be framed by other shapes.
   • How many marbles can you fit inside a square frame? What about a triangular one with the same area?)

7. Have the students work through mathematical problems related to the Rubik’s Cube. They will measure the length, width, and height of each side, then solve problems based on this information.
RUBIK’S CUBE MATH WORKSHEET

1. Measure the length and width of each side of the Rubik’s Cube.

<table>
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<tr>
<th>Side 1</th>
<th>Side 2</th>
<th>Side 3</th>
<th>Side 4</th>
<th>Side 5</th>
<th>Side 6</th>
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<tbody>
<tr>
<td>Length</td>
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2. What is area, in your own words? ____________________________

3. Calculate the area of each face. ____________________________

4. Is the Rubik’s Cube symmetrical? ☐ Yes ☐ No
   How do you know? ______________________________________
   ___________________________________________________

5. If the Rubik’s Cube were hollow, how much water could you pour into it (volume)? _______________

6. Calculate the volume of a six-sided di. ______________________________________

7. How does the volume of a Rubik’s Cube compare with the volume of a six-sided di? _______________
   ____________________________
   ___________________________________________________

8. Compare the relationship between the Rubik’s Cube and the six-sided di using a fraction(s). __________
   ___________________________________________________


• Students can do activities from Archidoodle: The Architect’s Activity Book at home.
• If you have time or an additional class session, proceed with Part 2 or see the Engineering and Construction: Solving Real-World Problems lesson for additional ideas.
Part 2: Live in A Rubik’s Cube! (60 mins)

1. In this activity, students will build a Rubik’s Cube house.

2. Using cardboard, tape, glue, and other supplies like wrapping paper, students will work together as a class to build one giant Rubik’s Cube that is large enough for students to enter and hang out in.

3. Instruct them to make the house look like a Rubik’s Cube. The faces can be made out of cardboard cut into squares. They can decorate the cube-shaped house with a combination of wrapping paper or paint. They can also make windows.

4. Throughout this activity, incorporate the math the students practiced while exploring the Rubik’s Cube. In order to build a proper cube-shaped house, they will need to measure each face to make sure it is a square. In order to calculate how much wrapping paper they need (or how much they used), they should calculate the surface area of each face.

5. Work with the students to calculate the number of Rubik’s Cubes that can fit inside the Rubik’s Cube house. Have them test their results by stacking Rubik’s Cubes inside the house.

6. As an alternative to wrapping paper, students may paint their creation.

7. This activity can also be done with two or three competing teams.

8. As homework, students will perform the same measurements on a room of their choice (a room at home, the classroom, etc). This is an opportunity for students to learn how to deal with asymmetrical shapes.

9. How many Rubik’s Cubes would it take to fill this room?

Optional Resources and Additional Reading


*This lesson can be combined with the Engineering and Construction: Solving Real-World Problems lesson.*
EDUCATIONAL GAMES: A CLASSROOM STUDY

Suggested Time: 60-120 minutes

Overview
There is a lot of research out there about how young animals learn through playing, and that playing games is helpful for childhood development in a variety of areas. Kids who play games are more likely to develop visual and spatial awareness, critical thinking abilities, agility, and other skills, depending on the games. But what do we learn from specific games? Are some games more educational than others? The class will work to systematically answer these questions, learning about the scientific method in the process.

Vocabulary
- Research
- Research question
- Research design
- Methodology
- Scientific method
- Experiment
- Comparative study
- Data
- Quantitative
- Results
- Qualitative
- Analysis
- Hypothesis
- Significance

Objectives
- Students will learn that there are different types of research designs depending on the goals of the study.
- Students will practice designing their own comparative study.
- Students will learn the steps of the scientific method.
- Students will gather and analyze data in order to answer a question.

Next Generation Science Standards
Obtaining, Evaluating, and Communicating Information
- Obtain and combine information from books and other reliable media to explain phenomena. (4-ESS3-1)

Developing and Using Models
- Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)
- Develop a model to describe phenomena. (5-PS1-1)

Project Materials
- Several Rubik’s Cubes (ideally enough for each student). Available from www.YouCanDoTheCube.com. Teachers may borrow up to 36 cubes at no cost or purchase cubes as a long-term resource
- An assortment of games, including classic board games, physical activity games, card games, video and computer games (old and new), and online game sites specializing in educational games
Resources
• “How to Think Like a Scientist.” https://student.societyforscience.org/how-think-scientist

Article Links:
• https://www.sciencenewsforstudents.org/article/pathways-research-problem-solving
• https://www.nps.gov/cagr/learn/kidsyouth/the-scientific-method.htm
• https://www.sciencenewsforstudents.org/article/problems-%E2%80%98-scientific-method%E2%80%99
• https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Problem-Solving_Using_the_Scientific_Method.html

Before the Lesson/Background Information
• Read and print the “You CAN Do the Rubik’s Cube” Solution Guide*. Review the stages of solving and set a goal for the class based on the experience of your students. Familiarize yourself with the White Cross and White Corners solving stages (or the following stages, if your class has already completed these stages).
• Separate games into categories: physical/outdoor games, board games, solitary puzzles, and video games. Think of examples in each category.
• Make a list of ideal games in each category for your students’ age ranges. Make sure instructions and supplies are available.
• If possible, have TAs or other adults on hand to help lead and direct the teams, especially if you choose sports/outdoor activities.

*Class sets of the printed “You CAN Do the Rubik’s Cube” Solution Guide are available. For more information, write to info@youcandothecube.com.

The Lesson
Part 1: What Do Games Teach Us? (40 mins)

1. Separate the students into small groups. Each group will solve the white cross and white corners of the Rubik’s Cube using the “You CAN Do the Rubik’s Cube” Solution Guide. Small groups will allow for peer to peer instruction as they are learning each stage. You can have the groups compete, or set a class goal.

2. Each group will make a list of things they learned from the activity. They should spend about ten minutes on this and then share their findings with the class. Allow each group to share for about a minute each.
3. Introduce the categories of games and show examples of each.

4. Brainstorm with the class different kinds of skills that players might learn in each category. Ask the students: Do we learn more from some games than others? What should we expect to learn from a game in a specific category?

5. Inventory what games students already play and what skills they already have.

6. Pick the category of games students are least familiar with. For example, if students usually play sports and video games, you might choose to study board games.

**Part 2: Set-up and Teams (20 mins)**

1. Announce to the students that they will be doing research to find out what they learn from games in the chosen category. There will be three or four teams. Each team will test one game in that category (for example, if you chose board games, Team 1 might play Checkers; Team 2 might play Scrabble; and Team 3 might play Battleship). The teams will gather data on what they learn, then will compare results.

2. Use this to talk about how studies are designed differently. Introduce the comparative study.

3. Go over the steps of the scientific method using the article *How to Think Like a Scientist* and selected videos from NASA as reference. Assist students in creating a research question (or questions) as a class. Write out the steps of the scientific method on the board.

4. Separate the students into three to four teams. Each team should select a game no one in the group has played before. You want them to enter into the experiment with as few skills as possible.

5. Students will complete Part 3 either as homework or in a subsequent class session.

**Part 3: Gathering and Presenting Data! (60 mins)**

1. Each team will play their chosen game. Have each student document:
   - How they learned the game (e.g., reading the instructions together)
   - What they learned while playing the game
   - Skills used (e.g., counting)
2. Allow time for groups to report back about what they learned from their games. Record the information as a class, using the board or other data form.

3. Some possible discussion questions and prompts:
   • Did each team learn different skills?
   • Did any team learn more skills than the other teams?
   • What are some skills they already had going into the game?
   • How did the students learn how to play the games as a group? Did individuals learn the game differently? (for example, some people might like listening to instructions, while others may prefer to read them)
   • What skills did the games all require (e.g., teamwork, reading)? How were the games different (e.g., required drawing skills, focused on strategy, required math)?

4. **Discuss as a class**: How could this study have been improved?

5. How could we show the results? Go over different ways of comparing, analyzing, and showing results (graphing, description, photos, etc). If you have time or an additional session, work as a class to come up with a presentation of the results.

**Optional Resources and Additional Reading**
- Board game recommendations: [https://www.fractuslearning.com/2015/04/14/best-board-games-for-kids/](https://www.fractuslearning.com/2015/04/14/best-board-games-for-kids/)
- Full inventory and reviews of board games at: [http://boardgamegeek.com](http://boardgamegeek.com)
- *How to Think Like a Scientist*. Stephen Kramer and Felicia Bond.
ENGINEERING AND CONSTRUCTION: SOLVING REAL-WORLD PROBLEMS

Suggested Time: 60-120 minutes

Overview*
This lesson covers some of the same concepts as Architecture and Design: Building Blocks, but from an engineering perspective. After reviewing basic shapes and mathematical concepts related to the Rubik’s Cube, students will approach engineering as a science that solves problems and improves human lives. One option is to explore mechanical engineering by building a robot that can solve a Rubik’s Cube. Another option is to work in a nearby playground or park, where students will work together to brainstorm improvements, then come up with designs and/or models of contraptions that would improve the lives of their fellow students.

Vocabulary
- Shape
- Cube
- Square
- Rectangle
- Triangle
- Circle
- Sphere
- Ovoid
- Two-dimensional
- Three-dimensional
- Angles
- Net
- Engineering
- Civil engineering
- Mechanical engineering
- Chemical engineering
- Electrical engineering
- Design
- Construction
- Public works
- Public/community benefits
- Configuration problem

Objectives
- Students will learn how engineering can improve quality of life.
- Students will learn the basic mechanics of a Rubik’s Cube.
- Students will become familiar with basic mathematical concepts in geometry.
- Students will gain hands-on practice either in civil engineering, or mechanical engineering.

Next Generation Science Standards
ETS1.A: Defining and Delimiting Engineering Problems
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (secondary to 4-PS3-4)
Analyzing and Interpreting Data
• Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2)

Obtaining, Evaluating, and Communicating Information
• Obtain and combine information from books and other reliable media to explain phenomena. (4-ESS3-1)

Developing and Using Models
• Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)
• Develop a model to describe phenomena. (5-PS1-1)

ESS3.C: Human Impacts on Earth Systems
• Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (K-ESS3-3)
• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)

Science Knowledge Is Based on Empirical Evidence
• Scientists look for patterns and order when making observations about the world. (2-LS4-1)
• Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)
• Construct an argument with evidence, data, and/or a model. (4-LS1-1)

PROJECT MATERIALS
• Several Rubik’s Cubes (ideally enough for each student). Available from www.YouCanDoTheCube.com. Teachers may borrow up to 36 cubes at no cost or purchase cubes as a long-term resource
• 8 sheets of white copy paper
• Scissors
• 6 markers in Rubik’s Cube colors, or paints
• String
• Clear packaging tape

RESOURCES
• Mistakes That Worked. Charlotte Jones, et.al.
• “Fastest Robot to Solve a Rubik’s Cube.” Guinness World Records. Video (1.01) https://youtu.be/by1y27Ioick
• You CAN Do the Rubik’s Cube Unit Study Lesson: Making a 2X2 Rubik’s Cube activity.

Interactive instruction on nets (two-dimensional shapes that can be folded into cubes): Illuminations. https://illuminations.nctm.org/activity.aspx?id=3544


Graphic Organizer Examples

Before the Lesson/ Background Information

• Pick a fun, engaging, and maybe a little unexpected chapter or story from *Mistakes that Worked*. (You can use stories from this book throughout the course.)
• Review the instructions for building a 2X2 Rubik’s Cube out of paper.
• Select paper robot designs most appropriate for your students to complete at home.
• Choose an outdoor area where students may identify needed improvements that can be made using engineering (optional).

THE LESSON

Part 1: What is Engineering? (20 mins)

1. Read the selected chapter from *Mistakes That Worked* with the students.

2. What is engineering? What is the purpose of engineering? While some people have accidentally stumbled on great ideas, others set about trying to solve real-world problems. Work with the class to come up with examples. *Bridges, for example, help people to travel across canyons and over water. They reduce the distance between two places and improve access. However, what do we have to consider when building bridges? Cover safety concerns, aesthetics, durability, etc.*

3. Define the main branches of engineering: *electrical*, *mechanical*, *chemical*, and *civil*. Draw a diagram on the board (something fun, like a spider or a tree) with engineering in the middle and each branch extending outwards or chose a graphic organizer to reproduce on the board/overhead while students fill out their own. Work with the class to come up with examples of things each type of engineer might build.


5. Watch the Rubik’s Cube Solving Robot videos with the class.
**Part 2: Make a Paper Rubik’s Cube (40 mins)**

1. Students will engineer a functional 2X2 Rubik’s Cube using paper.

2. Separate the students into teams. The students will watch “How to Make a Fully Functional 2X2X2 Rubik’s Cube” by ADHD Cuber and follow the instructions, using the video and “You CAN Do the Rubik’s Cube Unit Study Lesson: Making a 2X2 Rubik’s Cube” activity as guides.

3. Teams will collaborate to finish their 2X2 Rubik’s Cubes.

4. Work with the class to identify the shapes and angles that were used in the creation of the paper Rubik’s Cubes.

5. Define **net** in mathematics (*a two-dimensional figure that can be folded into a three-dimensional object*). Using a projector if possible, work through the interactive problems provided on the Illuminations website. As you work through each design, have the class vote on whether or not the 2D figures can be folded into cubes. For more advanced students increase the rigor by instructing the students to cut out only the colored squares of the Cube Template to create a viable net for a cube.


7. If you have time or an additional class session, proceed with Part 3 or see the Architecture and Design: Building Blocks lesson for additional ideas. Students may also complete the paper robot design at home. Once finished, display the paper robots in class.

**Part 3: Public Works That Do Good Work (60 mins)**

1. Take the students to the selected outdoor area. (If none is available, you can select an indoor area the children use, such as the cafeteria.) What are some things that could be improved? Examples could include: ugly or worn playground equipment; playground equipment that isn’t the right height or isn’t very fun; lack of interesting or fun activities in an indoor area; desks that don’t have storage inside them; unused or ugly space; space that could be more environmentally friendly; etc.

2. Once back in class, brainstorm a list of ideas to write on the board.
3. Students can work in groups, pairs, or individually. Each student or group will pick a problem and design a solution.

4. Students should work on drawing and diagramming the solution.

**Optional Resources and Additional Reading**


* This lesson can be combined with the Architecture and Design: Building Blocks lesson.
CUBE TEMPLATE

Cut out entire black shape. Fold on dotted white lines and secure with clear tape.
MATERIALS SCIENCE: HOW THINGS ARE MADE

Suggested Time: 120-180 minutes

Overview
Students will discuss various artificial materials that go into the design and manufacture of the Rubik’s Cube and other toys, and learn about the natural sources of these materials. Then they will design their own model of the Rubik’s Cube and, as an optional activity, make a mock assembly line.

Vocabulary
- Natural resources
- Raw materials
- Artificial or synthetic materials
- Materials Science
- Manufacturing process
- Plastic
- Polyurethane
- Molding
- Injection molding
- Parts Assembly
- Labeling
- Packaging
- Quality control
- Model

Objectives
- Students will learn the difference between natural and artificial/synthetic materials.
- Students will learn how plastic is made and what it is used for.
- Students will become familiar with the design, manufacture, and assembly processes associated with modern production.
- Students will consider the social and environmental impacts of certain materials.
- Students will learn how to construct and use models.

Next Generation Science Standards
ESS3.C: Human Impacts on Earth Systems
- Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (K-ESS3-3)
- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)

PS1.B: Chemical Reactions
- Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not. (2-PS1-4)
- When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)
• No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)

Influence of Science, Engineering, and Technology on Society and the Natural World
• Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world. (2-PS1-2)
• Engineers improve existing technologies or develop new ones. (4-PS3-4)
• Over time, people’s needs and wants change, as do their demands for new and improved technologies. (4-ESS3-1)

Interdependence of Science, Engineering, and Technology
• Knowledge of relevant scientific concepts and research findings is important in engineering. (4-ESS3-1)

Science Is a Human Endeavor
• Science affects everyday life. (4-PS3-4)
• Most scientists and engineers work in teams. (4-PS3-4)

Project Materials
• A Rubik’s Speed Cube (for demonstration)
• Several Rubik’s Cubes (ideally enough for each student). Available from www.YouCanDoTheCube.com. Teachers may borrow up to 36 cubes at no cost or purchase cubes as a long-term resource
• Foam, wood, or plastic cubes such as these (in color for youngest students): https://amzn.com/B000F8VB4G OR unpainted to add a layer of complexity: https://amzn.com/B01GKHF998
• Various other shapes (optional), such as: https://amzn.com/B00PR9IWDQ
• Paint (optional)
• Glue
• Wire
• Springs, such as: https://amzn.com/B007F0U6SO
• A limited supply of craft items
• Several Rubik’s Cubes in various states of deconstruction — or take apart and re-assemble one in class as a demonstration
• Screwdriver or other flat object for taking apart a Rubik’s Cube
• Awards/prizes

Resources
• “LEGO (Injection Moulded Plastic).” Video (3.38) https://youtu.be/y1Zhpdx-XtA
• “Inside LEGO’s Robot Factory Where Toys Get made.” Bloomberg Video (2.17) https://youtu.be/whv-krWnq0g
• “How It’s Made: LEGOs.” How It’s Made Video (5.36) https://youtu.be/zrrKih5rqD0
Before the Lesson/ Background Information

• Look over the Optional materials to decide what to use with your students. Look for more recent articles on the uses of plastics for conservation projects or other beneficial things.
• Print out and review “How Rubik’s Cube is Made” and “Erno Rubik: How We Made Rubik’s Cube.” Note that “How Rubik’s Cube is Made” covers a previous model of the Rubik’s Cube; modern ones are different.
• Practice taking apart and reassembling a Rubik’s Cube (there are various online sources with instructions on how to do this). Please note: Do not disassemble the Rubik’s Cubes if they were borrowed from the You CAN Do the Rubik’s Cube Lending Library program. Either have several Rubik’s Cubes on display in class in various states of assembly, or allow time in the lesson to do a demonstration of how to take it apart and put it back together again. Alternatively, you can show a video of how the Rubik’s Speed Cube is taken apart in class.
• If possible and you have time or an extra session, plan a field trip to a toy factory so that students can see the process of molding and assembly in person.

THE LESSON

Part 1: The Study of Materials (60 mins)

1. Define the field of Materials Science. Look around the room or at various games you’ve used in class and identify different materials (e.g., ceramic, porcelain, or plastic dominoes; wood blocks; thick cardboard for board games; thick paper for cards, etc). Discuss where these materials come from and how they are different. Identify and discuss natural resources and the fact that artificial or synthetic materials still come from natural resources.

2. Have students pass around a Rubik’s Cube and analyze what it is made of (modern ones are plastic).

3. Go over the article, “How Rubik’s Cube is Made” and show “Rubik’s Speed Cube — Taking the Cube Apart.”

4. Mention that polyurethane, and other types of plastic are frequently used to make toys. Read one of the optional books with the class. Then, show the videos “How Plastic is Made,” the videos about LEGO bricks, and “The Story of Bottled Water.” Discuss environmental drawbacks associated with plastics, such as the fact that they are made from petroleum, a limited natural resource; and that it accumulates in a lot of trash and doesn’t biodegrade.
5. Next, discuss the special properties of plastic and get the kids to think about why it’s potentially a wonderful material. Are there any materials that share the same properties? What are some beneficial uses of plastic? You may want to get into the articles about the robotic turtle, which is used in vital research projects, and the development of prosthetic limbs for wildlife as well as people.

6. Have the class come up with and discuss potential solutions to environmental problems associated with plastic. Are there ways to keep making plastic for great stuff like Rubik’s Cubes, and still take better care of our planet? Suggested video: https://www.ted.com/talks/melati_and_isabel_wijsen_our_campaign_to_ban_plastic_bags_in_bali?language=en

**Part 2: Make a Model of the Rubik’s Cube (60 mins)**

1. Demonstrate how to take apart a Rubik’s Cube or Speed Cube and put it back together again, or to save time, have several Rubik’s Cubes on display in different stages of deconstruction. Allow the students to inspect the parts by passing them around the classroom. **Please note:** Do not disassemble the Rubik’s Cubes if they were borrowed from the You CAN Do the Rubik’s Cube Lending Library program.

2. Encourage the students to ask questions and to play with the parts until you are satisfied that they understand how it works.

3. Note that Rubik’s Cube has been made in several different ways over the years. How is the modern Rubik’s Cube an improvement? Discuss.

4. Discuss the function of models. A model can help someone to understand something they can’t see. Instruct the class to make their own model of the Rubik’s Cube. Have the students imagine how they would show a younger sibling or friend how the Rubik’s Cube works and what it’s made of.

5. Using the materials provided and working in groups, students will come up with models of the Rubik’s Cube.

6. Pass out awards/prizes to the winning models or have the students vote and rank them.

7. If you have time/ an additional session, proceed with Part 3, or plan a field trip to a toy factory so that students can see the process of molding and assembly in person.
Part 3: Assembly Line and Manufacture (60 mins)

1. Separate students into four teams: Molding, Parts Assembly, Labeling, and Packaging, using “How Rubik’s Cube is Made” as a guide. Make sure the class understands that this article describes an older version of the Rubik’s Cube.

2. Students will play-act the role of each stage in the toy manufacture and assembly process. They can do this by:
   - Building and processing small models made with the cubes provided
   - Assembling real Rubik’s Cubes
   - Assembling the winning Rubik’s Cube Model in stages

3. The Molding Team will practice choosing and/or making the parts. The Parts Assembly Team will put together the parts. Labeling might paint the blocks or be part of the Molding Team, depending on the project you are doing. The Packaging Team should come up with the instructions that will be included with the model and come up with ideas for fun (and/or environmentally friendly!) packaging.

Optional Resources and Additional Reading

- A Plastic Bottle’s Journey (Follow It!). Suzanne Slade and Nadine Wickenden.
- From Plastic to Soccer Ball (Start to Finish: Sports Gear). Robin Nelson.
PHYSICS: MAY THE FORCE BE WITH YOU

Suggested Time: 60-120 minutes

Overview
Students will explore the physics of the Rubik’s Cube through attempting to solve a few stages of the Rubik’s Cube themselves (such as the white cross and white corners) and learning about speedcubing. They will learn how specific materials and the addition of lubricant is used to make speedcubing possible. Then, as an optional lesson, students may learn about the physics of sports and gaming, engage with practical physics through hands-on projects, and consider the importance of physics to a wide variety of fields and to everyday life. Finally, they will learn about the importance of physics applications in disciplines like astronomy.

Vocabulary
- Newton’s laws
- Gravity
- Center of mass
- Velocity
- Motion
- Speed
- Direction
- Horizontal Force
- Vertical Force
- Push and pull
- Lubricant
- Static Friction
- Dynamic Friction
- Energy
- Transfer of energy
- Thermodynamics
- Universe
- Astronomy

Objectives
- Students will study basic concepts in physics through hands-on application.
- Students will design their own physics experiments.
- Students will direct their own learning about concepts in astronomy.

Next Generation Science Standards
PS2.A: Forces and Motion
- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1)
- The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)
PS2.B: Types of Interactions
- Objects in contact exert forces on each other. (3-PS2-1)
- Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

PS3.C: Relationship Between Energy and Forces
- When objects collide, the contact forces transfer energy so as to change the objects’ motions. (4-PS3-3)

PS3.A: Definitions of Energy
- The faster a given object is moving, the more energy it possesses. (4-PS3-1)
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2), (4-PS3-3)

Planning and Carrying Out Investigations
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
- Make observations (firsthand or from media) to collect data which can be used to make comparisons. (2-LS4-1)
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-PS2-1)
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2)
- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)

Using Mathematics and Computational Thinking
- Measure and graph quantities such as weight to address scientific and engineering questions and problems. (5-PS1-2)

Cause and Effect
- Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)

Science Knowledge Is Based on Empirical Evidence
- Scientists look for patterns and order when making observations about the world. (2-LS4-1)
- Science investigations use a variety of methods, tools, and techniques. (3-PS2-1)
- Construct an argument with evidence, data, and/or a model. (4-LS1-1)

Energy and Matter
- Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4)
**PROJECT MATERIALS**

- Several Rubik’s Cubes (ideally enough for each student). Available from www.YouCanDoTheCube.com. Teachers may borrow up to 36 cubes at no cost or purchase cubes as a long-term resource
- At least one Speed Cube
- Older stickered Rubik’s Cubes, if possible (for best testing of the effects of lubricant)
- Rubik’s Lube (also available on rubiks.com)
- Straws, popsicle sticks, rubber bands, paper clips, toothpicks, recyclables from home, etc. (see *Junk Drawer Physics* for ideas and material lists)

**RESOURCES**

- Speedcubing on Rubik’s website: https://www.rubiks.com/speed-cubing
- “Lubrication” on Speedsolving Wiki: https://www.speedsolving.com/wiki/index.php/Lubrication
- “Rubik’s Speed Lube — How to Lube the Cube.” Video (1.21) https://youtu.be/Y5HplkThav0
- NASA Space Place: http://spaceplace.nasa.gov

**BEFORE THE LESSON/BACKGROUND INFORMATION**

- Read and print the summary of speedcubing from the Rubik’s website.
- Read and print the “You CAN Do the Rubik’s Cube” Solution Guide*. Familiarize yourself with the White Cross and White Corners solving stages (or the following stages, if your class has already completed these stages).
- Check the Speedsolving Wiki for fun activities (such as speedcubing while blindfolded), and tips and tricks for speedcubing
- Look online (such as on the Speedsolving Wiki and YouTube) for speedcubing videos you want to use in class.
- Review the texts for assignments and excerpts you want to use in class.
- Visit NASA’s Space Place and, if desired, select specific projects and activities for your students to begin with.

*Class sets of printed “You CAN Do the Rubik’s Cube” Solution Guide are available. For more information, write to info@youcandothecube.com.*
THE LESSON

Part 1: Rubik’s Physics (60 mins)

1. Explain how the physics and mathematics found in games are the very same laws that govern the universe — and everyday life. Use simple examples or ask the students for their own.

2. What laws of physics apply to solving a Rubik’s Cube? While simple, physics laws do apply. What kind of force do you have to apply to the Rubik’s Cube to solve it? How is friction involved? What is important about the engineering of the Rubik’s Cube, and the materials used to make it, related to physics?

3. Students will complete an activity from the “You CAN Do the Rubik’s Cube Solution Guide,” such as “Solve the White Cross” and “Solve the White Corners”.

4. Introduce speedcubing. Read the summary from the speedcubing section on the Rubik’s website and show any videos you found online.

5. Set up a test comparing a lubricated Rubik’s Cube with a Speed Cube. Please note: DO NOT apply lubricant to the Rubik’s Cubes if they are borrowed from the You CAN Do the Rubik’s Cube Lending Library Program. First, students will watch “How to Lube the Cube,” then follow the instructions or watch the teacher model the process.

6. Pass around the Speed Cube. Students will compare a lubricated Rubik’s Cube with the performance of the Speed Cube.

7. Discuss: What makes the Speed Cube faster? What is the function of lubricant? Compare static and dynamic friction. Note: the older stickered Rubik’s Cubes benefit the most from lubricant.

8. Go through the vocabulary concepts listed and relate them to the Rubik’s Cube.

9. Allow some time at the end of class to discuss how an understanding of physics through games can be applied to various disciplines, as well as solving problems in everyday life.

10. One of the major fields where the study of physics is extremely important is, of course, astronomy! As homework, assign topics and games on NASA’s Space Place. Mars Exploration is a great place to start!

11. Proceed with Part 2 if you have time/ an additional class session.
Part 2: The Physics of Games (60 mins)


2. Separate the students into groups. Assign the groups selected experiments from Junk Drawer Physics. Allow students to experiment with materials and come up with solutions on their own. When the groups are finished, they should demonstrate their experiments to the rest of the class. Encourage other students to ask them questions.

3. If you have extra outdoor time or another class session, allow students to practice and analyze physics principles through outdoor play, using an outdoor sport that involves hitting or aiming a ball (such as soccer or basketball). Have them explore the physics in class using graphs, equations, drawings, etc.

Optional Resources and Additional Reading

• How to Think Like a Scientist. Stephen Kramer and Felicia Bond.
• Various videos on Speedcubing (such as: https://www.speedsolving.com/wiki/index.php/Fastest_Videos_for_each_Method)
THE SCIENCE OF MEMORY AND LEARNING: BRAIN GAMES

Suggested Time: 60-120 minutes

Overview
Focusing on memory and how the brain learns by forming connections, students will learn about how the human brain works and how games (including the Rubik’s Cube) can help improve certain brain functions. Students will practice improving their own memories by practicing memory games.

Vocabulary
- Psychology
- Neuroscience
- Brain
- Neurons
- Cognition
- Learning
- Memory
- Nutrition

Objectives
- Students will explore the relationship between neuroscience and psychology.
- Students will work to improve their own memories and build reading comprehension.
- Students will learn how nutrition can affect brain function and development.

Next Generation Science Standards
LS1.A: Structure and Function
- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

LS4.D: Biodiversity and Humans
- There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)
- Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)

Planning and Carrying Out Investigations
- With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1)
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
**Project Materials**
- Diagram of the human brain
- Paper and markers
- Computers with access to the internet
- Rubik’s Cube Memory Game from Learn to Solve Curriculum.

**Resources**
- “Memory” Game online: http://www.knowledgeadventure.com/games/memory/
- *Scholastic Success with Reading Comprehension.* Workbooks available for Grades 1-6.
- *Eat Lots of Colors.* Helen Marstiller, et.al.
- *The Smart Brain Train.* Nina Anderson.

**Before the Lesson/ Background Information**
- Familiarize yourself with chants, acronyms, etc. associated with remembering how to solve the Rubik’s Cube.
- Look on YouTube for more fun chants, raps, etc. you’d like to show to the class.
- Print out copies of the National Geographic chapter, *the Mind-Blowing Science of Your Amazing Brain,* on how the brain remembers. Select activities and other useful excerpts from the book.
- Select the appropriate *Scholastic Success with Reading Comprehension* workbook. It is recommended to provide a challenge for students by selecting a grade higher than their level. Students can then work toward the higher level workbook by practicing memory-improvement games and activities.
- Select activities for the students to take home and complete with their families from *The Smart Brain Train.*
THE LESSON

Part 1: Rubik’s Rap (30 mins)

1. Ask students how they remember to solve parts of the Rubik’s Cube. People remember in different ways: by using a sequence of colors, or remembering a pattern of moves. Songs and dances can help with remembering, too.

2. Watch “How to Solve a Rubik’s Cube.”

3. With the class, explore what other people have come up with on YouTube (screen these in advance for language and content).

4. Work with the class to come up with an original dance and song/rap. Encourage the students to take leadership in this. For example, if students like to play clapping games or do a particular type of dance in their communities, they can make a Rubik’s Cube version.

5. Alternatively, split the class into two teams. Each team will come up with a different rap. Have them do a rap battle!

Part 2: How the Brain Works (30 mins)

1. Games like the Rubik’s Cube can help to improve cognitive function, including memory. Use the chapters and activities from National Geographic’s Brain Games to explore these facts.

2. Students will use the paper and markers, the brain diagram, and what they’ve learned to draw their own educational maps or mazes (their choice) of the human brain. (Example: How many important parts of the brain can they feature in a maze as "stops along the way?")

3. Proceed with Part 3 if you have time, or assign some of the educational resources as homework.
Part 3: Improving Memory (60 mins)

1. Introduce games that are specifically designed for improving memory. Discuss other ways to improve memory. Nutrition is very important for proper brain function and development. Read *Eat Lots of Colors* with the class or assign it as homework.

2. Students will play the memory games in class, starting with the “Memory” matching game online, then playing hands-on memory games together. Have them play the “Rubik’s Cube Memory Game” from the Learn to Solve Curriculum. If you have time, you may follow with one of the memory games listed under Optional Resources and Additional Reading, such as “Math Penguins Memory Game.”

3. Students will complete reading comprehension exercises from *Scholastic Success with Reading Comprehension*.

4. Throughout the course or as homework assignments, have students play the memory games from *Scholastic Success with Reading Comprehension* and use them to see if they can improve their performance in reading comprehension. Check back in with the students and document their improvements over time by testing them.

5. Assign homework for the students to complete with their families from *The Smart Brain Train*.

Optional Resources and Additional Reading

- National Geographic: “My Brilliant Brain.” Documentary (47.07).
- Eeboo matching games such as “Life on Earth”, OR “I Never Forget a Face” for slightly older students. May be available locally or at major distributors.
- “Math Penguins Memory Game” or similar. May be available locally or at major distributors.
BRAIN DIAGRAM
BRAIN DIAGRAM LABELED

Frontal Lobe

Parietal Lobe

Occipital Lobe

Temporal Lobe

Cerebellum

Brain Stem
**BRAIN DIAGRAM WORKSHEET (KEY)**

Use the word bank to label the parts of the brain diagrams. Some words will be used more than once.

**Word Bank**
- Cerebrum
- Cerebellum
- Brain Stem
- Frontal Lobe
- Parietal Lobe
- Occipital Lobe
- Temporal Lobe

**Diagram 1**
- Cerebrum
- Brain Stem
- Cerebellum

**Diagram 2**
- Frontal Lobe
- Parietal Lobe
- Occipital Lobe
- Temporal Lobe
- Cerebellum
- Brain Stem
- Cerebrum
TECHNOLOGY AND COMMUNICATION: BUILD YOUR OWN GAME!

Suggested Time: 60-120 minutes

Overview
Students will learn how logic is just as important for developing video and computer games as it is for developing physical games like the Rubik’s Cube. They will learn basic logic by programming their own simple games, starting with basic programming skills and becoming more advanced as they are able.

Vocabulary
- Computer
- Formal logic
- Logic programming
- Data/information
- Input
- Output
- Programming language
- Code
- Loops
- Conditionals
- Branching
- Iterative repetition
- Video Games
- Platform

Objectives
- Students will learn how to design and code their own games.
- Students will learn and practice logic through a hands-on activity.

Next Generation Science Standards
Obtaining, Evaluating, and Communicating Information
- Obtain and combine information from books and other reliable media to explain phenomena. (4-ESS3-1)

ETS1.A: Defining and Delimiting Engineering Problems
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (secondary to 4-PS3-4)

Developing and Using Models
- Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)
- Develop a model to describe phenomena. (5-PS1-1)
Project Materials

- Apple devices that can use apps (iPad, iPod Touch)
- Computers
- Alice: http://www.alice.org/index.php?page=what_is_alice/what_is_alice
- Scratch (free): https://scratch.mit.edu
- Browser recommended: Chrome (use other browsers at your own risk)

Resources

- Overview of logic and game theory: http://plato.stanford.edu/entries/logic-games/

Before the Lesson/Background Information

- Download Bee Bot, Daisy the Dinosaur, and Alice, and enroll the class in Scratch, which is free.
- Explore the Scratch website for inspiration and to get familiar with the tools.
- Structure the class based on technology required and available, and the abilities of your students. For example, if you are using computers or only mobile devices, plan accordingly. Some students may not be familiar with computer keyboards, for example, and may require extra instruction.
- If using Safari as your web browser, you may want to go to Preferences, click “Advanced”, and click “Enable Developer menu.” Under the Developer menu, click “Enable WebGL.”
- Review the resources on logic programming and the role of logic in game development and game theory, so that you are familiar with the topic and can help facilitate making connections for the students.

The Lesson

Part 1: Solving Rubik’s Cubes Online (20 mins)

1. Demonstrate or allow students to play with Google’s Interactive Doodle — Rubik’s Cube. Note that from the home page, you have to click on a link to pull up the interactive game. How was the interactive online game made? Use this to introduce programming language/code. Inform the students that they will learn how to code their own games today.

2. Allow students to solve the Google Interactive Doodle — Rubik’s Cube.

3. Have students search on scratch.com for 3D puzzles people have coded themselves. Have them solve the puzzles and compare them.
**Part 2: Create Your Own Game! (40-100 mins)**

1. Define basic logic and briefly describe the history and role of logic in gaming/game creation. Programming logic is related to the same logic one uses to solve a Rubik’s Cube. However, don’t lead a formal logic lesson; students will learn logic by doing.

2. Allow students to use the resources provided to progress at their own pace. Students should use the simplest programs to begin learning programming language and logic. Use the following guide to determine how each student should begin:
   - Beginners and Elementary: Bee Bot; Daisy the Dinosaur (in Challenge mode), then Free Play after that; Alice
   - Intermediate (for students that already have a basic concept of programming logic): Scratch

3. After each student becomes individually familiar with basic programming concepts, allow them to design and create their own very simple games in pairs or small groups. Depending on the levels of your students, you may want them all to use Scratch, which is ideal for ages 8 and up but can be used by younger students as well.

4. Separate students into pairs or groups.

5. First, each group should design and draw a 2D object. If they master this, they can move on to developing a 3D cube.

6. Have student groups test and rate each other’s creations and provide structured, constructive feedback to one another.

7. If possible, allow students to incorporate the feedback and revise the games.

8. Allow students to work on the games as homework, if necessary/possible.

9. If possible, publish the games on a school website, on the Scratch website (where users share their creations), or host an event to exhibit the creations for parents and teachers.

**Optional Resources and Additional Reading**
- For more inspiration and resources: http://code.org
- **Hello World! Computer Programming for Kids and Other Beginners.** Warren and Carter Sande.
- **Super Scratch Programming Adventure! Learn to Program by Making Cool Games.** The LEAD Project.
- Advanced programming options: Hopscotch, Tynker (only available to schools), and Codea.
- Codea: http://twolivesleft.com/Codea/
- Code Studio: Code.org
Allow students to test and rate each other’s creations and provide structured, constructive feedback to one another using the reproducible chart below. Fill in each category based on the skills you want your students to master.

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<th>Needs Improvement</th>
<th>Room to Grow</th>
<th>Excellent Work!</th>
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www.YouCanDoTheCube.com

Developed by: STEM.org
ADDITIONAL RESOURCES

- Rubik’s Home Page: https://www.rubiks.com
- Rubik’s Cube YouTube Channel: https://www.youtube.com/user/RubiksTV/featured
- You CAN do the Rubik’s Cube YouTube Channel: https://www.youtube.com/user/RubiksCubeSolution

SPECIFIC RESOURCES:

- Rubik’s Cube Solution- You CAN Do the Rubik’s Cube video: https://www.youtube.com/watch?v=XPFxFW596uY&t=12s

- Go Beyond Rubik’s Cube Traveling Exhibit: http://brc.lsc.org

- Interactive Google Rubik’s Cube Doodle: https://www.google.com/doodles/rubiks-cube


- Over 3300 puzzles and forums: http://www.twistypuzzles.com

- The Online Puzzle Museum: http://www.puzzlemuseum.com

OPTIONAL LABORATORY EXTENSIONS

OVERVIEW

These recommendations are for students that have additional laboratory hours, or who need to complete a semester-long project. They are also complementary with the lessons provided in this module. Using these resources, teachers can focus class studies on engineering, robotics, architecture, the scientific method, model-building, physics, biology, art and design, and any other specialized topics related to the STEM subjects covered in this course.
Optional Materials and Resources

- Mindcuber instructions for Mindstorms EV3: [http://mindcuber.com](http://mindcuber.com)
- For younger/ inexperienced students who want to get into programming and robot-building: BeeBot, available at [https://www.bee-bot.us](https://www.bee-bot.us)
- Art Lab for Kids. Susan Schwacke, et.al.
- Snap Circuits Lights Electronic Discovery kit, or similar
- Snap Circuit kits, various
- ScienceWiz electricity kit, or similar
- ScienceWiz DNA experiment kit, or similar
DIGITAL BADGES

Digital Badges:
Digital badges are a validated indicator of accomplishment, skill, quality or interest that can be earned in various learning environments.

Open Badges:
Open Badges are designed to serve a broad range of digital badge use cases, including both academic and non-academic uses. The Open Badge specification is made up of three different parts: Assertion, BadgeClass, and IssuerOrganization.
• An Assertion is a representation of an awarded badge, used to share information about a badge belonging to one earner.
• A BadgeClass is a collection of information about the accomplishment recognized by the badge.
• An IssuerOrganization is a collection of information about the entity or organization issuing the badge.

Mozilla Foundation:
Open Badges is the name of a group of specifications and open technical standards originally developed by the Mozilla Foundation with funding from the MacArthur Foundation. The Open Badges standard describes a method for packaging information about accomplishments, embedding it into portable image files as a digital badge, and establishing an infrastructure for badge validation. Mozilla’s Open Badges project is working to make it easy for anyone to issue, earn, and display badges across the web.

How to redeem your module badge online:
• Go to the link https://credly.com
• Create an account by clicking on “Create Account” in the top right corner of your browser.
• Enter your information
• Agree to the license agreement
• Click “Sign Up Now”
• Verify your email by clicking on the link in your email’s inbox
• Click on “Claim Credit” at the top of the main page
• Enter claim code BF7-622C-1CG
• Click “Claim Credit”
• Continue by clicking “Claim This Credit”
• Wait to recieve your badge in your email inbox after approval from Stem.org
Lesson 1: Introduction: Ancient Games and Puzzles Around the World
Lesson 2: Animals and Biology: How Animals Learn Through Play
Lesson 3: Architecture and Design: Building Blocks
Lesson 4: Educational Games: a Classroom Study
Lesson 5: Engineering and Construction: Solving Real-World Problems
Lesson 6: Materials Science: How Things Are Made
Lesson 7: Physics: May the Force Be With You
Lesson 8: The Science of Memory and Learning: Brain Games
Lesson 9: Technology and Communication: Build Your Own Game!