STEP-BY-STEP: INTRODUCTION TO CODING

OBJECTIVE: Students will gain an understanding of what algorithms are, and how they are translated into coding to drive the actions of computers and computer-controlled objects.

TIME: 30 minutes (60 minutes with lesson extension)

MATERIALS: Pencils or pens, "Step-by-Step" student worksheet

LESSON PLAN

1. **Pre-Activity Discussion: What Is Coding?** Ask students to describe some of the actions that we use computers to do. *(For example, send emails, play video games, perform calculations, etc.)* Ask students how they think the computer performs these complicated tasks. *(Students may say that there are computer programs that give computers instructions about what actions to take.)* Explain to students that computer programmers rely on **algorithms** to direct the actions of a computer or a computer-controlled device like a robot. An algorithm is a set of steps that can be followed from start to finish to complete a task. In an algorithm, a complicated action is broken into many small steps. Explain that computer programmers write algorithms for each task a computer needs to do. Then they translate the algorithms into a language that a computer can read and follow. This language is called computer **code**.

2. **Conduct the Activity:** Hand out the "Step-by-Step" student worksheet. In the exercise, students will follow an algorithm to draw an image and then write a code for the algorithm. When everyone has finished, discuss what they learned. Why was it important that each step was very simple? How might you make the code shorter? *(For example, a code may include instructions to repeat a small segment of the steps.)* Explain that computer programmers use loops to shorten the codes that they write. A loop is a group of actions that is repeated a given number of times. For example, take the following code:

   ↓•↓•↓•↓•↓•↓•↓•↓•↓•↓•↓•↓•

   This code can be shortened to **Repeat 12 times: ↓•**

STANDARDS FOCUS:

Science (NGSS)

Science and Engineering Practices: Asking Questions and Defining Problems, Developing and Using Models, Using Mathematics and Computational Thinking
ETS1.A: Defining and Delimiting an Engineering Problem

Language Arts (CCSS)

R7: Integrate content presented in diverse formats
RSci2: Follow precisely a multistep procedure when performing technical tasks

Art (National Core Arts Standards)

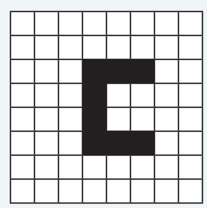
VA—Cr1: Generate and conceptualize artistic ideas and work

Math (CCSS)

MP5: Use appropriate tools strategically
MP7: Look for and make use of structure

ANSWERS TO STUDENT WORKSHEET

PART 1



PART 2

Code:
→→→↓↓ • ↓ • ↓ • ↓ • → • → • ↑↑↑ • ← •

EXTENSION

Coding Challenge: Challenge students to write code that can be used to create a more complicated image. Have them start by drawing a multicolored image on a piece of graph paper. Then ask them to write a code, using symbols that can be used to copy the image. Challenge them to include loops in their code. Have students test their code by giving it to a classmate. Were they able to successfully draw the image? Discuss the challenges students faced when writing their code.

DIVE DEEPER WITH KOOV

KOOV provides endless opportunities to explore how coding can drive the actions of a robot. The My First Coding Learning Course gives students an in-depth introduction to basic coding on the computer. To use KOOV to extend this lesson, open the KOOV interface and go to the Learning Course. Choose My First Robot Coding. Complete Stage 1: "Let's Start Coding with KOOV." As you complete the stage, discuss how the code breaks larger actions down into small steps. Experiment with changing the order of steps.

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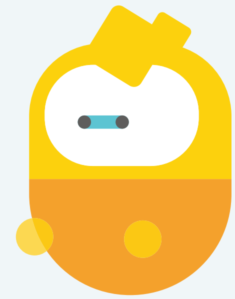
STEP-BY-STEP



Computers can perform very complicated tasks. Inside the computer, each complex action is broken down into smaller parts. These small steps are put together in a sequence, called an **algorithm (al-guh-ri-them)**. The computer follows the steps in the algorithm from beginning to end to complete a task.

In this activity, you'll draw an image on a grid by following the steps in an algorithm.

PART 1: Follow an Algorithm

DIRECTIONS: Start in the square in the left-hand corner of the grid below. Then follow the algorithm below.

Move one square right.
Move one square right.
Move one square right.
Move one square down.
Move one square down.
Color in square.
Move one square down.
Color in square.
Move one square down.
Color in square.
Move one square down.
Color in square.
Move one square right.
Color in square.
Move one square right.
Color in square.
Move one square up.
Move one square up.
Move one square up.
Color in square.
Move one square left.
Color in square.

START HERE							

What did you draw? ____________________

PART 2: Convert to Code

You probably noticed that it required a lot of text to guide you to draw a simple image. In computer programs, algorithms are written in a special language that can be read by the computer. This language is called computer code. Can you convert the algorithm above into a different form?

DIRECTIONS: Use the symbols below to change the algorithm you followed into a type of code.

← **Move one square left**
→ **Move one square right**
↓ **Move one square down**
↑ **Move one square up**
• **Color in square**

CODE: ____________________

CHALLENGE YOURSELF: Draw a more complicated image on a piece of graph paper. Then write your own code that can be used to copy the image. Test your code by giving it to a friend. Did they draw the same image?

INSTRUCT A ROBOT: PRACTICING CODING

OBJECTIVE: Students will learn how to translate a complicated task into an algorithm that has clear and simple steps.

TIME: 45 minutes

MATERIALS: Pencil or pen, "Instruct a Robot" student worksheet

STANDARDS FOCUS:

Science (NGSS)

Science and Engineering Practices: Asking Questions and Defining Problems, Developing and Using Models, Using Mathematics and Computational Thinking

ETS1.A: Defining and Delimiting an Engineering Problem

Language Arts (CCSS)

R7: Integrate content presented in diverse formats

RSci2: Follow precisely a multistep procedure when performing technical tasks

Art (National Core Arts Standards)

VA—Cr1: Generate and conceptualize artistic ideas and work

Math (CCSS)

MP5: Use appropriate tools strategically

MP7: Look for and make use of structure

LESSON PLAN

1. **Evaluate a Set of Instructions:** Tell students that you are going to give them instructions to bake a batch of cookies. Then write the following steps on the classroom board.

   - Gather eggs, butter, sugar, flour, baking soda, and chocolate chips.
   - Mix ingredients in large bowl.
   - Place cookie dough on a pan.
   - Bake until done.

   Guide students to evaluate your instructions. Ask the class: *Do they think a person could successfully bake cookies by following these steps? If 10 people followed these steps, would they all make the exact same cookies? Why or why not?* Prompt students to be specific when they describe the limitations of the instructions. (For example: The instructions don't say how much of each ingredient is needed. They don't explain the order in which the ingredients should be added. They don't specify how the dough should be placed on the pan—in balls or as one large layer. The temperature that the cookies should be baked at is not given. There are no instructions explaining how a person knows when the cookies are done.)

2. **Write a Recipe:** Explain to students that their task is to write an algorithm for baking cookies. An **algorithm** is a set of steps that can be followed from start to finish to complete a task. For example, scientists might write an algorithm that instructs a robot on how to bake cookies. As a class, try to write an algorithm for baking cookies. Make sure that each step is very specific. (For example: Break open 1 egg. Add 1 teaspoon of baking soda. Mix until there are no more lumps. Scoop out a 1-inch ball of dough.)

3. **Introduce Conditional Statements:** Computer codes are algorithms that give the computer instructions for how to complete an action. Explain that codes often include a specific type of language structure. They may include loops (See "Step-by-Step" lesson) or conditional statements. Also called if/then statements, a conditional statement instructs the computer to do a particular task if another condition is met. For example, a conditional statement might be "If the oven is at a temperature of 375°F, then place the cookie pan in the oven." Challenge the students to revise your code to include if/then statements. (For example, If the cookies are light brown in color, then remove them from the oven.)

4. **Conduct the Activity:** Hand out the "Instruct a Robot" student worksheet. In the exercise, students will write an algorithm that can be used by a fellow student—their "robot"—to complete a complicated task. Have them test their algorithms with another student. Discuss what went wrong if they are unsuccessful in their tests. Was there a step missing? Was the order of the steps accurate? Should the steps have been simpler actions?

DIVE DEEPER WITH KOOV

The KOOV platform makes it easy for students to challenge themselves to write complicated codes for their robots. Have them hone their skills by following the My First Robot Coding lessons in the Learning Course. Once they're mastered the basics, you can challenge the class to brainstorm a complex action for a KOOV robot and write the code to make it work. Experiment with using loops and conditional statements.

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INSTRUCT A ROBOT

Today, many robots perform complicated tasks—from building cars to sorting items in warehouses. Suppose you are an engineer who is designing a robot that can perform a task a human does today. Think about a task that can be completed in your classroom, such as sharpening your teacher's pencils or sorting recyclables. Your job is to write the instructions the robot needs to follow, called an **algorithm (al-guh-ri-them)**.

ASK

Identify the problem you want to solve. What job will your robot do?

____

____

What benefit would there be to having a robot do this task instead of a human?

____

____

PLAN

What actions does your robot need to do to complete this task? Write a list of the steps involved.

____

____

____

Does your robot need any materials to complete the task? If so, what is needed?

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____

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CREATE

On separate paper, write an algorithm for your robot to complete the task. Remember that an algorithm breaks complicated actions into very simple steps. For example, if your task is to sharpen a pencil, your instructions need to describe how to pick up the pencil, exactly how to use the sharpener, and how to know when the task is complete.

To write your own algorithm, follow these steps:

1. Plot out your work.
2. Write a first draft.
3. Review your draft and revise as necessary.

Try to use the following features in your algorithm:

A **loop**, which is a group of actions that is repeated a certain number of times. (***Example:*** *Repeat 10 times: Turn sharpener clockwise around the pencil.)*

An **if/then statement**, which is an instruction to perform a task if a certain condition is met. (***Example:*** *If the end of the pencil is a sharp point, then place the pencil on the desk.)*

TEST

Give your algorithm to another classmate to follow. Are they successful in completing the task? ____________

IMPROVE

Revise your algorithm if needed.

CREATE AN ANIMAL ROBOT: DESIGNING FROM NATURE

OBJECTIVE: Students will study the anatomy of an animal and use what they learned to design a robot that has similar characteristics.

TIME: 45 minutes

MATERIALS: "Create an Animal Robot" student worksheet, pens or pencils

LESSON PLAN

1. **Make Observations:** Show students images of several different types of animals, such as an alligator, a shark, a crab, and a bat. For each animal, ask students to describe the animal's features and their function. How do these features help the animal survive? Prompt students to consider how the animal moves, how it eats, features that keep it warm, etc. (For example, an alligator has four legs to walk on land and a tail that moves to help it swim and balance on land; a crab has 10 legs, eight that help keep it stable on the seafloor in moving water and two that are used to grasp things; a shark has sleek skin, strong jaws, and fins that help it move through the water; a bat has wings to fly; etc.)

2. **Link Observations to Engineering:** Show students a photo of an airplane. Ask students how they think scientists came up with the idea for the design of an airplane. (It has wings like a bird.) Explain to students that engineers are scientists who design new devices or objects in order to solve problems. Explain that engineers often look to organisms in nature for ideas about how to design new inventions. Instruct students to consider the features of the animals included in your classroom discussion. Brainstorm ways their characteristics could be useful in engineering design. (For example, the characteristics of a shark's skin may help make objects that move faster through the water; ocean-exploring robots may be designed with bodies that move easily through the water.)

3. **Design a Nature-Inspired Solution:** Hand out the "Create an Animal Robot" student worksheet and have students complete it independently. When everyone has finished, have the students share the models of their designs with the class for feedback. Give students the opportunity to revise or improve their designs based on the feedback.

STANDARDS FOCUS:

Science (NGSS)

Science and Engineering Practices: Asking Questions and Defining Problems; Developing and Using Models; Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information

LS1.A: Structure and Function

ETS1.B: Developing Possible Solutions

Language Arts (CCSS)

W2: Write informative/explanatory texts to examine complex ideas

SL5: Make strategic use of visual displays to express information

Art (National Core Arts Standards)

VA—Cr1: Generate and conceptualize artistic ideas and work

VA—Cr3: Refine and complete artistic work

EXTENSION

Engineering Design Process: Explain that engineers follow a series of steps to plan or build new objects. This is called the engineering design process. Review the steps below with the students. Ask students to analyze how they used the process.

STEP 1 Ask What Is the Problem?
STEP 2 Do Background Research
STEP 3 Identify Design Requirements
STEP 4 Brainstorm Possible Solutions
STEP 5 Make Models of Design
STEP 6 Build Design
STEP 7 Test Design
STEP 8 Improve Design

DIVE DEEPER WITH KOOV

KOOV's building blocks can be used to build working robots based on animal designs. Start by going deeper into the Block Artist Learning Course. Open KOOV and go to the Learning Course: Become a KOOV Block Artist. Complete Stage 4 of the course: "Learn by Watching and Copying." As students build, prompt them to analyze which parts of the robot are based on the animal's anatomy. Once they have completed this stage, have students move on to one of the Robot Recipes. These step-by-step guides for building robots are available in four different skill levels, and include examples with and without code. Once students have mastered the recipes, they can use what they learned to build their own designs based on a different animal.

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CREATE AN ANIMAL ROBOT

DIRECTIONS: Engineers often look to nature for inspiration when designing new inventions. For example, some robots built to explore the ocean are shaped like fish with fins that help them swim through the water. When trying to build a robot that can run fast, scientists copied the leg shape of a cheetah—the world's fastest land animal. Suppose that you are an engineer who is designing a new type of robot. How might studying an animal help you to design it? Answer the questions below to plan how you could make a robot that has features similar to those of an animal in nature.

1. What do you want your robot to be able to do?

___

2. What is an animal that has a shape or ability similar to what you want in your robot?

___

3. What features of the animal allow it to have that ability? For example, does it have an unusual shape or special feet? Do Internet research to find out more about your animal.

___

___

4. How do you think this ability helps the animal survive in the wild?

___

___

___

5. Explain how the animal's ability would be useful in your robot.

___

___

___

6. How would you design a robot that has the same shape or ability as your animal? Think about the materials you would use and how you would build important features of the body, such as parts that can move. Draw a model of your robot in the box to the right. Be sure to label different parts in your sketch. Use a separate piece of paper if necessary.

7. Create a poster or presentation to share your design with your class.

TURN ON THE LIGHTS: INTRODUCTION TO ELECTRIC CIRCUITS

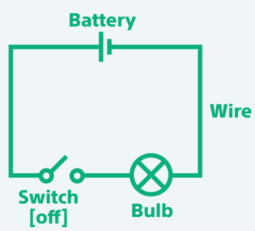
OBJECTIVE: Students will use the scientific process to carry out an investigation to determine how an electric circuit can be created to turn on a lightbulb.

TIME: 30–40 minutes

MATERIALS: One set of the following materials for each group of students: "Turn On the Lights" student worksheet, low-voltage LED lightbulb, large piece of aluminum foil, cotton string, paper clips, AA battery, tape, scissors, pen or pencil

LESSON PLAN

1. **Make Observations About Electricity and Light:** Show the class a flashlight and switch the light on and off. Ask students to describe components they can see or that they think may be found inside a flashlight. (Answers may include a bulb, a power source such as a battery, wiring, a switch, etc.) Ask students what they think happens inside the flashlight to cause the light to turn on. (They may say that electricity flows through the bulb.) Write the term "electric circuit" on the classroom board. Explain that an electric circuit is a closed loop through which electricity (moving charged particles) can flow. Draw the model of an electric circuit (below right) on the classroom board. Use the model to show that when you flip the switch to "on," it closes the loop between the battery (the electricity source) and the bulb. Once the loop is closed by turning on the switch, the electric circuit allows electricity to flow through the bulb and light it up.



2. **Conduct the Investigation:** Separate the class into small groups and hand out the student worksheet, "Turn On the Lights." Give each group the listed materials. As a class, briefly discuss which of the materials are similar to what is found in a flashlight. (For example, there is a bulb, a battery, and material [aluminum foil] that is similar to wiring.) Have students complete the activity in their groups.

3. **Analyze Results:** When everyone is finished, discuss their results. Ask the class: *What caused the lightbulb to turn on?* (The battery powered the bulb in a complete electric circuit. The path between the ends of the battery and the lightbulb was unbroken. The complete circuit allows electricity to flow through the bulb.) Discuss any problems students had with their designs. How did these factors prevent the light from turning on?

STANDARDS FOCUS:

Science (NGSS)

Science and Engineering Practices: Asking Questions and Defining Problems, Planning and Carrying Out Investigations, Constructing Explanations and Designing Solutions
PS3.B: Conservation of Energy and Energy Transfer
ETS1.A: Defining and Delimiting an Engineering Problem

Language Arts (CCSS)

SL1: Participate in collaborative discussions

Math (CCSS)

MP1: Make sense of problems and persevere in solving them
MP5: Use appropriate tools strategically

ANSWERS TO STUDENT WORKSHEET

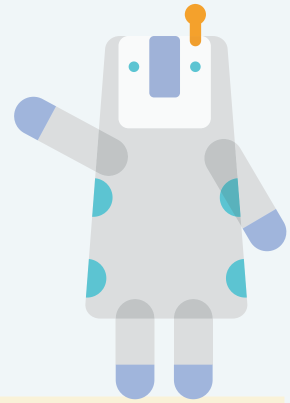
Students' setups for the experiment may vary. One possibility is to cut strips of aluminum foil and fold or roll them to form two "wires." Connect one end of one "wire" to the positive end of the battery and the opposite end to one of the metal spokes on the LED light. Then attach one end of the second "wire" to the negative end of the battery and the unattached end to the other spoke on the light. If using a typical lightbulb, the ends of the aluminum foil need to touch the base of the bulb and the side of the metal case. If the light doesn't work, make sure that the battery has enough voltage for the bulb.

Conclusions:

a. Answers will vary.

b. Answers may include that the students chose materials, such as aluminum foil, that allow electricity to flow. The electric current needs to flow from the battery to the bulb to turn it on.

TURN ON THE LIGHTS



In this activity, you'll use the scientific process to test how everyday materials can be used to make an electric circuit to turn a lightbulb on and off.

MATERIALS: Low-voltage LED lightbulb, large piece of aluminum foil, cotton string, paper clips, AA battery, tape, scissors

ASK A QUESTION How can we use everyday materials to create an electric circuit to turn on an LED lightbulb?

WRITE A HYPOTHESIS Consider the materials you have been given. Make a **prediction** about how some or all of the materials can be connected in an electric circuit to light up the bulb. Draw a model below that shows the arrangement that you think will work. Be sure to label the different materials. Use separate paper if necessary.

Make a prediction: ______________________________

____

Draw your model:

Write your hypothesis: ______________________________

____

CARRY OUT AN INVESTIGATION Use the materials to create the design you sketched above. When you connect your materials, does the bulb light up? If it does not work, try modifying your design until it is successful.

DRAW CONCLUSIONS

a. Did your final design match your model in your hypothesis? If not, how was it different?

____

____

b. What materials did you use to connect the bulb to the battery? Explain why you chose these materials.

____

____

IMPROVE YOUR DESIGN Evaluate your design. How does it compare to a typical flashlight? Could you make it sturdier or make it easier to turn the light on and off? Think about other materials you could use to improve your design.

TOWER CHALLENGE: CENTER OF GRAVITY AND BALANCE

OBJECTIVE: Students will learn about the center of gravity and analyze how it helps to make structures stable.

TIME: 45 minutes

MATERIALS: "Tower Challenge" student activity worksheet, electric fan, 10–15 small books, set of building materials for each group: 20 drinking straws, 4 paint stirrers, 10 Popsicle sticks, 4 paper-towel tubes, 2 sheets of cardboard, 10 rubber bands, masking tape

STANDARDS FOCUS:

Science (NGSS)

Science and Engineering Practices: Asking Questions and Defining Problems, Planning and Carrying Out Investigations, Constructing Explanations and Designing Solutions
PS2.A: Forces and Motion
PS2.B: Types of Interactions
ETS1.B: Developing Possible Solutions

Language Arts (CCSS)

SL1: Participate in collaborative discussions

Art (National Core Arts Standards)

VA—Cr1: Generate and conceptualize artistic ideas and work

Math (CCSS)

MP1: Make sense of problems and persevere in solving them

LESSON PLAN

1. **Classroom Demonstration:** Ask for one or two volunteers to come to the front of the class and stand with his or her feet shoulder-width apart. One at a time, place a lightweight chair roughly 6 inches in front of each volunteer. Ask them to try to pick up the chair. Instruct the rest of the class to observe the students' posture and movement. What, if anything, did the class notice about the students' bodies as they picked up the chairs? (They may notice that the students' hips pushed backward.) Ask the students: *Was it easy or difficult to pick up the chair?* (They will likely say it was easy.) Repeat the process, but this time have each student stand with his or her hips, legs, and heels flat against a sturdy wall. Ask: *What differences did they notice between the two trials?* (They will notice that it is more difficult to pick up the chair with their hips against a wall. They may feel like they are going to tip forward.)

2. **Discuss Forces:** Explain that the difference between the two trials has to do with the **center of gravity**. A person's center of gravity is located near his or her waist. If your center of gravity stays over your feet, you stay upright. But when you pick up an object in your hands, it adds weight to the front of your body—changing the location of your center of gravity. Normally, you compensate by moving your hips backward. This balances your total weight so that your center of gravity stays over your feet. When the students stood against the wall, they couldn't move their hips back to balance the weight. The center of gravity moved forward and they felt like they were going to tip over.

3. **Make Connections:** Ask students why engineers might need to consider center of gravity when building structures or other objects. (For example, buildings need to have the center of gravity located over the supporting base, a robot needs to keep its center of gravity over its support as it moves, etc.) What other factors might affect how well a building or object can stay upright? (Answers may include the strength of the materials used to build it, the size of the supporting base.)

4. **Build and Test Towers:** Hand out the "Tower Challenge" student activity worksheet. Break the class into pairs or small groups and have them use the worksheet to each build a strong tower. Prompt them to consider your classroom discussion as they plan their designs. After 5 minutes of planning time and 25 minutes of building time, test each group's designs. Discuss the results of the tests. Did each tower's center of gravity affect its stability? A tower with more weight on top (high center of gravity) will be more likely to tip over than one with a lower center of gravity. How did the tower's base size and width affect its stability? (In general, a wider base will be more stable.)

DIVE DEEPER WITH KOOV

When building with KOOV, understanding how different structures can balance is key. Several courses will guide students through learning about the structures that keep robots stable. Go to the KOOV Learning Course and open "Become a KOOV Block Artist." Complete Stage 2: "The 360 Connector and the Center of Gravity." Then move on to Stage 3: "Strengthening Boards," Stage 5: "How to Place and Balance," and Stage 6: "Objectives and Originality." Once they have completed the courses, challenge students to experiment with a changing center of gravity by adding movable parts to their creations. Can they keep their creations balanced even while they're moving or changing shape?

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TOWER CHALLENGE

Follow the steps below to design and build a tower. Your tower must be able to stay standing when wind blows on it and should be able to support a large weight.

DESIGN REQUIREMENTS:
Your goal is to build a tower that can stay standing even with powerful winds and which can hold as many books as possible. You may only use the given materials to build your tower. Your tower must be at least 40 centimeters (15 inches) tall.

BUILDING MATERIALS:
20 drinking straws, 4 paint stirrers, 10 Popsicle sticks, 4 paper-towel tubes, 2 sheets of cardboard, 10 rubber bands, masking tape

PLAN YOUR DESIGN: Spend 5 minutes planning your tower design. To the right, draw a model of your tower, labeling the building materials you will use.

BUILD YOUR DESIGN: You have 25 minutes to build your design.

TEST YOUR DESIGN: Compare your design to those of your classmates. Which do you think will stand up the longest?

WIND TEST: Place your design on the table 60 centimeters (24 inches) from the electric fan your teacher set up. Tape the base of your tower to the table. Tape only the side farthest away from the fan. Observe what happens when the fan is turned on low speed. Does the tower sway? Does it fall over? Increase the speed of the fan to medium. Observe what happens when the speed of the fan is increased to medium.

STRENGTH TEST: Place a thin book or magazine on the top level of the tower. Observe what happens. Does the tower begin to bend? One by one, add additional books or magazines until the tower begins to bend or break. How many did it hold?

EVALUATE YOUR DESIGN: How did your tower compare with those of your classmates? What features did the strongest towers have?

Think about the results of your tests. How would you change your design to improve it?