National Aeronautics and
Space Administration

Educational Product	
Educators	Grades K-4

EG-2003-10-001-ARC

Robin Whirlybird on her Rotorcraft Adventures Educator Guide

An Educator Guide with Activities in Aeronautical Sciences

http://rotored.arc.nasa.gov

Robin Whirlybird on her Rotorcraft Adventures Educator Guide is available in electronic format through NASA Spacelink--one of NASA's electronic resources specifically developed for the educational community.

This publication and other educational products may be accessed at the following address:

http://spacelink.nasa.gov/products

Robin Whirlybird on her Rotorcraft Adventures Educator Guide

National Aeronautics and Space Administration
Office of Education

Table of Contents

Acknowledgements

Denise Kiser
Instructional Designer

Susanne Ashby and Christina O'Guinn
Curriculum Specialists

Amberlee Chaussee
Design and Layout

Deborah Bazar
Editor

Brent Wellman
Scientific Review

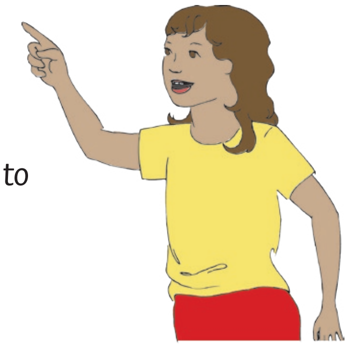
Rebecca Agin
Robin Whirlybird Character Illustration

Introduction to Rotorcraft Explorations

The purpose of these inquiry-based explorations is to stimulate students' curiosity and to engage them in activities that involve using the scientific method. In the first exploration students investigate the meaning of a model and how models are used in scientific research. In the next six explorations students investigate the factors that affect the flight of a rotorcraft, adjusting only one factor (or variable) at a time. This is referred to as "fair testing." In the last exploration students are asked to design a rotorcraft that will stay aloft for several seconds. They use the testing methods they learned in the previous explorations and their knowledge of rotorcraft flight to design their rotorcraft.

All the explorations use the inquiry-based approach to student learning. Classroom inquiry is driven by students' curiosity in the world around them, their desire to know more, to figure something out, or to answer a question. The teacher facilitates the process by guiding students' explorations and providing the tools and materials they need in order to have a satisfying inquiry experience. All the materials required for the explorations are readily available.

Exploration 1: What is a Model?



Students investigate the difference between toys, miniature replicas and scientific models. They learn that scientists and engineers use scientific models to understand how things work.

Main Concept

A scientific model is something that is used to understand how the real thing works.

Goal

Students will use the inquiry method to explore what a model is and how a model is used in scientific research.

Objectives and Standards

Objectives	Standards
1. *Students will state characteristics that describe a scientific model and differentiate a model from other objects.*	**Partially Meets:** NSES: A (K-4) #1 & #2
2. *Students will develop abilities necessary to do scientific inquiry.*	**Addresses:** ITEA: #9 2061: 1B (K-2) #1
3. *Students will develop an understanding of scientific inquiry.*	

Prerequisite Concepts

- *Airplanes and rotorcraft can fly.*

Links to Resources that Address Prerequisite Concepts

The Robin Whirlybird Web site:
http://rotored.arc.nasa.gov/

New Concepts

- *A scientific model is an object or idea used to understand something about the real thing.*

- *A model of an airplane can be used to understand how a plane flies.*

Links to Lessons and Resources that Also Address Concepts

- NASA CD-ROM *Exploring Aeronautics*:
  - ☆ How an Airplane Flies
  - ☆ Tools of Aeronautics

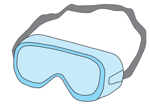
- Web sites:
  - ☆ Aviation for Little Folks (K-4 level)
    http://spacelink.nasa.gov/Instructional.Materials/On-line.Educational.Activities/Aviation/index.html
  - ☆ How Things Fly
    http://www.nasm.si.edu/galleries/gal109/
  - ☆ Problems and Solutions in Aircraft Design (K-2 level)
    http://quest.arc.nasa.gov/projects/aero/centennial/problem.html
  - ☆ Features and Limits of Aircraft Design (3-5 level)
    http://quest.arc.nasa.gov/projects/aero/centennial/features.html

Schedule

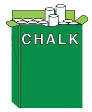
Allow 2-3 sessions of 20-30 minutes each.

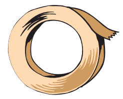
Materials

- Protective eyewear for each student, available from most school science supply stores and catalogs

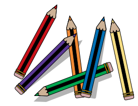


- Chalk or tape

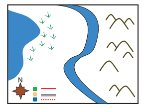




- Drawing paper and crayons or coloring pencils

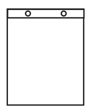


- A map of a city or state

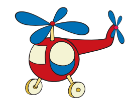


- Wheels and axles from a LEGO® or other construction toy

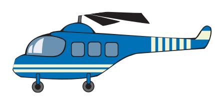
- Chart paper



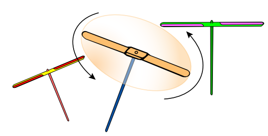
- A variety of lightweight plastic, metal and wood toy replicas of various sizes and types of helicopters (these won't fly because they are toys) available at most toy stores



- A variety of heavyweight plastic, metal and wood toy replicas of various sizes and types of helicopters (these won't fly because they are toys) available at most toy stores

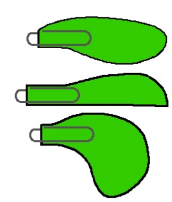


- A "flying dragonfly" toy rotor that flies (Shown at the right), available from most toy and hobby stores.

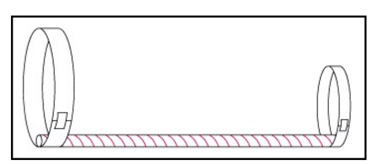


- A rubber-band-powered balsa helicopter called a "penni" helicopter available as a kit and flies reasonably well See: http://members.cox.net/arrio2/historic/penni.pdf

- If possible (this is optional), a "maple-seed" helicopter See: http://www.grc.nasa.gov/WWW/K-12/TRC/Aeronautics/Maple_Seed.html



- If possible (this is optional), a circular-winged paper airplane See: http://www.yesmag.bc.ca/projects/looper.html



- *Photographs or drawings of the following objects:*
  - ✰ Helicopter or helicopter part mounted on a strut in a wind tunnel
    http://rotored.arc.nasa.gov/activity/WindTunnelA.html
  - ✰ Helicopter or helicopter part mounted on a strut in a wind tunnel, see entry year 1976 of rotorcraft timeline
    http://rotored.arc.nasa.gov/timeline/parents.html
  - ✰ Helicopter or helicopter part mounted on a strut in a wind tunnel, see entry year 1993 or 1995 of rotorcraft timeline
    http://rotored.arc.nasa.gov/timeline/yourLife.html
  - ✰ Flight Simulator
    http://rotored.arc.nasa.gov/activity/simulator.html

Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Ask students what they know about models.
   Question: What is a model?
   Students' answers will probably include toys and miniature replicas.

2. Have students draw pictures of models.
   - Distribute the drawing paper and crayons or colored pencils and ask students to draw a picture of a model.

   - Ask students to explain why they consider their drawings to be models.

     Students' responses will probably reflect their misconceptions about models. Common misconceptions are the following:
     ☆ A miniature replica of a full-sized object is a model.
     ☆ A toy is a model.

   - Save students' drawings of models and use them for evaluation at the end of the lesson.

3. Tell students that today they will learn about scientific models and explain that scientific models help us understand something about the real thing.

4. Provide examples of scientific models.
   - Show the map and ask if that is a model.
     A map is a model because it tells us where the roads are so we understand more about the real thing.

   - Show the wheels and axle and ask if that is a model. This is a model because it helps us understand how wheels on a real car or truck work.

5. Ask for an example of a model.
   - If students still provide examples of miniature replicas or toys, ask them how the object can be used to understand something about the real thing. Simply looking like the real thing is not enough.
   - Explain that miniature replicas and toys are not *scientific* models because they do not help engineers and scientists understand something about the real thing.

6. Have students make a list of objects that make good scientific models.
   - Explain that students will be researchers in aeronautics (flight or flying). Their task will be to find a good aeronautical model for test flights.

   - As a class, develop a list on chart paper of possible objects or assembled items that could be used to test new ideas about aeronautics.

Explore

1. *Place the following objects from the "Materials" list on a table:*
   - *Lightweight plastic, metal and wood toy replicas of various sizes and types of helicopters*
   - *Heavyweight plastic, metal and wood toy replicas of various sizes and types of helicopters*
   - *A "flying dragonfly" toy rotor that flies or a rubber-band-powered balsa helicopter called a "penni" helicopter*
   - *Photographs or drawings of the following objects:*
     - ☆ *Helicopter or helicopter part mounted on a strut in a wind tunnel*
     - ☆ *Helicopter or helicopter part mounted on a strut in a wind tunnel, from the entry year 1976 of rotorcraft timeline*
   - *If possible, add the items listed by the students during the "Engage" segment.*

2. *Ask students to work in pairs and instruct them as to what they will be doing.*
   - *Set safety precautions before the students start to explore*
   - *Challenge students to find a way to determine which of the objects would make good models or could be put together to make good models and used for flight explorations.*
   - *Delineate a process with the students or have them come up with their own during their exploration.*
   - *Ask students to draw a picture that depicts the results of their exploration. Ask them to indicate on their drawings the items they think would make good scientific models.*
   - *Give students approximately 10 - 20 minutes to explore the objects.*

3. *Gather students together for a discussion.*

4. *Ask them to focus on each proposed model with the question: Is this a model?*

5. *Ask the group to draw a conclusion about which models are the best to experiment with to study flight.*

Explain

1. *Ask the class to draw a conclusion about the characteristics of a model used for scientific experiments.*

2. *Write the list of characteristics on chart paper.*

   Some of the noted characteristics could include the following:
   - *Its performance is highly similar to the actual object.*
   - *Its parts are functional and perform just like the parts on the actual object.*
   - *A particular part is functional and performs just like it would on the actual object.*
   - *Accurate measurements of its performance can be made (that can also be scaled to the actual object's size).*
   - *Models can be used to learn about the real thing.*
   - *Models may not look like the real thing.*

3. *Reveal the remaining objects from the "Materials" list and ask students to use their list of characteristics to compare and test to see if any of these new items/objects depicted could be used as a model for scientific experiments:*

   - ***Photograph of a flight simulator***
     This is a model for scientific experiments because it simulates flight and helps us learn about flight.
   - ***A metal toy airplane*** *(incapable of flight)*
     This is not a model for scientific experiments. Since it cannot fly, it does not perform like the actual object.
   - ***A plastic toy helicopter*** *(incapable of flight)*
     This is not a model for scientific experiments. Since it cannot fly, it does not help us learn about flight.
   - ***A "maple-seed" helicopter***
     This is a model for scientific experiments because it can be made to fly and may help us learn something about rotorcraft flight.
   - ***A circular-winged paper airplane***
     This is a model for scientific experiments because it can be made to fly and may help us learn something about flight.

Extend

1. *Have a local researcher bring samples of models used in their work and discuss how the models helped them learn new things safely before trying the new ideas on the actual object or machine.*

2. *Ask students if they can think of ways that models are used to understand how the human body works. They may come up with pumps used to understand how the heart works, models of DNA, and models of the brain.*

3. *Discuss how models are used to build new cars, first with drawings on paper and computer. Parts of the car are modeled before the whole thing is put together. Ask students if they can think of the parts that would be modeled separately.*

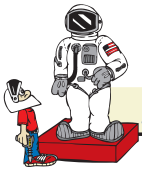
Evaluate

1. *To evaluate students' understanding of a model, give them the following scenario:*
   - *Students are scientists and they are going to design a new: bicycle, roller blades, skateboard, car or any other vehicle they choose. They need to draw a model that will help them design their vehicle.*
   - *Ask students to list or indicate on their drawings why they think their model is a good model. Remind students that their models may not look like the real thing, but must help them understand something about the real thing.*
   - *Have students present their drawings to the class and explain how they are good models.*

2. *Look for the following in students' drawings and lists:*
   - *An indication of how the objects drawn will enable students to learn something about the real thing.*
   - *The drawings may consist of part of a vehicle, such as the gear mechanism on a bicycle, the brakes, or the surface of a skateboard. For example, the surface of a skateboard must have a suitably rough surface so the rider's shoes don't slide off.*

3. *Compare students' drawings with the drawings they made in the "Engage" segment of the exploration.*

4. *Wrap up the exploration.*
   Say: In the next exploration we will use models to understand how rotorcraft fly.

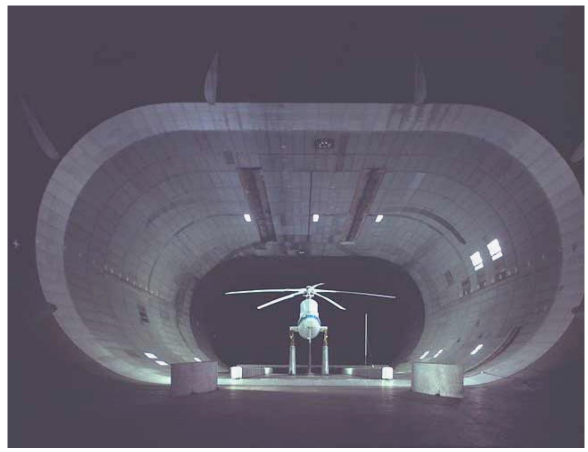


Further Exploration

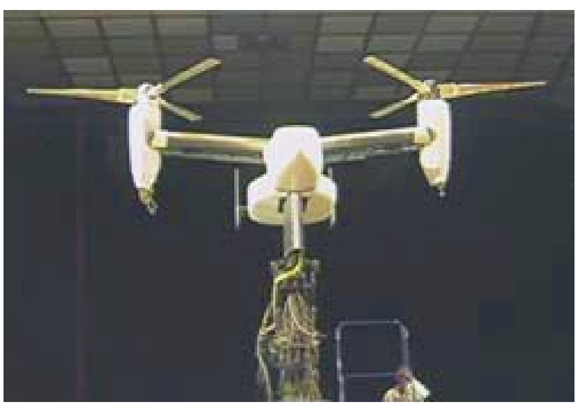
Students might have additional questions regarding the connection between models and actual objects being researched by scientists. If time and interest permits, transform their ideas, questions, observations and/or hypotheses into another investigation.

Reference Photographs

Tiltrotor in wind tunnel



Sirorsky helicopter in wind tunnel

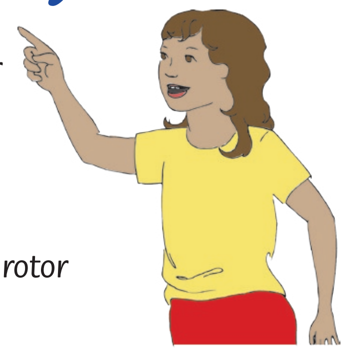


Tiltrotor model in wind tunnel

S-76 rotor test

Exploration 2: How Do Rotorcraft Fly?

Students choose a model and use it to explore rotorcraft flight. They use a "fair test" and conclude that a spinning rotor is required for a rotorcraft to fly.



Main Concept

The process of scientific inquiry can be used to discover that a spinning rotor provides the lift necessary for rotorcraft flight.

Goal

Students will conduct a scientific investigation of rotorcraft flight and conclude that a spinning rotor is necessary for a rotorcraft to fly.

Objectives and Standards

Objectives	Standards
1. *Students will use a model to conduct an investigation in rotorcraft flight.* 2. *Students will describe the purpose of a rotorcraft's rotor blades.* 3. *Students will explain the difference between the effects of a spinning rotor and a non-spinning rotor on a rotorcraft model.* 4. *Students will develop abilities necessary to do scientific inquiry.* 5. *Students will develop an understanding of scientific inquiry*	**Partially Meets:** NSES: A (K-4) #1, #2 **Addresses**: 2061: 1B (K-2) #1 2061: 1B (3-5) #1

Prerequisite Concepts

- A scientific model is an object or idea used to understand something about the real thing.
- A model of an airplane can be used to understand how a plane flies.

Links to Resources that Address Prerequisite Concepts

See Robin Whirlybird Exploration #1: What is a model?

New Concepts

- A spinning rotor is required for a rotorcraft to fly.
- People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.
- Scientific investigations may take many different forms, including observing what things are like and doing experiments.

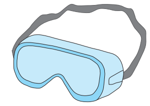
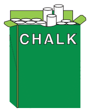
Links to Lessons and Resources that Also Address Concepts

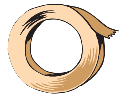
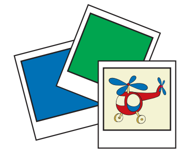
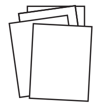
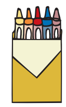
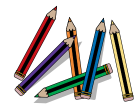
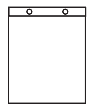
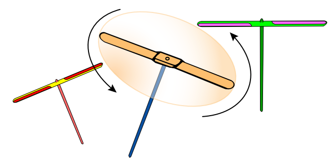
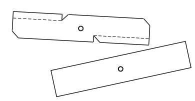
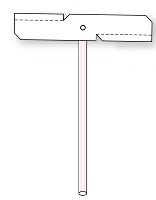
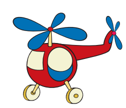
- Web sites:
  Robin Whirlybird
  http://rotored.arc.nasa.gov/story/robin18.html
  http://rotored.arc.nasa.gov/story/robin3.html
  Click the "Rotorcraft Activities" button.

Schedule

Allow 2-4 sessions of 20-30 minutes each.

Materials

- Protective eyewear for each student, available from most school science supply stores and catalogs 
- Chalk or tape 


- Photos or pictures of different types of rotorcraft (helicopters), available at: http://ails.arc.nasa.gov/Images/Aeronautics/index.html#rotor 
- Drawing paper and crayons or coloring pencils   
- Chart paper 
- One "flying dragonfly," which is a toy rotor that flies (shown right), for each pair of students 
- Lightweight paper propeller made using the template in this chapter's appendix
- Heavyweight paper propeller made using the template in this chapter's appendix 
- Drinking straw with the lightweight paper propeller securely taped to one end 
- Drinking straw with the heavyweight paper propeller securely taped to one end
- Miniature plastic toy helicopter, available from most toy stores 

Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Draw on students' prior knowledge of rotorcraft by asking them:
   - Have you seen helicopters or rotorcraft?
   - Where have you seen them?
   - What were they doing?
   - What kind were they?
   - What did you notice about them?

   Students will probably say that they have seen rotorcraft in real life or on television. They may have seen rotorcraft used by radio or television crews checking on traffic, or by the police and other organizations. They may observe that rotorcraft have rotating blades and make noise.

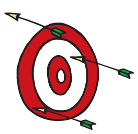
2. Show various pictures of rotorcraft.
   Question: "What do these rotorcraft have in common?"

3. Write students' responses on chart paper as they point out the similarities of the rotorcraft.

4. Distribute drawing paper and crayons.

5. Ask students to create an illustration that explains how they believe a rotorcraft flies.
   Note to Teacher: This is their scientific hypothesis; however, at the kindergarten through 2nd grade level it is unnecessary to use this terminology.

6. Have each student show their illustration and give their explanation of how rotorcraft fly.

7. 
   Address common misconceptions such as the following:
   - Aircraft are held up in the air by giant sky hooks or ropes.
   - Aircraft are held aloft by the wind.

   Ask students if they can see anything holding up the rotorcraft or if the rotorcraft would fly if there were no wind.

8. Segue into how scientists explore ideas and phenomena using models. Remind students of the previous exploration, where they learned what a model really is and how models help us understand something about the real thing.

9. Ask students what could be used as a model of a rotorcraft and compile a short list. Include the "flying dragonfly" toy rotor (pictured in the "Materials" list).
   Say: We will now choose a model to explore what it is that makes a rotorcraft fly.

Explore

Explore Part A: Students choose a model to explore rotorcraft flight.

1. Display the "flying dragonfly" toy rotors, drinking straws with propellers attached, propellers and miniature plastic toy helicopters listed in the "Materials" section.

2. Have students work in teams or pairs.

3. Set safety precautions before the students start to explore!

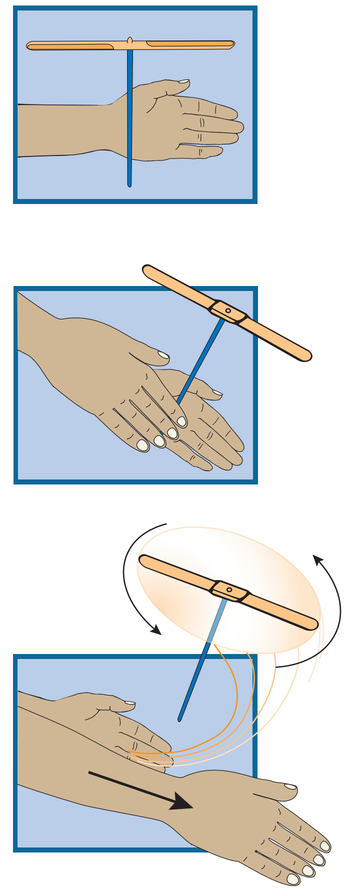
4. **Questions**:
   - Which one of these objects would be a good model to use to find out how rotorcraft fly?
   - What can you do to find out?

   Allow 10 minutes for open exploration.

5. Circulate through the group, recording students' observations, actions, ideas and questions. Your records will become the basis for further explorations and discussions.
   - Monitor safety and proper use of materials.

6. Have students in pairs draw a picture that depicts the results of their models and their flights.

7. Gather students together for a discussion.
   Question: What did you notice about flying with this model?
   Focus on each model in turn.



How to fly your flying dragonfly.

8. **Question**: Which model is the best to use to learn about rotorcraft?
   Note to Teacher: Students should conclude that the "flying dragonfly" toy propeller (pictured in the "Materials" list) is the best model unless they develop other models that work as well. The rotor blades on the "flying dragonfly" toy propeller are shaped to create maximum lift and the "fuselage" is lightweight yet sturdy enough to "hold cargo."

Explore

Explore Part B: Students use their model to explore rotorcraft flight.

1. Review with students the previous days' explorations regarding rotorcraft, models and flight as well as any questions posed.

2. Explain to the students that based upon their previous observations, today they will conduct experiments (like scientists) using their model (the "flying dragonfly" toy propeller or other model that they build that works as well).

   - ***Say***: Yesterday we noticed that this model was one of the better models for flight. Today I want you to see what happens when you hold this model in different ways and let it go.

   - ***Question***: What kind of different ways can we hold the model before we release it? Have a few students demonstrate their technique using a drinking straw with propeller attached.

   - ***Question***: How can we make this a fair test?

   Note to Teacher: In the primary grades students use the concept of "fair testing." A "fair test" is an investigation involving two variables in which one of the variables is controlled by the researcher (i.e. the students). Through a series of fair tests during which students manipulate the variables, they revise their own hypotheses (or theories about the world or even scientific misconceptions) based on earlier observations and move their thinking in the direction of conventional scientific ideas. A fair test is performed a prescribed number of times to authenticate its predictability. Students can set the number of repetitions performed, which usually ranges between 3 and 5.

3. ***Question***: Why is it important to make this a fair test?
   Answer: A fair test is one where we change just one aspect of the flight, like the height from which the model is released. If the test was not "fair," and we changed many things about the flight, then we would not know which of our changes affected the flight.

4. Solicit ideas and direct focus toward holding the model the same distance from the ground each time. Also, key students in on testing in an area without moving air.

5. Students will most probably spin the rotor before releasing the model. Ask them what would happen if everything stayed the same and they did not spin the rotor.

6. Ask students how many times they should perform each test, and have the group come to consensus on the number of tests per position.

7. Ask students what they think they might find out.

8. Record students' hypotheses on chart paper for class viewing.

9. Have students draw the holding position for each test and the model's flight path for each position tested.

10. Give students 10 minutes to explore these questions/positions. Upon completion, discuss their findings.

Explain

1. After students perform their explorations have them display their drawings while discussing their findings.

2. Direct their focus with the following questions.

   Question: What is the difference between not spinning the rotor and spinning the rotor?
   Answer: When the rotor spins the model flies and gradually falls to the ground. When the rotor is not spinning the model does not fly and falls to the ground.

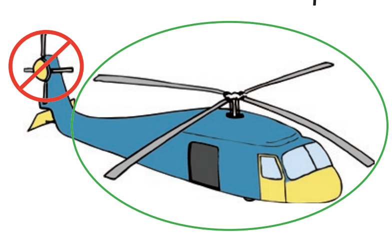
   Question: When you held the model in different positions and then made it spin, what happened? Was there a difference? If so, describe the difference.
   Answer: When the model is held upright, the rotor blades work the most efficiently. When the model is released from other positions it falls to the ground.

   Question: What part of this model makes it "fly"? (Use the students' terminology to describe the model's flight.)
   Answer: The spinning rotor makes the model fly.

Evaluate

1. Distribute drawing paper and ask students to draw a picture of a rotorcraft flying.
   Students' pictures should include the body of the rotorcraft (or fuselage) and the main rotors.

2. Ask students to circle the part of the rotorcraft that causes the rotorcraft to fly.
   Students should circle the main rotors. Some students may circle the tail rotor as well. Explain to these students that the tail rotor stabilizes the rotorcraft.



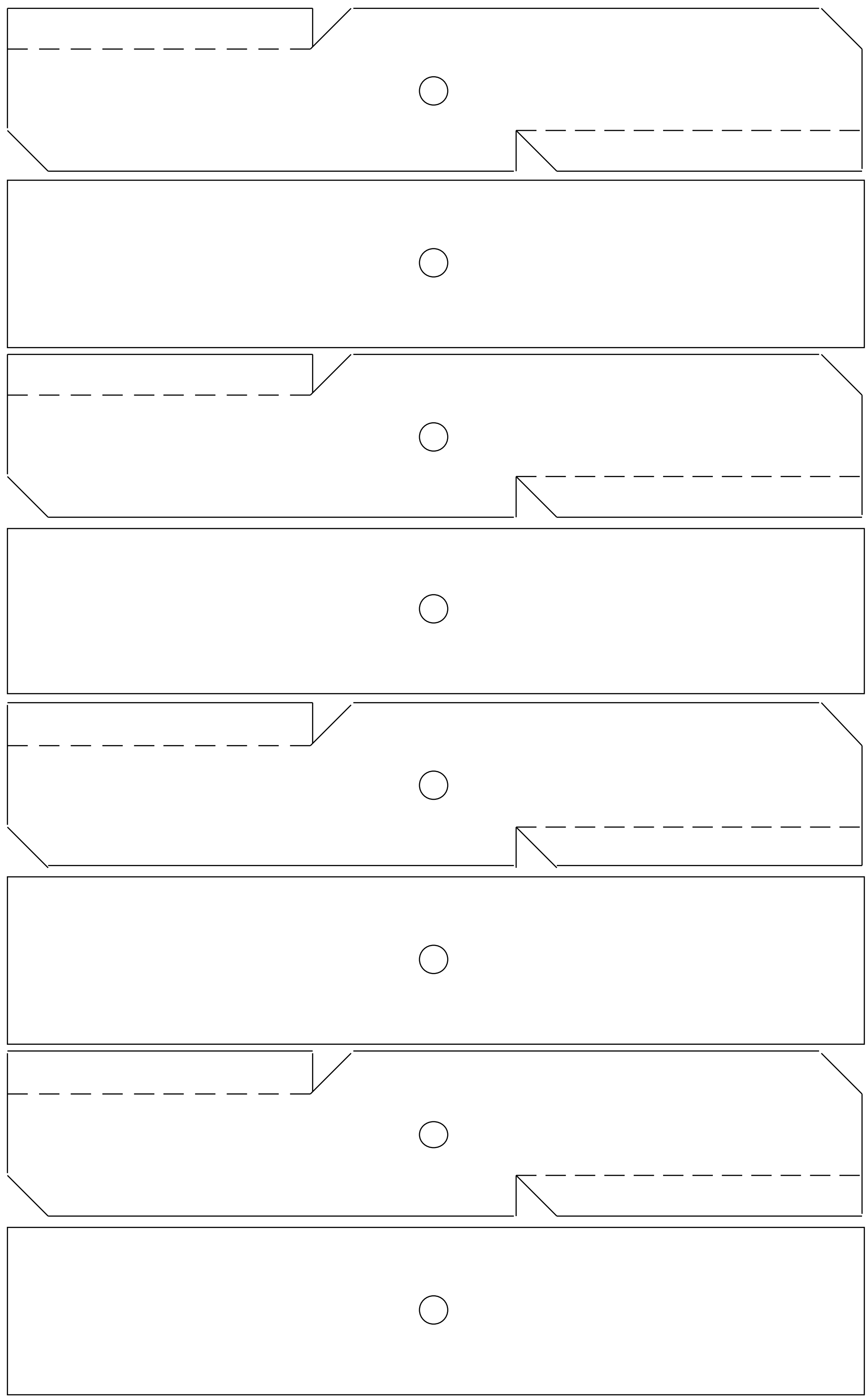
3. *In the "Explain" segment of this activity, students should be able to explain that a spinning rotor causes a rotorcraft to fly.*

4. *Have students use arrows to show how the rotors generate lift.*
   Students should draw arrows from the rotor blades pointing down towards the ground, indicating the movement of air, and lines above the rotor blades indicating the upward movement of the rotorcraft.

Further Exploration

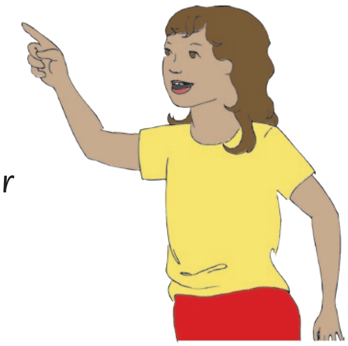
Students might have additional questions regarding the connection between how fast the rotor blades turn with how long the rotorcraft stays in the air and/or how high it flies. Ideally, students will suggest that there is "something" in the air that the rotor is affecting that generates the lift force. They may mention the air movement caused by the spinning rotor. Listen and record any new questions that spring from this exploration. Post on chart paper and examine these questions later for possible explorations. If time and interest permits, transform their ideas, questions, observations and/or hypotheses into another investigation.

Appendix: Propeller Template



Exploration 3: How Do Rotors Create Lift?

Part 1: Air is Made of Something
Part 2: Spinning Rotors and Lift



Students learn that air takes up space and that a spinning rotor affects the air and generates lift for rotorcraft.

Main Concept

Air is a substance that surrounds us, takes up space, and whose movement we feel as wind.

Goal

Students will conduct a scientific investigation and learn that air takes up space and rotorcraft blades move the air and generate lift.

Objectives and Standards

Objectives	*Standards*
1. *Students will conduct investigations with air and learn that air takes up space.*	**Meets**: 2061: 4B (3-5) #4
2. *Students will describe how rotor blades move air and generate lift.*	**Partially Meets:** 2061: 4F (3-5) #1
3. *Students will make scientific observations.* 4. *Students will work collaboratively with a team and share their findings.*	**Addresses**: 2061: 1B (K-2) #1 2061: 1C (K-2) #2

Prerequisite Concepts

- *A spinning rotor is required for a rotorcraft to fly.*
- *People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.*
- *Scientific investigations may take many different forms, including observing what things are like and doing experiments.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click the "Rotorcraft Activities" button.

Robin Whirlybird Exploration #1: What is a Model?

Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?

New Concepts

- *Air takes up space and is made up of particles that are too small to see.*
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Links to Lessons or Resources that Also Address Concepts

- *Websites:*
  - ✰ Aviation for Little Folks (K-4 level)
    http://spacelink.nasa.gov/Instructional.Materials/On-LineEducational.Activities/Aviation/index.html
  - ✰ How Things Fly
    http://www.nasm.si.edu/galleries/gal109/
  - ✰ How Things Fly—Air is Stuff
    http://www.aero.hq.nasa.gov/edu/airisstuff.html

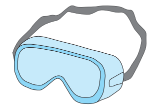
Schedule

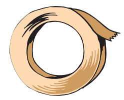
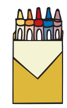
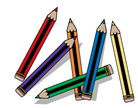
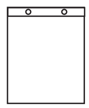
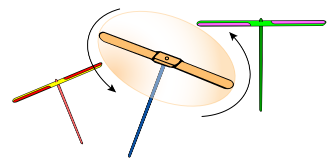
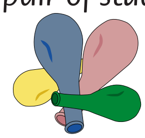
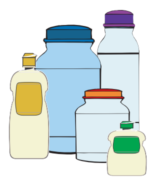
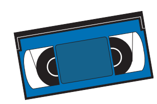
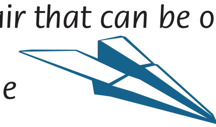
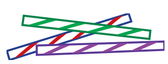
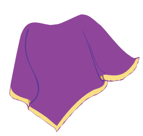
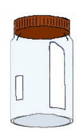
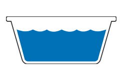
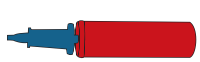
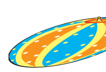
Allow 2-4 sessions of 20-30 minutes each.

Materials

Part 1:

(This is a suggested list as students will have their own needs based upon their demonstrations.)

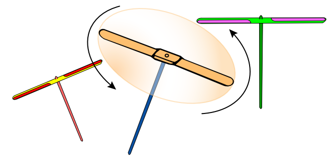
- *Protective eyewear for each student, available from most school science supply stores and catalogs* 
- *Chalk or tape* 


- *Drawing paper and crayons or coloring pencils*   
- *Chart paper* 
- *One "flying dragonfly," which is a toy rotor that flies (shown right), for each pair of students* 
- *Balloons* 
- *Empty plastic bottles or jars* 
- *Wide-mouthed plastic container or bucket for water* 
- *Video about air that can be obtained through your school district's video library* 
- *Paper airplane* 
- *Drinking straws* 
- *Handkerchief or small cloth* 
- *Plastic, clear, wide-mouth jar with lid* 
- *Tub of water* 
- *Hand pump* 
- *Small, deflated rubber ball* 

Materials

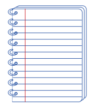
Part 2:

- One "flying dragonfly," which is a toy rotor that flies (shown right), for each pair of students

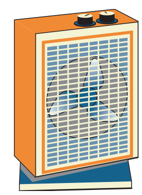


- Cellophane tape for each student group

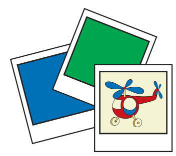
- Notebook paper sheets



- 2-5 small box fans with reversal spin switch (in which the fan blades are covered and cannot be accessed or reached by small hands or fingers)



- Picture of a room with a wood-burning stove



Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

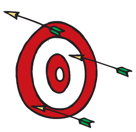
Part 1: Air is Made of Something

Engage

1. Draw on students' prior knowledge with the following questions:
   - What is inside a balloon?
   - What makes dry leaves blow about on a windy day?
   - Have you ever felt wind?
   - What is wind?
   - What is air?

   List students' answers on chart paper. These answers are their hypotheses.

2. As a class, develop a list on chart paper of the characteristics that determine that an object is "something" or that "something is here." The list could include the following characteristics or descriptors:
   - Takes up space
   - Has weight
   - Can form a shape
   - Has thickness or height or width



A common misconception is that air is empty and consists of nothing. This misconception is difficult to change with students below the 3rd grade due to their level of cognitive development. However, the misconception can be challenged through the examples given in this exploration.

Explore

1. Have students work in teams or pairs.

2. Ask students to design a demonstration that clearly shows that air is "something" or is NOT empty.

3. Have students share their demonstration design with the class and ask for input.

4. Have students revise their demonstrations based upon input and then develop a list of the materials they will need to perform the demonstration for the following session.

5. At the following session, set safety precautions before the students begin to practice their demonstrations! Distribute the protective eyewear.

6. Give students approximately 10 minutes to practice their demonstrations.

7. Ask students to draw a picture that depicts the results of their demonstration.

Explain

1. Have students present their demonstrations with their explanations to the class. Ask questions that are challenging yet appropriate to students' level of cognitive development.

   If students do not come up with convincing demonstrations here are some ideas:

   - Blow up a balloon and ask students what the balloon is filled with.
     Note to Teacher: Do not ask very young students to blow up balloons as this can be a choking hazard.

   - Half fill a plastic container with water. Plunge the plastic bottle into the water and observe the bubbles of air that come out of the plastic bottle.

2. Distribute drawing paper.

3. Ask students to work in their teams or with partners to draft a conclusion about the characteristics of air.

4. Ask students to draw a picture or diagram to illustrate what they have learned about air.

5. Collect the diagrams or pictures and use them for evaluation purposes.

6. Show the short video about air.

Extend

1. Take a paper airplane and make the statement: "Because the Earth has the kind and amount of air it has, we can do this …" Then, gently toss the paper airplane.

2. Encourage students to discuss this statement and their observations of the airplane's flight with their teams or partners.

3. Hand out a sheet of paper and ask students to write down their explanation of what they saw. Allow them to draft their explanation in any way they need to, for example, with a drawing or diagram with a brief explanation, concept map or narrative. Collect these explanations and post them for reference throughout the coming explorations.

Evaluate

Collect students' conclusions about the characteristics of air for evaluation. Look for characteristics that include the following:

- Air takes up space.
- Air moves.
- Air can form a shape.

Further Exploration

1. Students might have additional questions regarding the specifics of what happens with air in terms of air pressure, etc. To explore this further use the NASA CD-ROM Exploring Aeronautics:
   - How an Airplane Flies
   - Tools of Aeronautics

   This CD-ROM can be obtained from NASA CORE http://core.nasa.gov

2. Students might have additional questions regarding the Earth's atmosphere and air. They might want to compare the Earth's atmosphere with the atmosphere on the Moon or on other planets. This might lead students to question whether an airplane could fly in the atmosphere of the Moon or other planets.

Part 2: Spinning Rotors and Lift

Engage

1. Challenge your students to prove to you how air moves around a spinning rotor blade. Emphasize that the demonstration must meet your classroom safety standards and that they can use only the items you provide.

2. Review with the students the items you will allow them to use. These items are in the materials list for Part 2.

   Caution: Students should NOT use these items unless closely monitored by the teacher or a responsible adult classroom aide.

Explore

1. Set safety precautions before the students begin to explore! Make sure students have protective eyewear.

2. Allow the students working in their teams/pairs approximately 10 minutes to explore their ideas about how air moves around a spinning blade, using the materials you have provided. Monitor them closely.

Explain

1. Ask students working in their teams/pairs to draw a picture or diagram with text that depicts the results of their exploration.

2. Have each team or pair share their exploration and explanation with the class.

   - What the students may find is that when the box fan or the rotor model spins counter-clockwise (as one is facing the top of the rotor model's blades or the front of the box fan blades) the air is pulled toward the spinning blades and moves quickly through, coming out the other side forming a "wind."

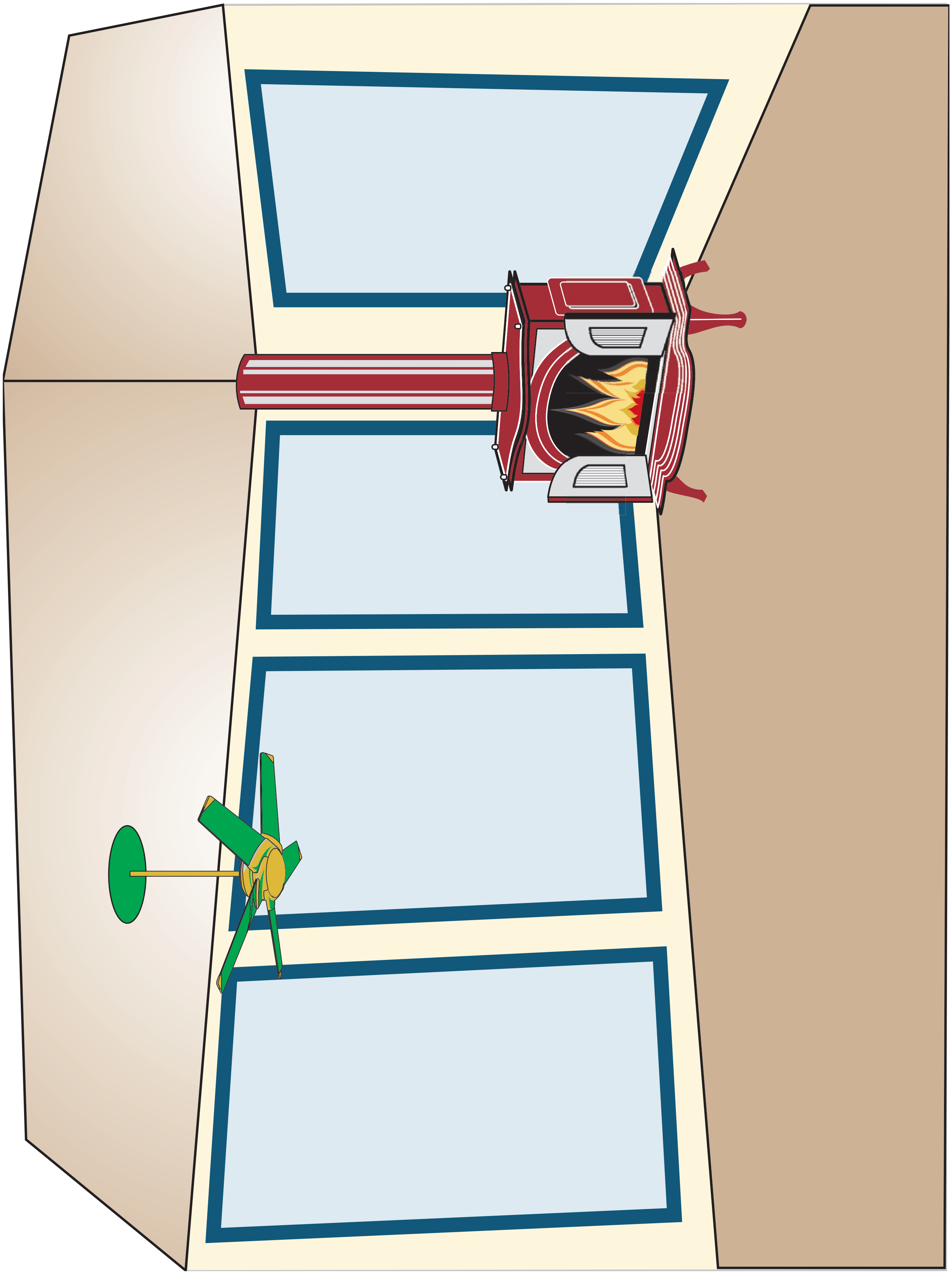
   - When either the box fan or the rotor model's blades spin clockwise (as one is facing the top of the rotor model's blades or the front of the box fan blades) the air is pushed out from the spinning blades, creating a "wind" to those standing in front of the box fan or rotor model.

3. Demonstrate the above by hanging a sheet of paper in front of the spinning blades. DO NOT allow the paper to get sucked through the protective grid and into the rotor mechanism of the fan.

4. Collect the diagrams or pictures and use them for evaluation purposes.

Extend

1. Show the students a picture of a room with a wood-burning stove for heat, a series of windows that are low to the floor, and a high-pitched ceiling with a ceiling fan hanging from the apex of the ceiling.



- *Tell students that you know that if the ceiling fan turns in one direction (clockwise or counter-clockwise), the cooler air near the floor will be pulled up toward the ceiling.*

- *You also know that if the ceiling fan spins in the opposite direction it will push the warm air down toward the floor.*

2. *Ask the students to help you figure out which direction (clockwise or counter-clockwise) the ceiling fan should move in summer and winter to circulate the cool air and the warm air.*

3. *Encourage students to discuss their statements with their teams or partners.*

4. *Hand out sheets of paper and ask students to write down their explanation. Allow students to draft their explanation any way they need to, for example, with a drawing or diagram and a brief explanation, a concept map, or in narrative form.*

Evaluate

- *Use students' diagrams and conclusions about the airflow around a spinning rotor blade for evaluation. The diagram should show the air flowing in a direction perpendicular to the plane of the blades.*

Further Exploration

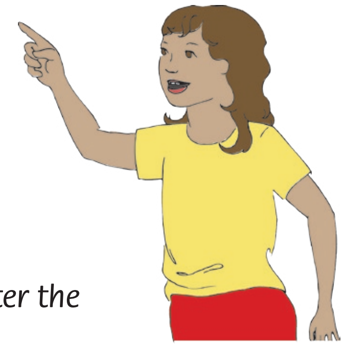
Students might have additional questions regarding the specifics of what happens with air in terms of air pressure, etc. To explore this further use the following:

- Robin Whirlybird http://rotored.arc.nasa.gov/story/robin18.html
  - ☆ Click on button "Rotorcraft Activity"

- NASA CD-ROM Exploring Aeronautics:
  - ☆ How an Airplane Flies
  - ☆ Tools of Aeronautics

  (This CD-ROM can be obtained from NASA CORE http://core.nasa.gov)

Exploration 4: Rotorcraft Flight and Lift



Students use appropriate terminology to describe the various stages of flight and discover that the lift force changes with the amount of air moved by the rotor blades.

Main Concept

Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.

Goal

Students will conduct a scientific investigation and discover that the amount of air moved by the rotor blades affects the lift of the rotorcraft.

Objectives and Standards

Objectives	Standards
1. Students will describe the flight motion of a rotorcraft model. 2. Students will explain the aspects of a rotorcraft that affect lift. 3. Students will make scientific observations. 4. Students will work collaboratively with a team and share their findings.	**Partially Meets:** 2061: 4F (3-5) #1 **Addresses**: 2061: 1B (K-2) #1 2061: 1C (K-2) #2

Prerequisite Concepts

- Air takes up space and is made up of particles that are too small to see.
- Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.
- The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration on #3: How Do Rotors Create Lift?

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button “Rotorcraft Activities”

New Concepts

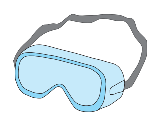
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Schedule

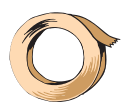
Allow 2-3 sessions of 10-20 minutes.

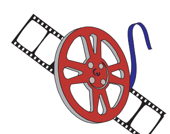
Materials

- *Protective eyewear for each student, available from most school science supply stores and catalogs*



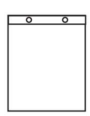
- *Chalk or tape*



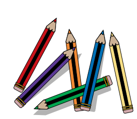


- *Video clip of a rotorcraft taking off and landing, or,*
    - A computer connected to the internet so you can show the following page of the Robin Whirlybird web site: http://rotored.arc.nasa.gov/story/robin11.html or
    - A printout of the page (with the link above) of the Robin Whirlybird web site

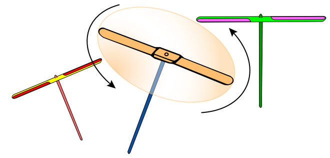
- *Chart paper*



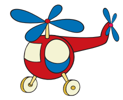
- *Drawing paper and crayons or coloring pencils*



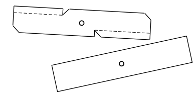
- One “flying dragonfly,” which is a toy rotor that flies (shown right), for each pair of students



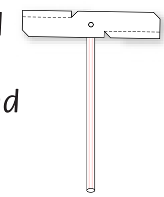
- Small plastic commercially-made, toy helicopters with free spinning rotors



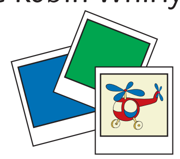
- Lightweight paper propeller made using the template in this chapter’s appendix
- Heavyweight paper propeller made using the template in this chapter’s appendix



- Drinking straw with a lightweight paper propeller securely taped to one end
- Drinking straw with a heavyweight paper propeller securely taped to one end



- Pictures of various rotorcraft or the following page of the Robin Whirlybird Web site: http://rotored.arc.nasa.gov/story/robin15.html



Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students’ input. Mark on the ground with chalk or tape, where all “test flights” will take place. Caution students to “secure the area” before beginning any “test flight.”

Engage

1. Draw on students’ prior knowledge by asking them about their experiences with commercial flights:
   - Have you ever flown on an airplane?
   - What steps does the plane go through?
   - Have you watched airplanes at an airport?
   - What did you see the airplanes do?
   - Have you seen a helicopter?
   - What was the helicopter doing?

2. *If you have a video clip of a rotorcraft taking off and landing, show it now.*

3. *If you do not have a video clip, then show the page of the Robin Whirlybird Web site or a picture of the page indicated in the Materials list.*

4. *Ask students to describe how the rotorcraft moves during different phases of flight. Write students descriptions of the stages on chart paper.*

5. *Provide the following terms that describe various phases in a typical flight:*
   - ***Takeoff**: rotorcraft engines are activated and blades gradually spin faster. The rotorcraft lifts off the ground or landing area.*
   - ***Departure**: rotorcraft moves higher and away from the landing area and turns its body toward its flight direction. The rotor blades are spinning.*
   - **En Route**: *rotorcraft reaches steady flight (not ascending or descending) or maneuvers around tall buildings.*
   - **Descent**: *rotorcraft descends or loses altitude moving closer to the ground and orienting itself in the general direction of its landing area.*
   - ***Approach**: rotorcraft has the landing site in view, is slowing its speed and is preparing for landing.*
   - ***Landing**: the rotorcraft touches down on the ground. The rotors are deactivated and the blades gradually stop spinning.*

6. *Distribute drawing paper and ask students to create an illustration that explains how a rotorcraft flies during all or some of the following phases of its flight: takeoff, departure, en route, descent, approach and landing.*

7. *Have each student show their illustration and give their observation of the main rotor's rate of rotation.*

8. *Tell students that they are going to act as scientists studying what makes a rotorcraft takeoff, fly (en route) and descend.*
   - *Draw on students' prior knowledge of how scientists explore ideas.*
     - ✰ **Question:** How do scientists study how things work?
       Scientists use models to study how things work.
     - ✰ **Question:** What is a model?
       A model is something that is used to understand how the real thing works.

   - *Show students the following and ask them which could be used as a model to study rotorcraft flight:*
     - ✰ The "flying dragonfly" toy rotor
     - ✰ Toy helicopters that do not fly
     - ✰ Drinking straw with a lightweight paper propeller securely taped to one end
     - ✰ Drinking straw with a heavyweight paper propeller securely taped to one end

Explore

1. **Questions**:
   - *Using our model, how can we investigate how rotorcraft fly?*
   - *What can we find out about how rotorcraft fly?*

2. *Record students' responses on chart paper.*

3. *Tell students that they can release the model from various heights and spin the rotors at various speeds.*

4. *Ask students how they will record their observations.*
   Students may have some good ideas. Suggest that they draw pictures of the flight of their rotorcraft models.

5. *Discuss safety issues. Distribute the protective eyewear.*

6. *Emphasize proper observation skills and the importance of "thinking aloud."*

7. *Allow 10 minutes for open explorations.*

8. *Circulate through the group, recording students' observations, actions, ideas and questions.*
   Your written record of what the students are doing becomes the basis for discussion and further explorations.

9. *Monitor safety and proper use of materials.*

10. *Have students working in pairs draw a picture that depicts the results of their model's flight.*

Explain

1. *Gather students together for a discussion. Ask the group to discuss their observations about what happens during each stage of the rotorcraft's flight. Here are some possible responses:*
   - *The rotor blades are still before takeoff. Rotor blades come in different shapes and sizes.*
   - *The rotor blades start to spin. The rate of spin increases.*
   - *The rotorcraft takes off.*
   - *The rotorcraft lands and the rotor blades gradually stop spinning.*

2. *Ask the following questions:*
   - ***Question:*** *What do the spinning rotor blades do?*
     In the last exploration students learned that spinning rotor blades generate lift.

   - ***Question:*** *What happens to the air when the rotor blades spin?*
     Answer: *The air moves.*

   - ***Question:*** *In which direction does the air move?*
     Answer: *The air gets pushed down and the rotorcraft moves up.*

   - ***Question:*** *What happens when the rotor blades spin faster?*
     Answer: *Students may guess that the air will move faster, so more air will be pushed down.*

   - ***Question:*** *What do you think would happen if the rotor blades spun faster and faster?*
     Students might answer that the rotorcraft would fly higher and faster.
     Say: *Let's think about that a little. What would happen if you rode your bicycle, skateboard, scooter (or other vehicle) faster and faster?*
     Answer: *It becomes more difficult to control the vehicle. There are limits to how fast you can make something go by simply making the motor run faster. Sometimes you have to change things about the vehicle itself.*

3. *Show students the pictures of rotorcraft.*
   - ***Question:*** *How are these rotorcraft different?*
     Answer: *Students observe that rotorcraft have different fuselages and a variety of blade shapes.*

4. *Ask students to draw the various shapes of rotor blades.*

5. *Ask students the following questions.*
   - ***Question:*** *What does a rotorcraft need in order to gain more lift?*
     Answer: *The rotorcraft needs to push down more air.*

   - ***Question:*** *How can a rotorcraft push down more air?*
     Answer: *There is "something" about the rotor blades that make them push down more or less air.*

6. *Tell students that in the following explorations they will discover how changing the shape and size of rotor blades affects the amount of air the blades push down.*

Extend

1. Have a local rotorcraft enthusiast bring his/her remote controlled radio helicopter for a demonstration. Have the helicopter perform takeoff, hovering, forward and backward flight, up/down maneuvers and landing.

2. Ask a rotorcraft pilot to visit (or make a visit to a pilot's rotorcraft).

3. Have students prepare questions beforehand and assign specific students to ask specific questions.

Evaluate

1. Distribute to the students in small groups, small plastic commercially-made, toy helicopters with free spinning rotors.

2. Have students gather in an open area and pretend to fly their helicopters
   (Note: These types of helicopters are NOT models, they are merely toys.)

3. Tell students that they are going to fly their helicopters on a short flight. Give them instructions from takeoff through to landing and have them "fly" their helicopter in those phases.

4. Observe as the students "fly" their rotorcraft.

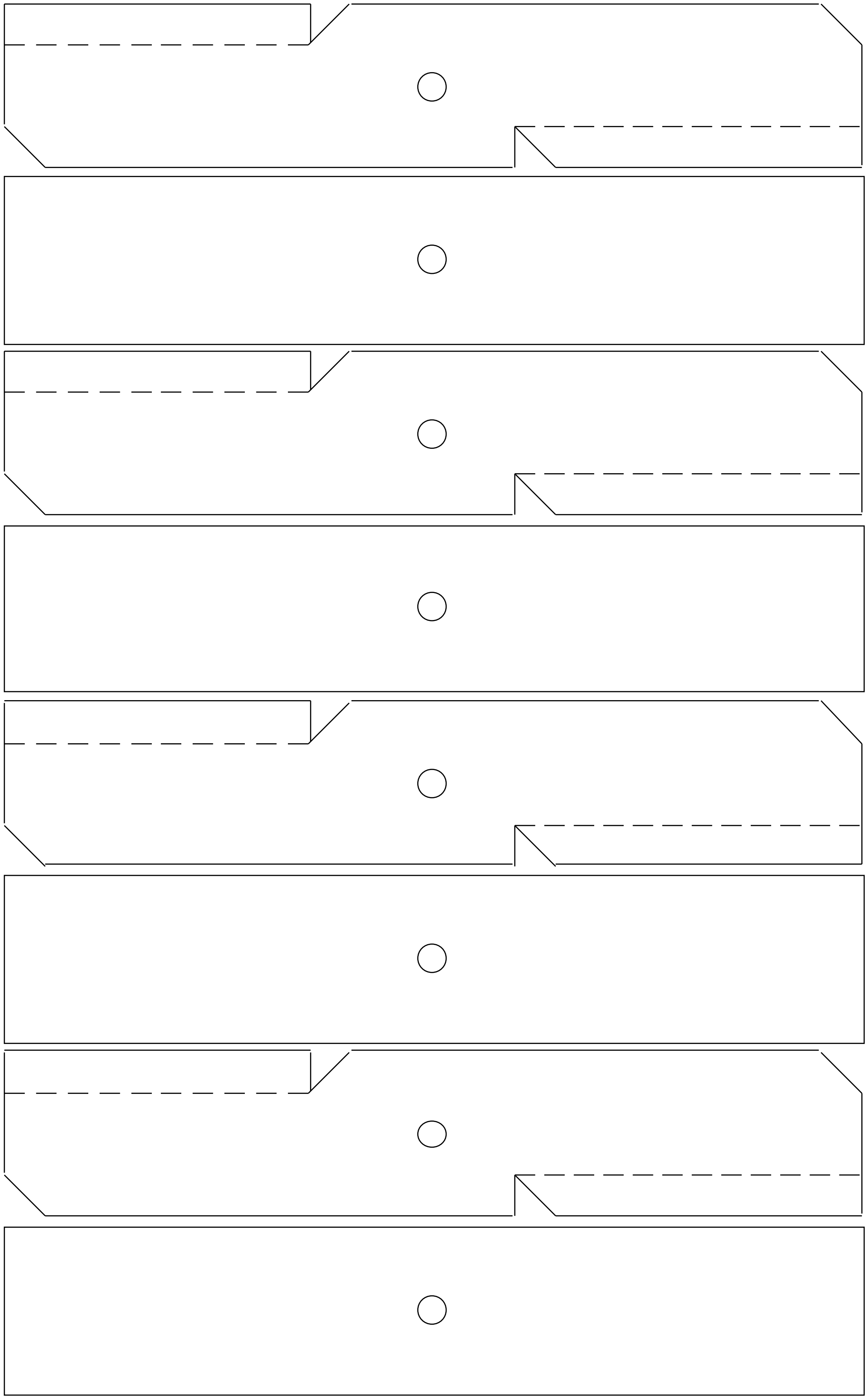
5. Have students draw a rotorcraft in flight and indicate the direction of the airflow and which part of the rotorcraft "pushes" the air down.

Further Exploration

1. Have students create their own lightweight and heavy weight paper propellers and attach them to drinking straws to investigate how long they stay aloft.

2. Another exploration could arise from a question about the shape of the rotor blade. Would changing the shape of the rotor blade change the way it flies or change its flight performance? If time and interest permit transform their ideas, questions, observations and/or hypotheses into additional investigations.

Appendix: Propeller Template



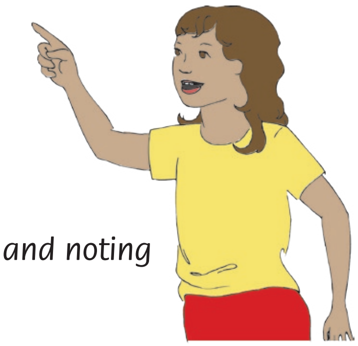
Rotorcraft Explorations 5-7

Explorations five through seven prepare students for the Rotorcraft Challenge in Exploration 8. In each of these explorations students conduct a scientific investigation and work collaboratively with their teams.

Exploration	*Objectives*	*New Concepts*	*Prerequisite Concepts*	*Standards*
Exploration 5: Rotor Blade Shape and Flight Students investigate how a change in the shape of a rotor blade affects the amount of lift it generates. **Exploration 6: Long and Short Rotor Blades** Students investigate how a rotor blades' length affects the amount of lift it generates. **Exploration 7: Rotor Blade Weight and Flight** Students investigate how a rotor blades' weight affects its ability to generate lift.	1) Students will conduct investigations in rotorcraft flight using models that they construct. 2) Students will develop the ability to do scientific inquiry. 3) Students will develop an understanding of scientific inquiry. 4) Students will work collaboratively with a team and share their findings.	1) Scientific inquiry involves learning about things by doing something to the things and noting what happens. 2) Scientific investigations may take many different forms, including observing what things are like, what is happening somewhere, and doing experiments.	1) A model of a rotorcraft can be used to test how a rotorcraft flies. 2) The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft. 3) Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.	**Meets**: 2061: 1B K-2 #1 2061: 1C K-2 #2 NSES: A K-4 #1, #2 **Partially meets**: 2061: 1B 3-5 #1 2061: 1C K-2 #1 2061: 4F 3-5 #1 *(Additional standards are listed in the explorations.)*

Exploration 5: Rotor Blade Shape and Flight

Students investigate how a change in the shape of rotor blades affects the amount of lift they generate.



Main Concept

People can often learn about things by doing something to the things and noting what happens.

Goal

Students will design and construct simple models and use them to conduct a scientific investigation into how the shape of a rotor blade affects the amount of lift it generates.

Objectives and Standards

Objectives	*Standards*
1. *Students will design and construct simple models that use rotor blades of different shapes for flight. (For example, flat vs. curved.)* 2. *Students will conduct an investigation in rotorcraft flight using the models they construct.* 3. *Students will differentiate between the flight of a model using one shape of rotor blade and the flight of a model using a different shape of rotor blade.* 4. *Students will develop the ability to do scientific inquiry.* 5. *Students will develop an understanding of scientific inquiry.* 6. *Students will work collaboratively with a team and share their findings.*	**Partially Meets:** 2061: 1B (K-2) #1 2061: 1C (K-2) #2 2061: 1B (3-5) #1 NSES: A (K-4) #1, #2 **Addresses**: 2061: 4F (3-5) #1

Prerequisite Concepts

- *A model of a rotorcraft can be used to test how a rotorcraft flies.*
- *The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.*
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration #3: How Do Rotors Create Lift?
Robin Whirlybird Exploration #4: Rotorcraft Flight and Lift

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button "Rotorcraft Activities"

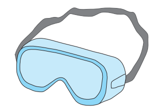
New Concepts

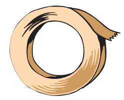
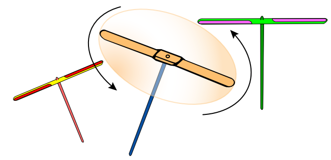
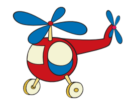
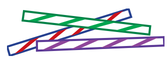
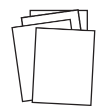
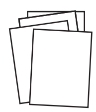
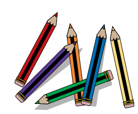
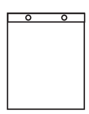
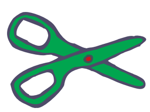
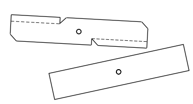
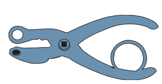
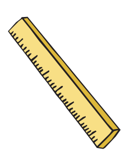
- *Scientific inquiry involves learning about things by doing something to the things and noting what happens.*
- *Scientific investigations may take many different forms, including observing what things are like, what is happening somewhere, and doing experiments.*

Schedule

Allow 2-3 sessions of 20-40 minutes.

Materials

- Protective eyewear for each student, available from most school science supply stores and catalogs 
- Chalk or tape 


- One "flying dragonfly," which is a toy rotor that flies (shown right), for each pair of students 
- A variety of lightweight and heavyweight plastic, metal and wood toy replicas of various sizes and types of helicopters available at most toy stores 
- Sturdy drinking straws 
- Cardstock paper for students to use in their rotor blade construction based upon their own designs 
- Drawing paper and crayons or coloring pencils   
- Chart paper 
- Scissors 1 per team/pair 
- Propeller template in this lesson's appendix 
- Hole punchers 1 per team/pair 
- Cellophane tape roll 1 per team/pair 
- Rulers 1 per team/pair 
- Stopwatches or watch/clock with second-hand 

- At least one Data Table (in this chapter's appendix) for each team/pair
- Evaluation rubric in this chapter's appendix

Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Draw on students' prior knowledge by asking them about models.
   - **Question:** Why do scientists use models?
     Scientists use models so they can test how the real thing would work.

2. Tell students that today they will be scientists investigating how the shape of rotor blades affects the flight of rotorcraft.

3. **Question**: How do you think the flight of a rotorcraft will be affected if we change the shape of the rotor blades?
   List students' responses on chart paper. These responses are their hypotheses.

4. Show students some possible models from the previous explorations:
   - The "flying dragonfly" toy rotor
   - Toy helicopters that do not fly

5. Ask students whether they could use one of these models to test their ideas.
    - If students suggest that they use the toy rotor, ask them how they would make adjustments to the rotors.

    - Students might suggest that they build a model using the commercially-made rotor as the "model for their model." This can be done using heavyweight straws and cardstock paper, but allow the students freedom to come up with their own designs and decide on their own materials for construction.

6. Distribute the drawing paper and crayons or coloring pencils for students' designs.

7. Engage students in the design process either as a whole class, in teams, or pairs.

8. Have each team/pair present their design to the class.
    - Follow up each short presentation with a brief discussion as to the design's viability. Students can choose to put all their design ideas together into one really good idea or agree to use two of the more viable designs.

    - Whichever design is agreed upon, this exploration could continue using the template found in this exploration's appendix. Students construct their flat and curved rotor blades from the template, cutting out the shapes, and connecting the rotor blades to straws using tape.

9. Once the models are constructed proceed to the next section.

Explore

1. **Question**: Using our model, how can we find out if there would be a difference in the way the model flies using a _______ rotor blade or a _______ rotor blade? (For example, the words "flat" and "curved" could be placed in the blanks, but use whatever shapes the students decide upon for their tests.)

2. Invite students to discuss and explore the answer to this question.

3. Working in teams or with partners:
    - Have students draw out step-by-step how they would set up a test to verify each rotor blade's flight.
    - Have students share their experiment ideas with the class.
    - After discussing each proposed experiment have students help each team make revisions in their experiment design by asking questions about "how it will work."

4. Have each team revise their experiments:
    - Give students time to revise their experiments.
    - Have the teams share their revised experiment ideas again with the class.

5. After discussing all the proposed experiments, decide if only one test should be developed from all the good ideas or whether each team should go ahead with their own.
Note to Teacher: The best way for students to learn the importance of the concepts involved in a "fair test" is to allow them to create their own test (regardless of its results) and then, MOST IMPORTANTLY, follow these tests with a class discussion of why the results occurred and how to make the test a fair one. Discussion is important throughout the process! Without this interaction before, during and after the process, much learning may be lost.

6. **Question**: What do you think you might find out when you conduct this test?
Record their hypotheses on chart paper and place this next to their previous hypotheses.

7. **Question**: How can we make this a "fair test"?
Solicit ideas and direct students' focus toward holding the model the same distance from the ground each time, testing in an area without moving air, performing the test a certain number of times and making the rotor blades rotate at the same rates (as far as possible). Have the group come to consensus on these test factors.
Note to Teacher: What would make this a "fair test" is if both rotors are made of the same materials, are the same weight, are the same length and width, are flown under the same conditions and perhaps are carrying the same "load" (or weight).

8. Discuss safety issues. Emphasize proper observation skills and the importance of "thinking aloud." Distribute the protective eyewear.

9. Allow 10 minutes for open explorations. As you circulate through the group, record their observations, actions, ideas and questions. Monitor safety and proper use of materials.

Explain

1. Gather students' data perhaps regarding length of time each rotor flew.

2. Record the data in a table like the Data Table in this chapter's appendix. The left column of the table can be used to draw the shape of the blade, and the right column to list the length of time the rotorcraft stayed aloft.

3. Have the class decide how this data could be depicted. (For example, a bar graph, line graph or pictograph.)

4. Gather students together for a discussion. Reflect upon the questions the students raise based upon your own classroom observations during their exploration time.

5. Ask the group to draw a conclusion about the rotor's shape and its flight performance.
Note to Teacher: In a fair test using a flat versus a curved rotor blade, the results should demonstrate that the curved rotor blade pushes down more air and generates more lift than the flat rotor blade.

6. Show students their hypothesis and compare the hypothesis with the conclusion. Ask students how their hypothesis should be changed.

Extend

1. If possible, bring a domesticated, caged bird into the classroom and ask students to observe the bird's wing as the teacher or owner gently extends it. Ask students to explain how the shape of a bird's wing could be useful to the shape of rotor blades on a rotorcraft.

2. If possible bring in a boat's propeller and/or an airplane's propeller. Pictures of a boat or airplane propeller could be used as well. Ask students how its shape might be used to design the shape of rotor blades on a rotorcraft.

3. If possible, bring in a box fan and have students examine the shape of the blades (while it is unplugged). Ask students why the company that makes the fans shaped the blades the way they did.

Evaluate

Use the evaluation form in the appendix and evaluate students on the following:

1. Rotor blade design and construction of the rotorcraft model
   Students can also use the rotor blade design in this chapter's appendix to construct their models.

2. Investigation
   - Students should carry out the investigation with a partner or a team.
   - They conduct a "fair test" and collect and record data.

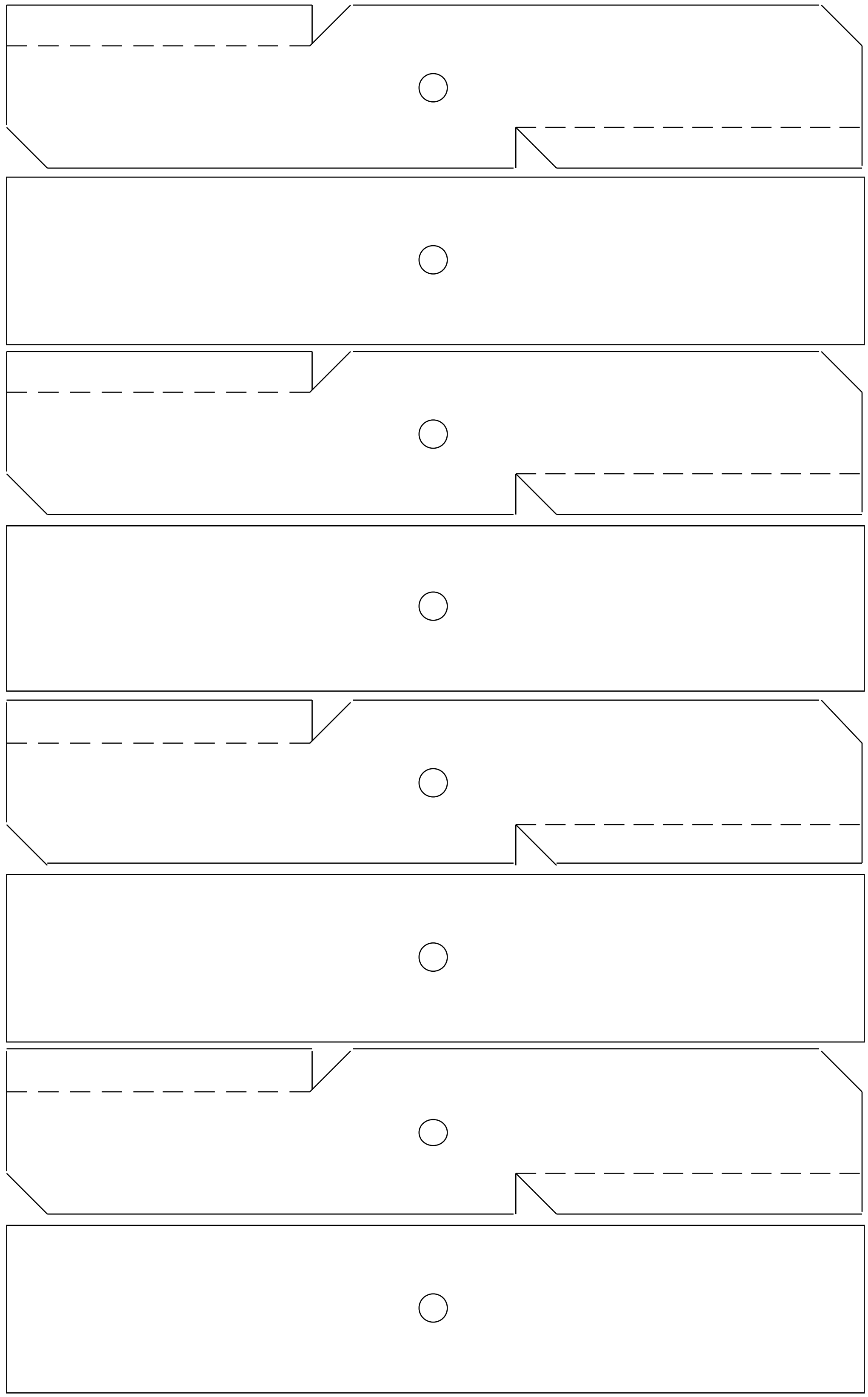
3. Reaching a conclusion
   Students reach a conclusion based on their data.

4. Revise hypothesis
   Students revise their hypothesis based on their data.

Further Exploration

An exploration could arise from a question about rotorcraft design. That is, are rotorcraft designed to perform certain tasks? If so, would the shape of the rotor blades make flight easier or harder?

Appendix: Propeller Template



Exploration 5: Rotor Blade Shape and Flight

Data Table

Team Members:

____________________ ____________________

____________________ ____________________

Use this table to record your observations. Draw or describe the rotor blade.

Rotor Blade Shape	Time

Exploration 5:
Rotor Blade Shape and Flight Rubric

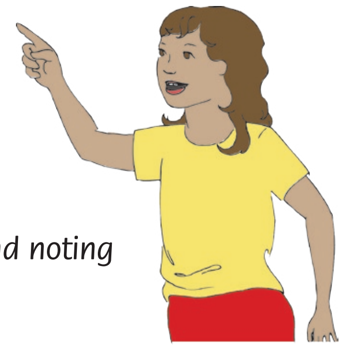
Students investigate how a rotor blades' shape affects its ability to generate lift.

Evaluate students' work using the following rubric:

4	• *Clear rotor blade design and construction of the rotorcraft model* • *Conduct a "fair test" and collect and record data* • *Reach a conclusion based on the data* • *Revise hypothesis based on data and conclusion*
3	• *Some attempt at rotor blade design and construction of the rotorcraft model* • *Attempt to conduct a "fair test" and collect and record data* • *Attempt to reach a conclusion based on the data* • *Attempt to revise hypothesis based on data and conclusion*
2	• *Construction of the rotorcraft model without a design* • *Some attempt to conduct a "fair test" and collect and record data* • *Reach a conclusion based on some of the data* • *Attempt to revise hypothesis*
1	• *Little or no rotor blade design and construction of the rotorcraft model* • *No "fair test" conducted* • *Conclusion not based on data* • *Limited revision of hypothesis*

Exploration 6: Long and Short Rotor Blades

Students investigate how a rotor blade's length affects the amount of lift it generates.



Main Concept

People can often learn about things by doing something to the things and noting what happens.

Goal

Students will design and construct simple models and use them to conduct a scientific investigation into how the length of a rotor blade affects the amount of lift it generates.

Objectives and Standards

Objectives	Standards
1. Students will design and construct simple models that use long rotor blades and short rotor blades for flight. 2. Students will conduct an investigation in rotorcraft flight using the models they construct. 3. Students will differentiate between the flight of a model using a long rotor blade and the flight of a model using a short rotor blade. 4. Students will measure the length of rotor blades with a ruler. 5. Students will develop the ability to do scientific inquiry. 6. Students will develop an understanding of scientific inquiry. 7. Students will work collaboratively with a team and share their findings.	**Partially Meets:** 2061: 1B (K-2) #1 2061: 1B (3-5) #1 2061: 1C (K-2) #2 NCTM: Measurement, (K-2) #7 NSES: A (K-4) #1, #2 **Addresses**: 2061: 4F (3-5) #1

Prerequisite Concepts

- *A model of a rotorcraft can be used to test how a rotorcraft flies.*
- *The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.*
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration #3: How Do Rotors Create Lift?
Robin Whirlybird Exploration #4: Rotorcraft Flight and Lift
Robin Whirlybird Exploration #5: Rotor Blade Shape and Flight

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button "Rotorcraft Activities"

New Concepts

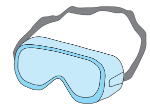
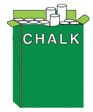
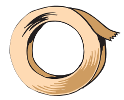
- *Scientific inquiry involves learning about things by doing something to the things and noting what happens.*

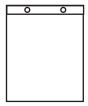
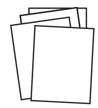
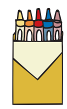
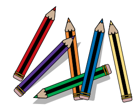
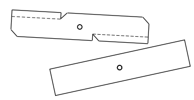
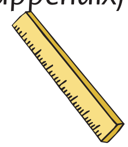
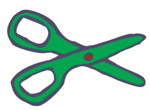
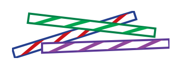
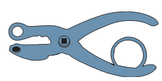
- *Scientific investigations may take many different forms, including observing what things are like, what is happening somewhere and doing experiments.*

Schedule

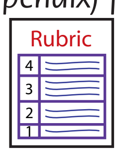
Allow 2-3 sessions of 20-40 minutes.

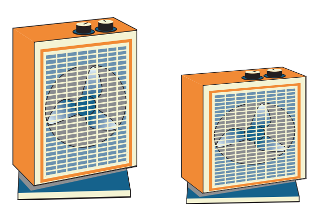
Materials

- Protective eyewear for each student, available from most school science supply stores and catalogs 
- Chalk or tape  

- Chart paper 
- Drawing paper and crayons or coloring pencils   
- At least one template for long and short rotor blades (See this exploration's appendix) for each team/pair 
- Rulers 1 per team/pair 
- Cardstock for constructing rotor blades 
- Scissors 1 per team/pair 
- Sturdy plastic drinking straws (approximately 3 straws per team/pair) 
- Hole punchers 1 per team/pair 
- Cellophane tape roll 1 per team/pair 
- Stopwatches or watch/clock with second-hand 

- At least one Data Table (see this exploration's appendix) for each team/pair 

- Evaluation rubric in this exploration's appendix 

- Two house fans with blades that rotate at close to the same rate, one with longer blades than the other 

Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Draw on students' prior knowledge of rotorcraft.
   - Question: What do rotorcraft need so they can fly?

   Rotorcraft need spinning rotor blades in order to gain lift.

2. Tell students that today they will be scientists investigating how the length of rotor blades affects the flight of rotorcraft.
   - **Question:** How do you think the flight of a rotorcraft will be affected if we change the length of the rotor blades?
   - List students' responses on chart paper. These responses are their hypotheses.
   - Ask students how they can test their guesses or hypotheses. Students may want to proceed as they did in the last exploration, and design and create rotorcraft models and test them.

3. Students will need to be engaged in the design process as a class or in teams or pairs.
   - Have each team or pair present their design to the class.
   - Follow up each short presentation with a brief discussion as to the design's viability.
   - Students can choose to put all their design ideas together into one really good idea or agree to use two of the more viable designs.

4. Use the students' designs or the template in this exploration's appendix.

5. Ask students to use the rulers to measure the length of their rotor blades.

6. Have students construct their long-bladed and short-bladed rotors from cardstock, using the template, cutting out the shapes and connecting the rotors to straws using tape.

7. Once the models are constructed proceed to the next section.

Explore

1. Ask: Using our model, how can we find out if there would be a difference in the way the model flies using a long rotor blade or a short rotor blade?

2. Invite students to discuss and explore the answer to this question.

3. Working in their student teams or with partners, have the students draw out step-by-step how they would set up a test to verify each rotor blade's flight.

4. Have students share their experiment ideas with the class.

5. After discussing each proposed experiment have students help each team make revisions in their experiment design by asking questions about "how it will work."

6. Give each team time to revise their experiments.

7. Have students share their revised experiment ideas again with the class. After discussing all the proposed experiments, decide if only one test should be developed from all the good ideas or whether each team should go ahead with their own.

8. **Question:** How can we make this a fair test?

9. Solicit ideas and direct students' focus toward holding the model the same distance from the ground each time, testing in an area without moving air, performing the test a certain number of times and making the rotor blades rotate at the same rates (as much as possible). Have the group come to consensus on these test factors.

   Note to Teacher: This will be a "fair test" if both the short and long rotor blades are made of the same materials, are the same width, are flown under the same conditions and carry the same "load" (or weight).

10. Discuss safety issues. Emphasize proper observation skills and the importance of "thinking aloud." Distribute the protective eyewear.

11. Distribute stopwatches.

12. Allow 10 minutes for open explorations. Record students' observations, actions, ideas and questions.

13. Monitor safety and proper use of materials.

Explain

1. Have students in pairs draw a picture that depicts the results of their long/short blade experiments and the model's flight.

2. Record the data in a table like the Data Table in the Appendix. The left column of the table can be used to draw the length of the blade, and the right column to list the amount of time the rotorcraft stayed aloft.

3. Have the class decide how this data could be depicted. (For example, a bar graph, line graph or pictograph.)

4. Gather students together for a discussion.

5. Reflect upon the questions the students raise based upon your own classroom observations during their exploration time.

6. Ask the group to draw a conclusion about the rotor's length and its flight performance.

   Note to Teacher: In a fair test the results should demonstrate that the long rotor blade is better at generating lift than the short rotor blade, however, it takes more effort to rotate the long rotor blade. Students may notice that it takes more effort to get the long rotor blade to fly. This does NOT mean that longer rotor blades are always better. For example, one would not need really long rotor blades for a two-seater, lightweight helicopter. However, a heavy-lifting helicopter would need longer rotor blades to generate the lift it needs while carrying a heavy load through the air.

7. Show students their hypothesis and compare the hypothesis with the conclusion. Ask students how their original hypothesis should be changed.

Extend

1. If possible, find two house fans with blades that rotate at close to the same rate and have identical fan blade shape, but one has longer fan blades. Present these two fans to the class. Before turning them on, ask the students to predict which one will generate more air movement.
   Note: The fan with longer blades will generate more air movement.

2. Ask students to explain how a fan is like the rotor blades on a rotorcraft.

Evaluate

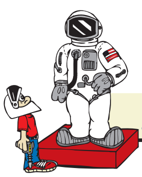
Use the rubric in this exploration's appendix and evaluate students on the following:

1. Rotor blade design and construction of the rotorcraft model
   Students can also use the rotor blade design in this exploration's appendix to construct their models.

2. Investigation
   - Students should carry out the investigation with a partner or a team.
   - They conduct a "fair test" and collect and record data.

3. Reaching a conclusion
   Students reach a conclusion based on their data.

4. Revise hypothesis
   Students revise their hypothesis based on their data.

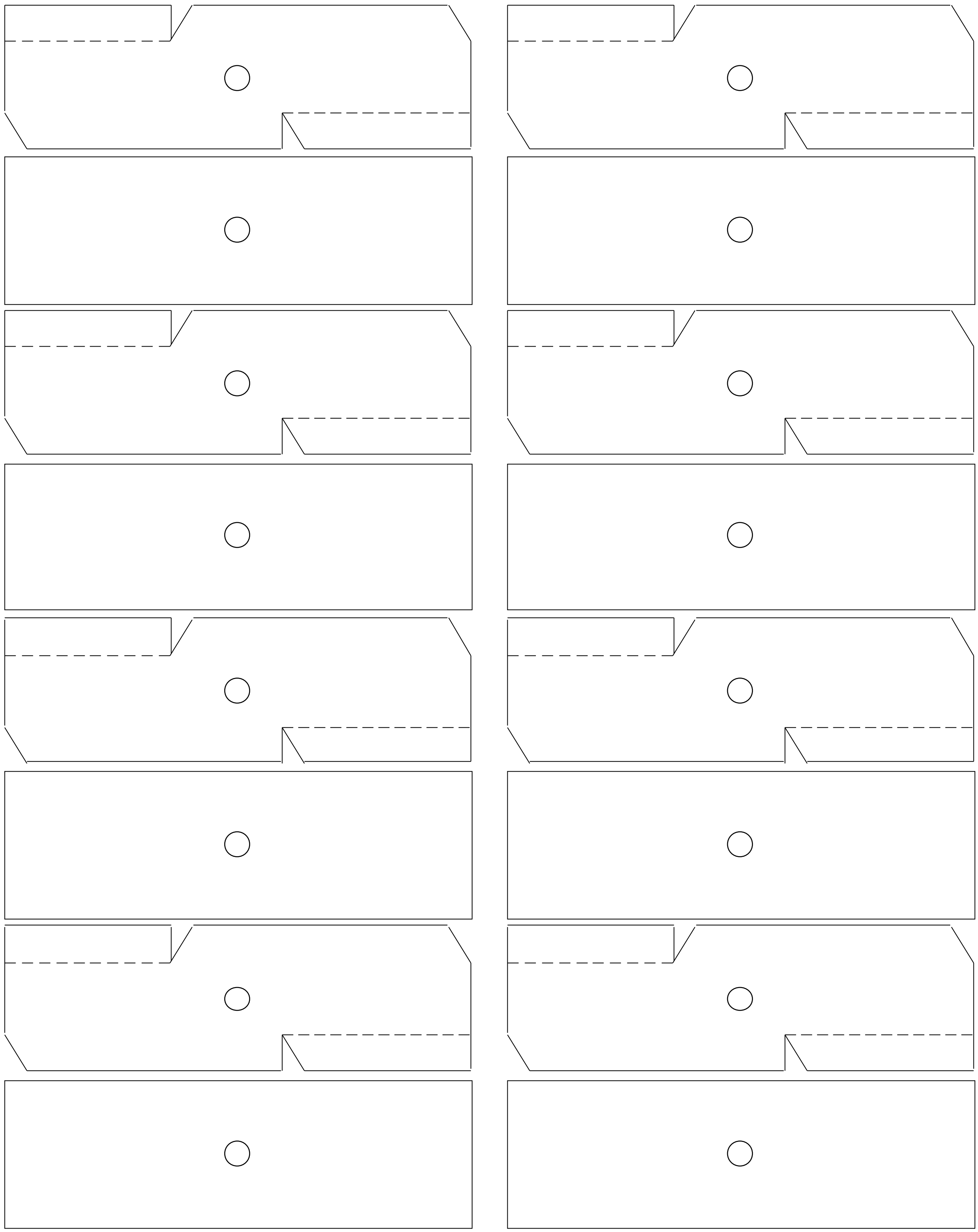


Further Exploration

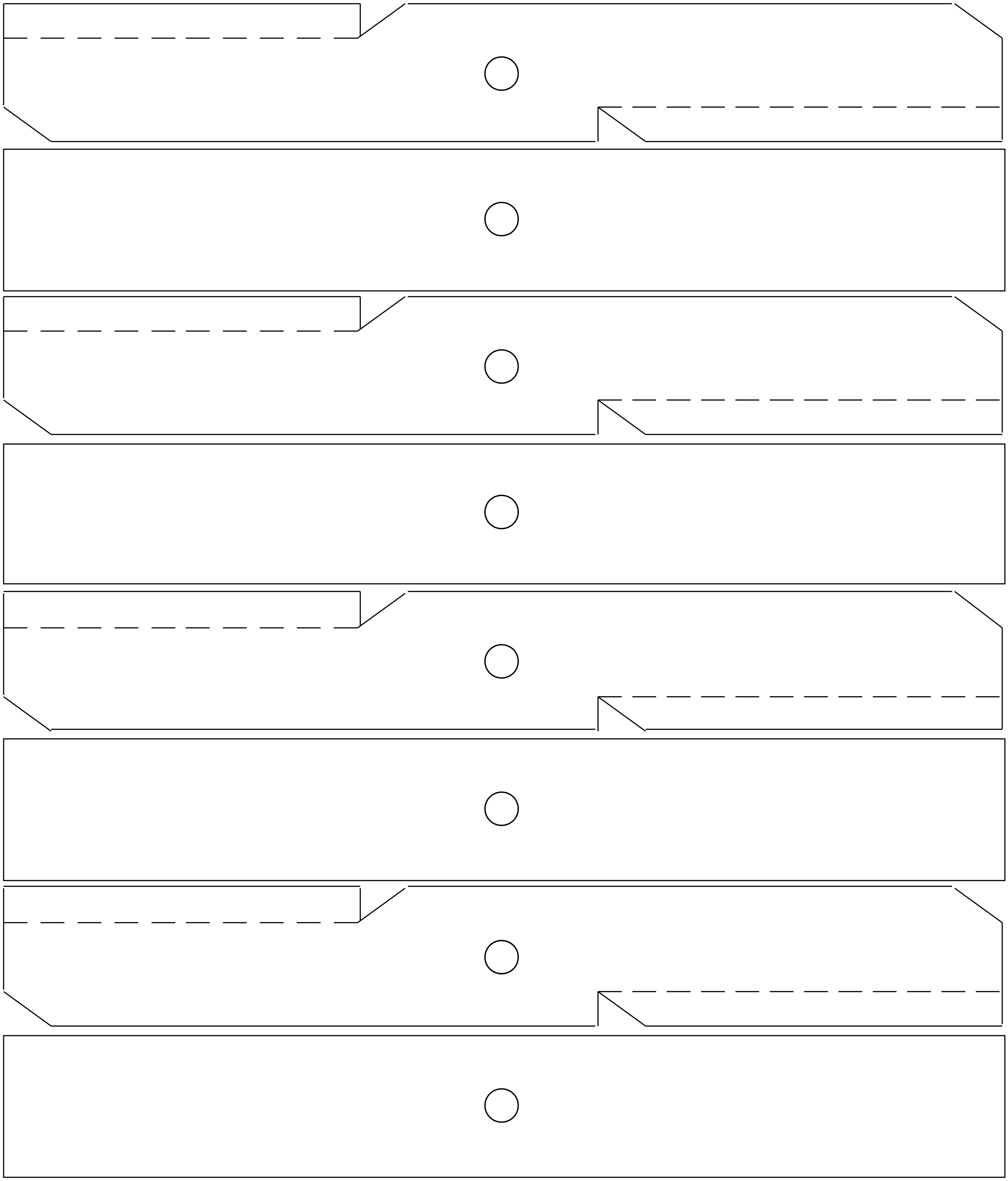
- Students might have additional questions such as whether long rotor blades can carry more weight in flight than short rotor blades.

- Another exploration could arise from a question about the shape and length of the rotor blade. That is, can the shape and length of the rotor blade be adjusted so that more weight can be carried?

Appendix: Propeller Template - Short



Appendix: Propeller Template - Long



Exploration 6: Long and Short Rotor Blades

Data Table

Team Members:

____________________________ ____________________________

____________________________ ____________________________

Use this table to record your observations. Draw or describe the rotor blade.

Rotor Blade Length	Observation	Time

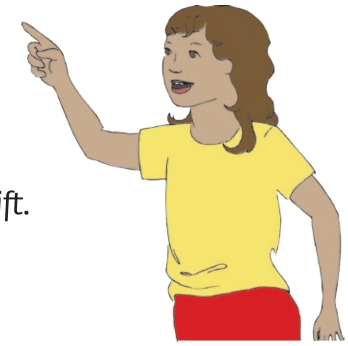
Exploration 6: Long and Short Rotor Blades Rubric

Students investigate how a rotor blades' length affects its ability to generate lift.

Evaluate students' work using the following rubric:

4	• *Clear rotor blade design and construction of the rotorcraft model* • *Conduct a "fair test" and collect and record data* • *Reach a conclusion based on the data* • *Revise hypothesis based on data and conclusion*
3	• *Some attempt at rotor blade design and construction of the rotorcraft model* • *Attempt to conduct a "fair test" and collect and record data* • *Attempt to reach a conclusion based on the data* • *Attempt to revise hypothesis based on data and conclusion*
2	• *Construction of the rotorcraft model without a design* • *Some attempt to conduct a "fair test" and collect and record data* • *Reach a conclusion based on some of the data* • *Attempt to revise hypothesis*
1	• *Little or no rotor blade design and construction of the rotorcraft model* • *No "fair test" conducted* • *Conclusion not based on data* • *Limited revision of hypothesis*

Exploration 7:
Rotor Blade Weight and Flight



Students investigate how a rotor blades' weight affects its ability to generate lift.

Main Concept

People can often learn about things by doing something to the things and noting what happens.

Goal

Students will design and construct simple models and use them to conduct a scientific investigation into how the material from which a rotor blade is made affects the amount of lift it generates.

Objectives and Standards

Objectives	*Standards*
1. *Students will design and construct simple models that use rotor blades of different weights or rotor blades made from differently weighted materials for flight. (For example, lightweight paper vs. cardstock vs. cardboard vs. plastic vs. aluminum foil, etc.)* 2. *Students will conduct an investigation in rotorcraft flight using the models they construct.* 3. *Students will differentiate between the flight of a model using one type of rotor blade material/weight and the flight of a model using a different type of rotor blade material/ weight. (For example, lightweight paper vs. cardstock vs. cardboard vs. plastic vs. aluminum foil, etc.)* 4. *Students will develop the ability to do scientific inquiry.* 5) *Students will develop an understanding of scientific inquiry.* 6) *Students will work collaboratively with a team and share their findings.*	**Partially Meets:** 2061: 1B (K-2) #1 2061: 1C (K-2) #2 2061: 1B (3-5) #1 NSES: A (K-4) #1, #2 **Addresses**: 2061: 4F (3-5) #1

Prerequisite Concepts

- *A model of a rotorcraft can be used to test how a rotorcraft flies.*
- *The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.*
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration #3: How Do Rotors Create Lift?
Robin Whirlybird Exploration #4: Rotorcraft Flight and Lift
Robin Whirlybird Exploration #5: Rotor Blade Shape and Flight
Robin Whirlybird Exploration #6: Long and Short Rotor Blades

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button "Rotorcraft Activities"

New Concepts

- *Scientific inquiry involves learning about things by doing something to the things and noting what happens.*

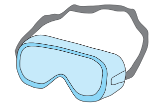
- *Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, and social questions.*

Schedule

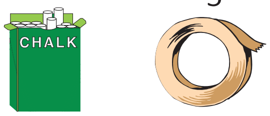
Allow 2-3 sessions of 20-40 minutes.

Materials

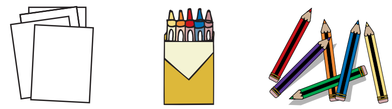
- Protective eyewear for each student, available from most school science supply stores and catalogs



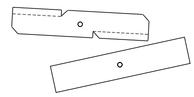
- Chalk or tape



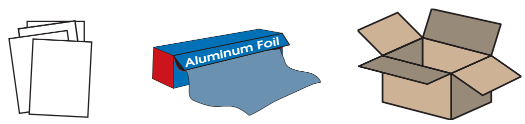
- Drawing paper and crayons or coloring pencils



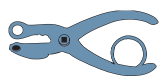
- Template for rotor blades preferably of the students' design



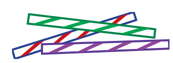
- Paper of various weights, heavy aluminum foil, and cardboard of various weights



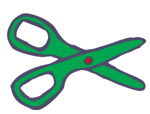
- Student-stipulated materials from which students will construct rotor blades based upon their own designs
- Hole punchers 1 per team/pair



- Sturdy plastic drinking straws (approximately 3 straws per team/pair)

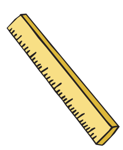


- Scissors 1 per team/pair

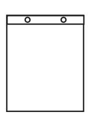


- Cellophane tape roll 1 per team/pair

- Rulers 1 per team/pair

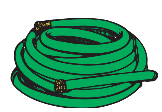


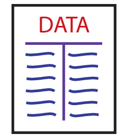
- Chart paper

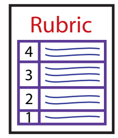


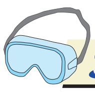
- Stopwatches or watch/clock with second-hand

- Two, 1-foot long pieces of rubber tubing or a rubber hose of varying flexibility from soft to stiff



- A small section of large link, heavy-duty chain 
- At least one Data Table (in this exploration's appendix) for each team/pair 

- Evaluation rubric in this exploration's appendix 



Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Draw on students' prior knowledge of rotorcraft by asking them:
   - What do rotorcraft need so they can fly?
   - What have you discovered about how a rotor blade's length affects the rotorcraft's flight?
2. Ask students what sort of a model they would use to investigate the effect of a rotor blade's weight on the rotorcraft's flight. Students may choose the type of model they used in Exploration #5 and Exploration #6, or choose a different design altogether.
3. Distribute drawing paper and crayons or colored pencils so students can draw their designs.
4. Engage students in the design process either as a whole class, in teams, or in pairs.
   - Have each team or pair present their design to the class.
   - Follow up each short presentation with a brief discussion as to the design's viability.
   - Students can choose to put all their design ideas together into one really good idea or agree to use one or two of the more viable designs.

5. Have students construct their rotor blades, cutting out the shapes in the material of their choosing, and taping the rotors to the straws.

6. Once the models are constructed proceed to the next section.

Explore

1. **Question**: Using our model, how can we find out if there is a difference in the way the model flies using a heavyweight rotor blade or a lightweight rotor blade?

2. Ask students, in their teams or with partners, to draw out step-by-step how they would set up a test to verify each rotor blade's flight.

3. Have students share their experiment ideas with the class.

4. Discuss each proposed experiment.

5. Have students help each team make revisions in their experiment design by asking questions about "how it will work."

6. Give each team time to revise their experiments.

7. Have the teams share their revised experiment ideas again with the class. After discussing all the proposed experiments, decide if only one test should be developed from all the good ideas or whether each team should go ahead with their own.

8. **Question**: What do you think you might find out?
   Record and post their hypotheses on chart paper.

9. **Question**: How can we make this a fair test?
   - Solicit ideas and direct students' focus toward holding the model the same distance from the ground each time, testing in an area without moving air, the number of times they should perform each test, as well as the rotation rate of the rotor blades. Have the group come to consensus on these test factors.

   Note to Teacher: This would be a "fair test" if the heavyweight rotor and the lightweight rotor are the same shape, length and width, carry the same "load" (or weight), have the same "fuselage" (the drinking straw), and are flown under the same conditions.

10. Discuss safety issues. Constantly monitor safety and the proper use of materials.

11. Emphasize proper observation skills and the importance of "thinking aloud."

12. Allow 10 minutes for open explorations. As you circulate through the group, record students' observations, actions, ideas and questions.

Explain

1. Have students draw a picture that depicts the results of their rotor blade experiments and each model's flight.
   - Gather students' data, perhaps regarding length of time each rotor flew.
   - Record the data in a table like the Data Table in this exploration's appendix. The left column of the table can be used to indicate the weight of the blade, and the right column to list the amount of time the rotorcraft stayed aloft.
   - Ask the class to decide how this data could be depicted. (For example, a bar graph, line graph or pictograph.)

2. Gather students together for a discussion. Reflect upon the questions the students raised based upon your own classroom observations during their exploration time.

3. Ask the group to draw a conclusion about the rotor blades' weight and its flight performance.

   Note to Teacher: In a fair test in which differently weighted rotor blades are made in the same shape, length, and width are flown under the same conditions and carry the same "load" (or weight), the results will depend upon the materials used. Students will find that with the "fuselage" weight and the rotor blade shape constant, a continuum will emerge in which lighter weight rotor blades will generate less lift than heavyweight rotor blades, but only up to a certain weight. After a certain weight, the rotor blades will be too heavy for the "fuselage" and the students will NOT be able to spin the rotor fast enough to generate lift. Line up the blades from lightest to heaviest. With this added data, the results can be graphed and students will clearly see the progression or continuum. What should emerge for the students will be the concept that heavier is not always "better." In terms of design, rotor blades need to be constructed from materials that are strong and stiff enough to maintain their shape during the spinning motion in order to generate lift. Students will notice that the lightweight paper that "droops too much" will not be capable of generating much lift. However, in the aviation world, the rotor blades on rotorcraft do need some flexibility in order to withstand the stresses of flight. This is why when a helicopter is at rest, the rotor blades droop toward the ground and when the rotor blades spin the tips actually bend upward. That's how strong, yet flexible the material has to be.

4. Show students their hypothesis and compare the hypothesis with the conclusion. Ask students how their original hypothesis should be changed.

Extend

1. Bring 2 one-foot long pieces of rubber tubing or a rubber hose. Have one be highly flexible and the other quite stiff.

2. Pass these around to the students and then have the class give the characteristics of each.

Hose #1	Hose #2
Bendable/flexible	Stiff
Color	Color
Texture	Texture
Material	Material

3. Note these characteristics on large size paper or the front board. See the box for topics.

4. Ask students to think of everyday objects/tools they have around their house.

5. Create a list of two columns, one titled flexible/bendable objects and the other titled stiff or inflex-ible.

6. Ask students to place the objects they thought of into one of the two categories. Review each one, noting the materials from which it is formed (plastic, metal, rubber, wood) and ask whether this tool would work as well if it were NOT flexible or stiff.

Flexible / Bendable	Stiff / Inflexible
Garden hose	Mop handle
Bristles on a broom or hand brush	screwdriver
Electrical cord	Pencil
Rope	Large Mixing spoon

6. Hold up a large link heavy-duty chain and ask in which category it should be placed. Ask the reasoning for their categorization.
   Note to Teacher: A chain has both properties; each link is stiff, yet when linked together all the links work in a more flexible way.

7. Ask students in their teams to design a tool that can be used to dust the ceiling fans that hang 20 feet above the floor. How flexible should the tool be? Would it have the same amount of flexibility throughout? Would the handle be made out of different materials from the part that dusts the fans?

8. Have each group share their design and their reasons for their design.

Evaluate

Use the rubric in this exploration's appendix and evaluate students on the following:

1. *Rotor blade design and construction of the rotorcraft model*
   Students can also use the rotor blade design in the appendix to construct their models.

2. *Investigation*
   - *Students should carry out the investigation with a partner or a team.*
   - *They conduct a "fair test" and collect and record data.*

3. *Reaching a conclusion*
   Students reach a conclusion based on their data.

4. *Revise hypothesis*
   Students revise their hypothesis based on their data.

Further Exploration

- *Students might have additional questions regarding the connection between how fast the rotor blades turn with how long the rotorcraft stays in the air, how high it flies, fast it flies, or if long rotor blades can fly with more weight than short rotor blades.*

- *Another exploration could arise from questions about how combining these factors (such as length and width of rotor blades, weight of rotor blades, AND weight of fuselage/model) affect lift.*

- *Another exploration could arise from a question about rotorcraft design. Are rotorcraft designed to perform certain tasks? If so, would the shape and length of the rotor blades make lift better or worse?*

- *If time and interest permits transform students' ideas, questions, observations, and hypotheses into additional investigations.*

Exploration 7:
Rotor Blade Weight and Flight

Data Table

Team Members:

________________________ ________________________

________________________ ________________________

Use this table to record your observations. Draw or describe the rotor blade.

Rotor Blade Weight/Material	Time

Exploration 7:
Rotor Blade Weight and Flight Rubric

Students investigate how a rotor blades' weight affects its ability to generate lift.

Evaluate students' work using the following rubric:

4	• *Good, clear design of rotorcraft model* • *Well-constructed rotorcraft model* • *Use of "fair testing" with one variable changed at a time* • *Data recorded clearly* • *Reached reasonable conclusion based on tests and observations* • *Revised hypothesis* • *Good exchange of ideas and collaborative teamwork*
3	• *Clear design of rotorcraft model* • *Adequately constructed rotorcraft model* • *Use of "fair testing" with one variable changed at a time* • *Data recorded but not organized clearly* • *Reach reasonable conclusion based on tests and observations* • *Revised hypothesis* • *Some exchange of ideas and collaborative teamwork*
2	• *Attempt to design of rotorcraft model* • *Rotorcraft model constructed but inadequate for test* • *Attempt to use "fair testing" with one variable changed at a time* • *Data recorded* • *Reach conclusion based on some tests* • *Attempted to revise hypothesis* • *Little exchange of ideas and collaborative teamwork*
1	• *Little attempt to design of rotorcraft model* • *Attempt to construct rotorcraft model* • *Limited understanding and use of "fair testing"* • *Little or no data recorded* • *Conclusion not reached or not based on tests* • *Did not adequately revise hypothesis* • *Limited exchange of ideas and collaborative teamwork*

Exploration 8: The Rotorcraft Challenge

Students work in teams and use their knowledge of rotorcraft flight, models, and "fair tests" to design a rotorcraft model that will carry an unsharpened pencil for at least three seconds.

Main Concept

Engineering design involves the use of models and "fair tests" to find the optimum shape, size, weight, and strength for rotor blades in order to generate lift.

Goal

Students will work in a team and use methods of scientific investigation to design a rotorcraft model.

Objectives and Standards

Objectives	Standards
1. Students will design and construct simple models that use rotor blades of different shapes, lengths, widths and weight/strength to create lift. 2. Students will conduct an investigation in rotorcraft flight using these models. 3. Students will measure the length and width of rotor blades with a ruler. 4. Students will develop an understanding of engineering design.	**Meets:** 2061: 1B (K-2) #1 2061: 1C (K-2) #2 2061: 1B (3-5) #1 NSES: A (K-4) #1, #2 **Partially Meets:** ITEA: #9 **Addresses**: 2061: 4F (3-5) #1 2061: 4F (3-5) #1 NCTM, Measurement, K-2 #7

Prerequisite Concepts

- *A model of a rotorcraft can be used to test how a rotorcraft flies.*
- *The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.*
- *Spinning rotor blades generate lift.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration #3: How Do Rotors Create Lift?
Robin Whirlybird Exploration #4: Rotorcraft Flight and Lift
Robin Whirlybird Exploration #5: Rotor Blade Shape and Flight
Robin Whirlybird Exploration #6: Long and Short Rotor Blades
Robin Whirlybird Exploration #7: Rotor Blade Weight and Flight

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button "Rotorcraft Activities"

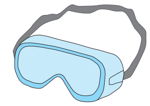
New Concepts

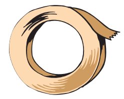
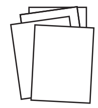
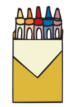
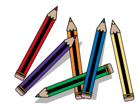
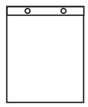
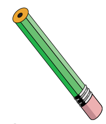
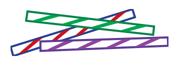
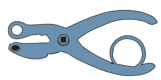
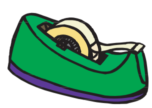
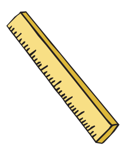
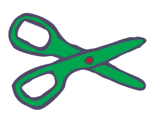
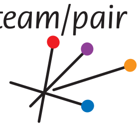
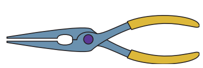
- *Methods of scientific investigation can be used to design a rotorcraft model.*

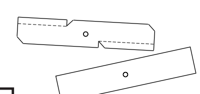
Schedule

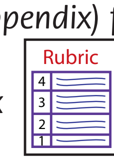
Allow 2-3 sessions of 20-40 minutes.

Materials

- Protective eyewear for each student, available from most school science supply stores and catalogs 
- Chalk or tape 


- Drawing paper and crayons or coloring pencils   
- Chart paper 
- Two unsharpened pencils per pair or group of students 
- Non-articulated, plastic drinking straws of a sturdy variety (approximately 5-10 straws per team/pair) 
- Sheets of paper of various weights for students to use in their rotor blade construction based upon their own designs 
- Hole punchers 1 per team/pair 
- Cellophane tape roll 1 per team/pair 
- Rulers 1 per team/pair 
- Scissors 1 per team/pair 
- Straight pins 
- Needle-nose pliers 
- Stopwatches or watch/clock with second-hand 

- Template for rotor blades of 3-5 different lengths (see this exploration's appendix) 
- At least one Data Table (in this exploration's appendix) for each team/pair 

- Evaluation rubric in this exploration's appendix 

Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Review what students have learned about models by asking them:
   - How do scientists study how things work?
   - How did you study what type of rotor blade creates the greatest lift?

   Students should say that they used models and "fair tests." They might also say that they changed the shape, length and weight of rotor blades.

2. Tell students that their challenge in this lesson is to create a rotorcraft model that can carry an unsharpened pencil and stay aloft for at least three seconds.

3. Ask students to work in pairs or groups of three.

4. Distribute drawing paper and crayons or colored pencils.

5. Ask students to draw their model designs.

6. Circulate among the groups and have students explain their model designs.

Explore

1. Discuss safety issues. Distribute the protective eyewear.

2. Have students build their models and test them.

3. If the models do not stay aloft for at least three seconds, ask students what they could change to improve the performance of their rotorcraft models.

4. Remind students that they have tested each aspect of a rotor blade: the shape, length and weight/strength. They should perform "fair tests" and change only one aspect of the rotor blade at a time.

5. Ask students to modify their designs before they proceed with a modification to their models.

6. Remind students that they may need to go back and redesign their rotorcraft many times. Seldom does the first design work.

Explain

1. Have students show their rotorcraft designs to the class and explain why they came up with that particular design.

2. Ask students to describe how they plan to change their design if the flight is not successful. Look for responses that indicate that they will change one variable at a time.

3. Have students rebuild and test their models.

4. Gather students together for a discussion. Reflect upon the questions the students raised based upon your own classroom observations during their exploration time.

5. Ask the group to draw a conclusion about the rotor blades' characteristics for optimum flight performance. If age appropriate, ask each group to write their conclusions.

Extend

- Ask students to change their models so that they stay aloft longer or lift two pencils.

Evaluate

1. Collect student's original and modified designs.

2. Students are successful if they modify one aspect of the blades at a time and then test their rotorcraft model.

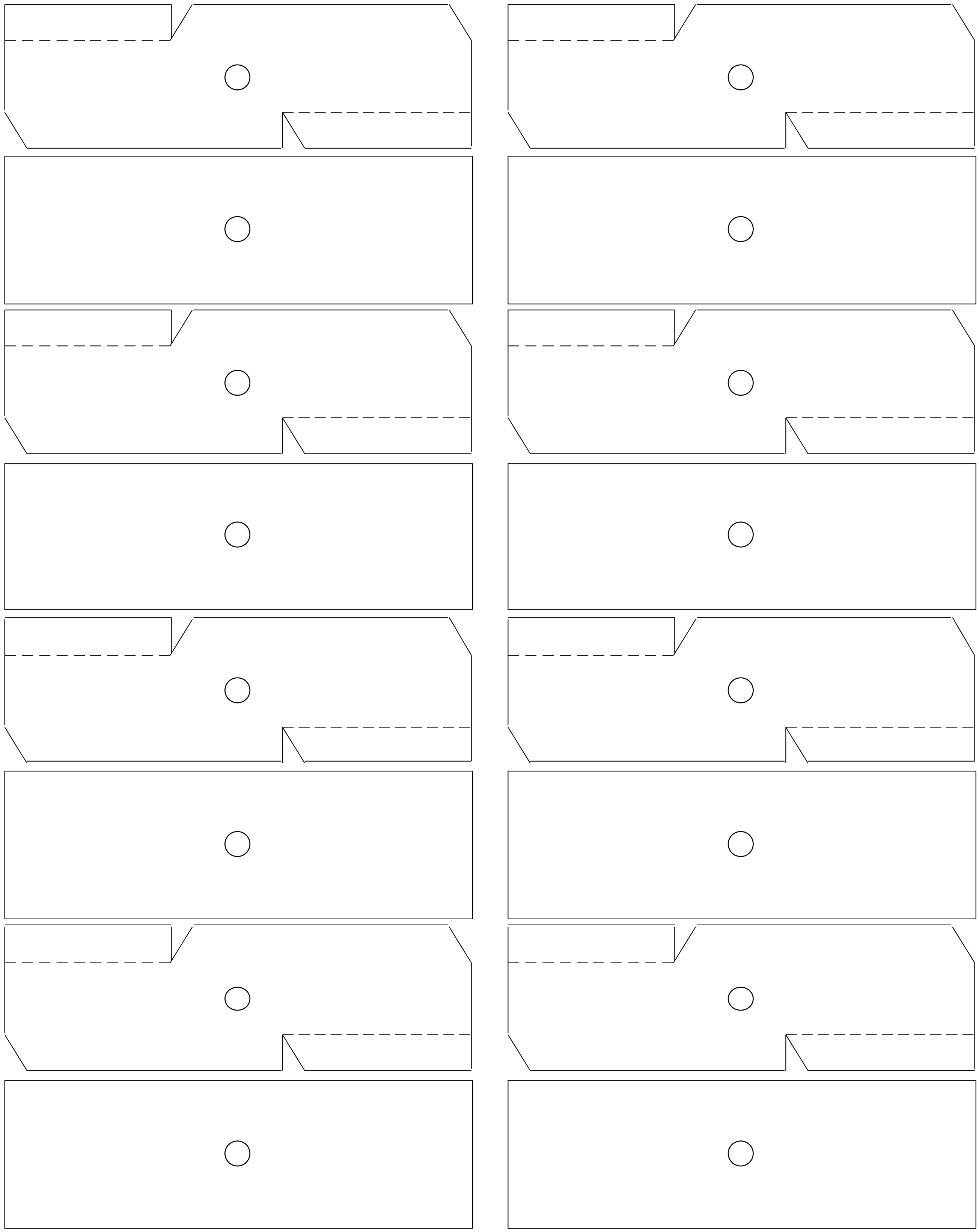
3. Use the rubric in this exploration's appendix for assessment.

Further Exploration

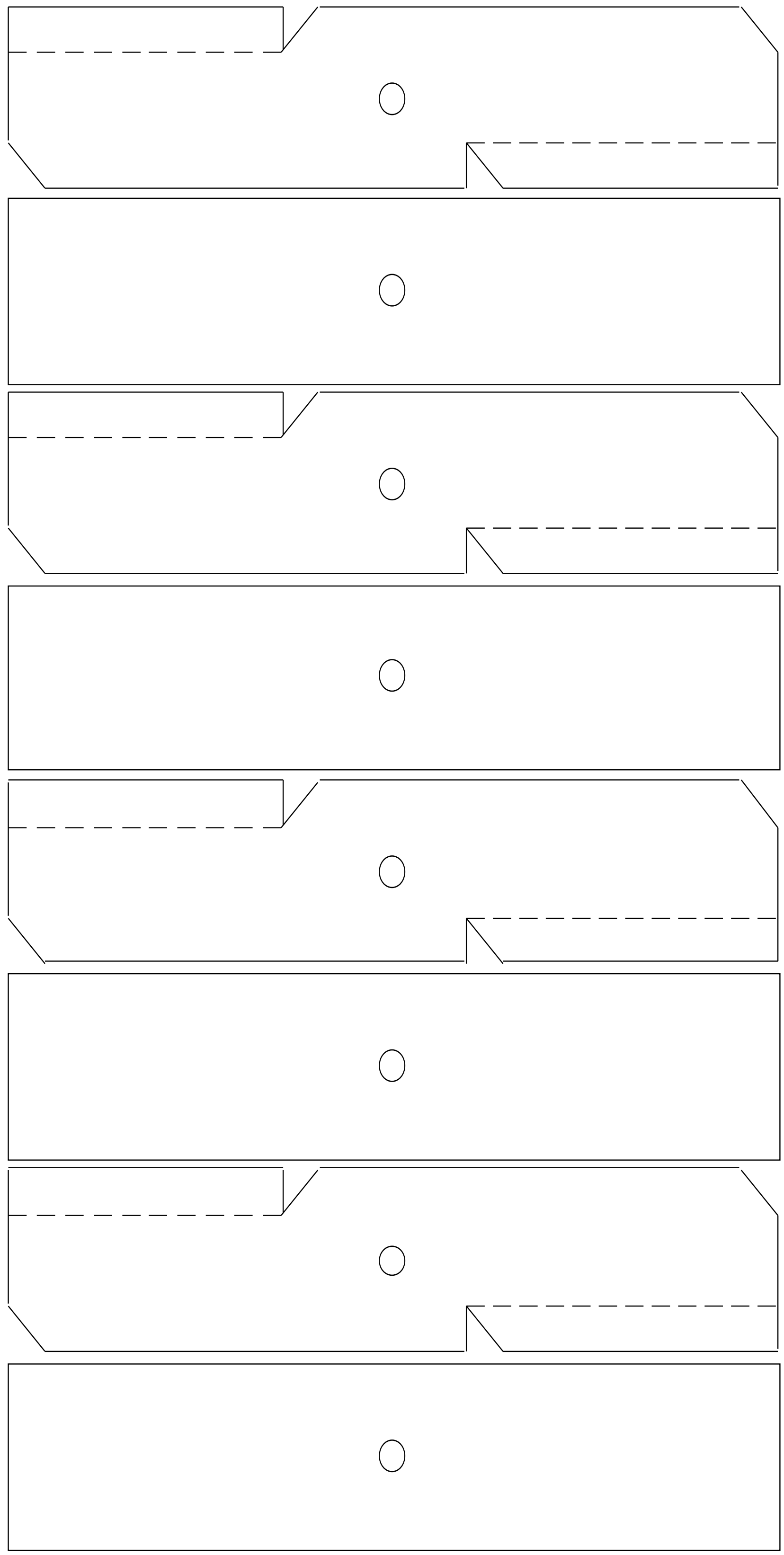
- Students might have additional questions regarding the connection between a rotorcraft's design and its intended usage. That is, are rotorcraft designed to perform certain tasks? If so, how would the shape and length of the rotor blades be different for different tasks (tasks such as heavy lifting, speed, high maneuverability, observation, and passenger or cargo transportation).

- Use the Web to research various types of helicopter uses as well as helicopter manufacturers to review the many different types of rotorcraft.

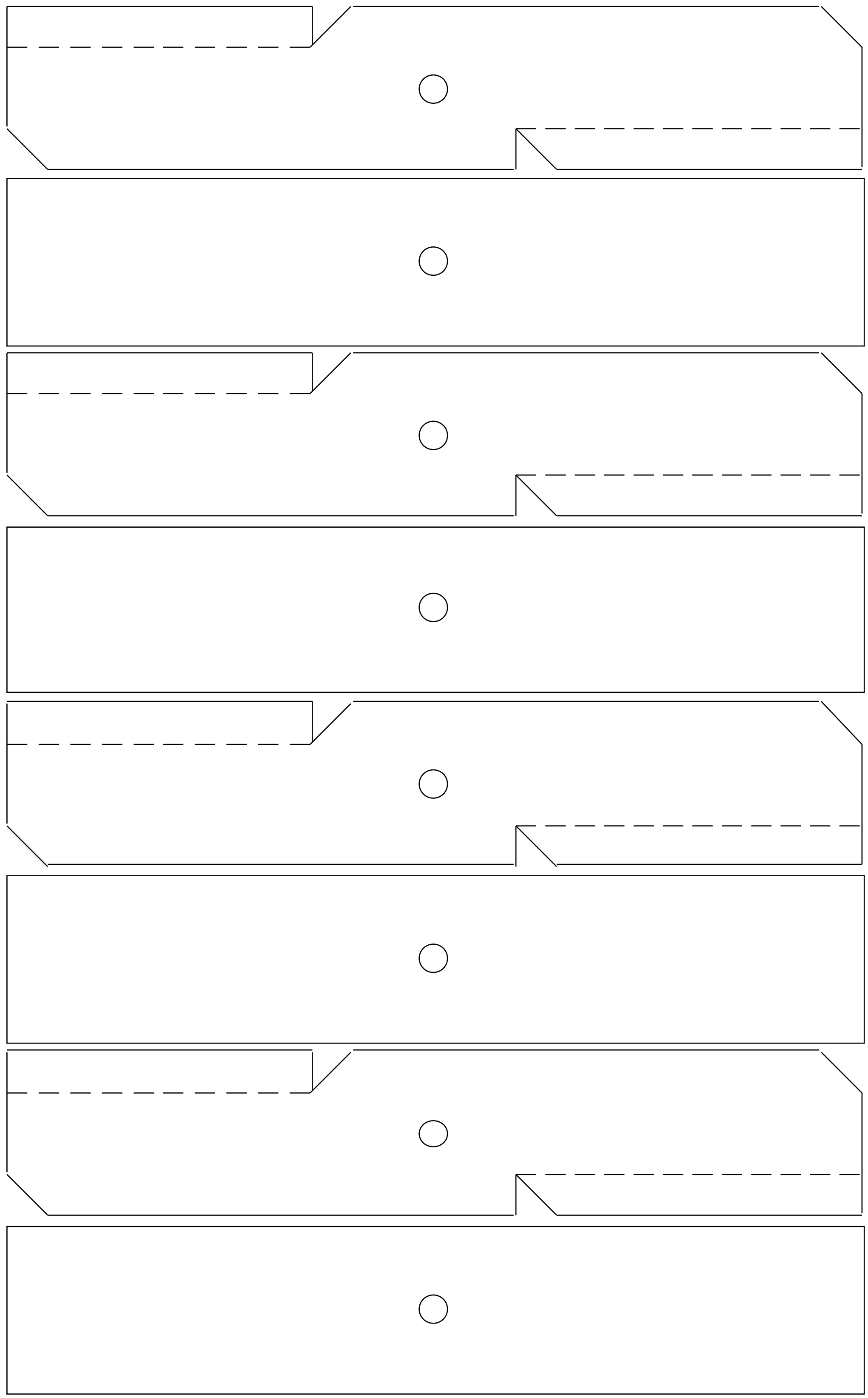
Appendix: Propeller Template - Size 1



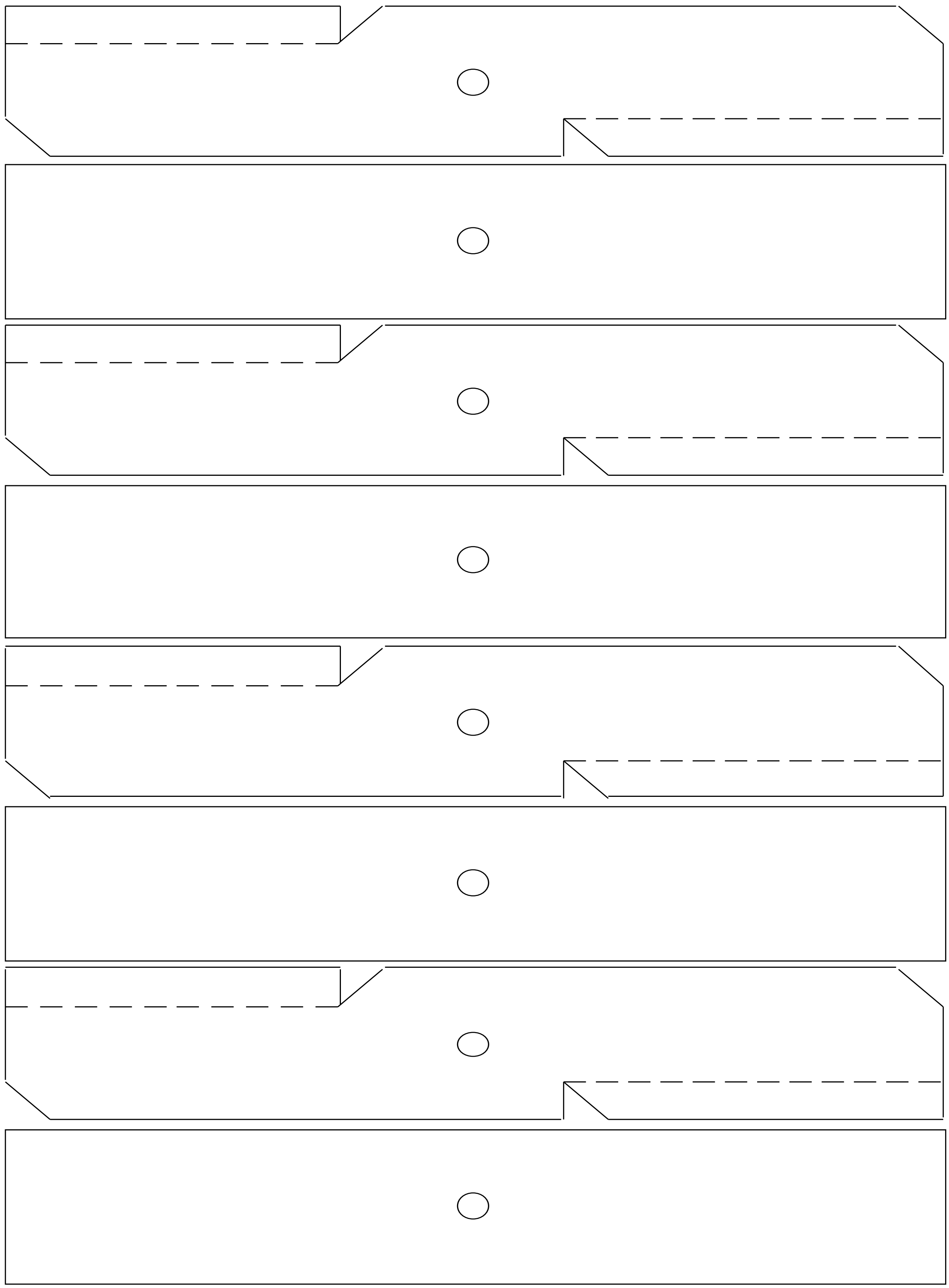
Appendix: Propeller Template - Size 2



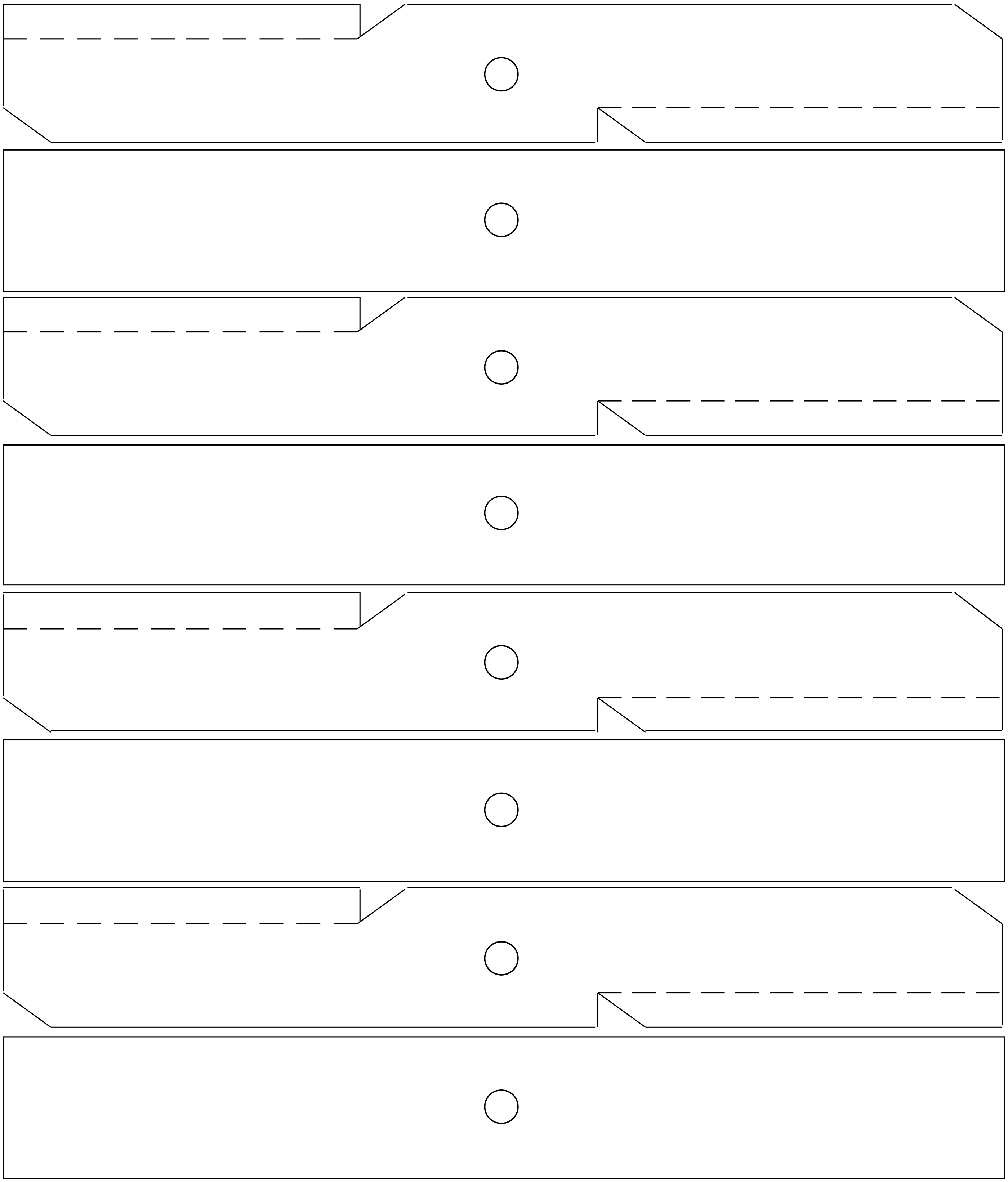
Appendix: Propeller Template - Size 3



Appendix: Propeller Template - Size 4



Appendix: Propeller Template - Size 5



Exploration 8: The Rotorcraft Challenge

Data Table

Team Members:

____________________________ ____________________________

____________________________ ____________________________

Use this table to record your observations. Draw or describe the rotor blade.

Rotor Blade	Time

Exploration 8:
The Rotorcraft Challenge Rubric

Students work in teams and use their knowledge of rotorcraft flight, models, and "fair tests" to design a rotorcraft model that will carry an unsharpened pencil for at least three seconds.

Evaluate students' work using the following rubric:

4	• Good, clear design and drawing of model design • Use of "fair testing" with one variable changed at a time • Redesign based on tests and observations • Good exchange of ideas and collaborative teamwork
3	• Fair drawing of model design • Attempt to conduct a "fair test" and some understanding of variables • Some redesign based on tests and observations • Some exchange of ideas and collaborative teamwork
2	• Sketchy drawing of model design • Test method shows some understanding of variables • Redesign based on only a few observations • Attempts at teamwork
1	• Drawing not entirely suitable for design • Test method exhibits lack of understanding of variables • Little or no redesign • Little or no teamwork

Robin Whirlybird on her Rotorcraft Adventures
An Educator's Guide with Activities in Aeronautical Sciences
EDUCATOR REPLY CARD

To achieve America's goals in Educational Excellence, it is NASA's mission to develop supplementary instructional materials and curricula in science, mathematics, and technology. NASA seeks to involve the educational community in the development and improvement of these materials. Your evaluation and suggestions are vital to continually improving NASA educational materials.

Please take a moment to respond to the statements and questions below. You can submit your response through the Internet or by mail. Send your reply to the following Internet address:

http://ehb2.gsfc.nasa.gov/edcats/educator_guide

You will then be asked to enter your data at the appropriate prompt.

Otherwise, please return the reply card by mail. Thank you.

1. With what grades did you use the educator guide?
   Number of Teachers/Faculty:
   ______ K-4 ______ 5-8 ______ 9-12 ______ Community College
   College/University - ______ Undergraduate ______ Graduate

   Number of Students:
   ______ K-4 ______ 5-8 ______ 9-12 ______ Community College
   College/University - ______ Undergraduate ______ Graduate

   Number of Others:
   ______ Administrators/Staff ______ Parents ______ Professional Groups
   ______ General Public ______ Civic Groups ______ Other

2. What is your home 5- or 9-digit zip code? __ __ __ __ __ — __ __ __ __

3. This is a valuable educator guide?
   ❏ Strongly Agree ❏ Agree ❏ Neutral ❏ Disagree ❏ Strongly Disagree

4. I expect to apply what I learned in this educator guide.
   ❏ Strongly Agree ❏ Agree ❏ Neutral ❏ Disagree ❏ Strongly Disagree

Fold along line and tape closed.

5. What kind of recommendation would you make to someone who asks about this educator guide?
   ❏ Excellent ❏ Good ❏ Average ❏ Poor ❏ Very Poor

6. How did you use this educator guide?
   ❏ Background Information
   ❏ Demonstrate NASA Materials
   ❏ Group Discussions
   ❏ Integration Into Existing Curricula
   ❏ Lecture
   ❏ Team Activities
   ❏ Critical Thinking Tasks
   ❏ Demonstration
   ❏ Hands-On Activities
   ❏ Interdisciplinary Activity
   ❏ Science and Mathematics Standards Integration
   ❏ Other: Please specify: ____________

7. Where did you learn about this educator guide?
   ❏ NASA Educator Resource Center
   ❏ NASA Central Operation of Resources for Educators (CORE)
   ❏ Institution/School System
   ❏ Fellow Educator
   ❏ Workshop/Conference
   ❏ Other: Please specify: ____________

8. What features of this educator guide did you find particularly helpful?

9. How can we make this educator guide more effective for you?

10. Additional comments:

Today's Date: ____________

EG-2003-10-001-ARC

Please Place
Stamp Here
Post Office
Will Not Deliver
Without Proper
Postage

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
EDUCATION DIVISION
MAIL CODE FE
WASHINGTON DC 20546–0001

Fold along line and tape closed.