Playing With Physics

José G. Tapia
Love Elementary School

INTRODUCTION

Love Elementary is a Title I school with over thirty five percent economically disadvantaged students. The school is located in the Central region of HISD. It has a population of over 400 students from pre-K through 5th grade, of which ninety-five per cent are Hispanic and the rest are white Americans, African-Americans and Asian students. Nearly a half of Hispanic students fall into the LEP (Low English Proficiency) group. About one percent of the entire population belongs to the special education population.

Being a science teacher in elementary school is an interesting experience because children at such a young age are still imbedded in a world of fantasy and believe in some magic behind some everyday physical phenomena; yet, they already have the first skills in logical thinking processes and are well aware that most things in the world around them have an explanation that they could understand. At this age, formal thinking skills are being developed based on two interrelated processes: observation and discovery on one hand, and experimentation and invention on the other.

The focus of this unit is to reveal to the students some of the laws behind everyday physical phenomena by means of experimental activities that lead them to scientific reasoning and explanations.

RATIONALE

This unit has been developed with the dual purpose of making the student apply and learn the scientific method on the one hand and solve some puzzling questions about physical phenomena on the other. The lessons presented here address some concepts that are usually difficult to understand just from reading a text book and are best understood through hands-on activities, covering the objectives mentioned in the previous section in a form that is engaging for the students.

The experiments presented here do not require specialized equipment or materials, and, therefore, can be carried on in any elementary school, regardless of the socio-economic status of the student population or the resources devoted to science activities. The lessons go from simple to more elaborate in both the concepts involved and in the materials preparation from the side of the teacher; nevertheless, they do not need to be presented in such sequence.

The lesson Changing Density focuses on the concepts of density and buoyancy, clarifying the questions of why some things float and some others don't and exemplifying how the density of matter can be changed (increased) by compression. It can also exemplify how matter contains air pockets within itself.

The lesson "Growing with Heat" focuses on the concepts of heat energy, transfer of heat by conduction and expansion of matter due to heat. It exemplifies how heat changes a substance by making it to expand because its molecules are moving more rapidly and, therefore, require more space.

The lesson “Wings: 2X8 is Different from 4X4” focuses on the concepts of variable and constants which, even if they may seem simple to us, are hard to grasp for the students of this age; it will also show the effect of drag depending on the distribution of the wing area. This lesson is particularly suitable for practicing the steps of an experimental investigation by, among other things, using models, making repeated trials, collecting data, analyzing data, obtaining average results, and drawing conclusions.

The lesson “Changes in Air Flow” will help the student to understand the air as a fluid by making an air flow visible, and by showing how it “goes around” objects, as well as showing the disturbances that different shapes can bring to its flow. It will also serve to demonstrate the lesser density of hot gases as compared to cooler gases, which is directly connected to the physics of the air masses that affect our weather and climate.

OBJECTIVES

Through this unit the students will investigate some phenomena through experimental activities in the field of physics. Leading the students to apply the scientific method is a key part in this unit because it is in elementary school where they receive the foundations of such practice. The objectives covered through this unit are listed below; and the corresponding Texas Essential Knowledge and Skills (TEKS) district numeration, also referred to as student expectations, are provided in parenthesis.

1. Define a scientific question and plan an investigation in order to answer it (5.2 A).
2. Use models in order to investigate a physical phenomenon (5.3 C).
3. Investigate the effect of modifying one variable in the experiment (5.5 B).
4. Collect data from the experimental activities (5.2 B).
5. Analyze the data from experimental activities (5.2 C).
6. Repeat an experiment in order to increase the reliability of the results (5.4 B).
7. Communicate valid conclusions after the results from the experiment (5.2 D).
8. Identify and understand some changes in the physical properties of matter (5.7 C).

UNIT BACKGROUND

Lesson One. Changing Density

For children, the fact that something floats or sinks in water is just a given, but when you ask them the “why?” many of them just don’t know, whereas for some others it is because of the weight of the objects: light objects float whereas heavy objects sink. But if you show them that a light paper clip sinks whereas a much heavier wooden cube floats, their answer turns invalid.

Things float or sink because they are less or more dense than, in this case, water, but, how can we explain density to our students?

Density is the result of two properties of matter combined: that is, mass and volume. Density is the mass of an object divided by its volume, often measured as grams per milliliter or as kilograms per liter, although it can also be measured as grams per cubic centimeter. Water (at 4 degrees Celsius and at sea level) has a density of 1 gram per cubic centimeter.

It is important to teach the students that all matter has spaces between its molecules, and may be necessary to explain to them that molecules are particles so small that they cannot be seen even with a microscope, and that these molecules are the smallest building blocks of the material or substance we have in hand; if we break the molecules, we are changing the material itself. As molecules are so small, so the spaces between them are.

It is relatively simple to change the density of a gas or combination of gases by mechanically compressing or expanding it, as for example when we play with the air inside a syringe, but it is not so often that we can mechanically change the density of a liquid or a solid. A material that can be used to illustrate a change in density by mechanical compression is bread soft crumb. The demonstration consists in taking two equal sized pieces of crumb and a cup of water. When we put the crumb in water it floats, but when we crush the crumb in our fingers up to its minimum size or volume, it sinks. As mentioned before, it is indeed an illustration, because the reason the crumb floats is because it is full of air bubbles whereas when we compress the crumb we are squeezing the air out. Nevertheless, it is a fact that the overall density of the regular crumb is less than that of water, and that of the compressed crumb is higher.

Lesson Two. Growing With Heat

After lesson one, we are ready to learn something else about density: it can be changed not only by mechanical compression or expansion, but also by adding or subtracting heat. This is well known and easily seen in gases, as it happens in rubber balloons under hot or cold temperatures, and also in liquids, as seen in thermometers, but it is not so readily observable in solids: this lesson is designed in order to show that.

This demonstration comes from a failed attempt to make a neutral buoyancy toy submarine which consisted of a piece of candle with a penny inside. The wax was “shaved” or trimmed until it barely floated in water, therefore being just slightly denser than the water in which it floated. Next I warmed the water up under the assumption that warm water would become less dense than before and less dense than the submarine and the submarine would sink, but it didn’t. Then I shaved more wax out of the candle until it started to sink and once it reached the bottom, I let the water to cool down in the hope that by becoming denser than the submarine, it will surface again. I was puzzled when it didn’t happen as expected. After trials and errors I realized that when I warmed the water up, the submarine surfaced, and when I cooled the water down, it sank.

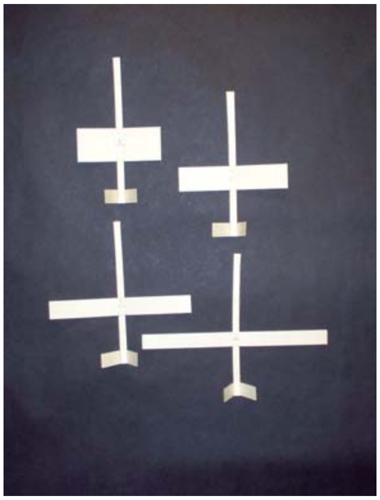
What indeed happens is that the heat in the water is transferred by conduction to the wax and it expands at a higher rate than water, and the submarine surfaces, whereas when the water cools down the wax contracts at a higher rate that water and it sinks. In order to perform this demonstration the teacher or the students must carefully trim the wax to the point at which the submarine barely sinks in water at room temperature, and it will surface even with the warmth of the hands around the container. Adding hot water or ice will make sinking or floating much more immediate.

Lesson Three. Wings: 2 X 8 Is Different From 4 X 4

This experiment, by its quantitative approach, is particularly suitable for practicing the scientific method. Four cardboard airplanes are to be tested, which are identical in every aspect: “V” tail, center of gravity (CG) positioning, total mass (around 2.8 grams) fuselage length (21.5 cm) and wing area (54 cm^2), except for the wing’s length/width ratio as shown in the pictures and table below.

The explanation of such differences is that the too wide (and short) wing of airplane 1 receives the turbulence created by the leading edge at the trailing edge, causing the airplane to loose speed and “dead leaf” stall. At the other end of the spectrum, in airplane 4, a too long wing presents a large frontal air resistance at the leading edge and a huge drag at the trailing edge, making the airplane to nose dive. The best flying characteristics occur somewhere in between both extremes, in this case in airplane 3; the optimum wing configuration and best flight characteristics must be somewhere around this wingspan/wing-width ratio. It is up to the teachers, or the students to experiment and find it!

Templates and instructions for building the airplanes are provided in appendices. Do they fly equally well? If not, which one is the best? Why? The experimental approach will be developed in the lesson plan. The results of their flying characteristics (after my own trials) are provided as teacher background below.



Wing shapes in airplanes 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right).

Front view showing the "V" tail and triangular prism fuselage.

Airplane Nr	Wingspan* in cm	Wing Width in cm	Total Wing Area in cm^2
1	11.39	4.75	54
2	15.18	3.56	54
3	20.66	2.66	54
4	27.00	2.00	54

*The wingspan increases approximately one third from one airplane to the next; the wingspan has been corrected for the fuselage width.

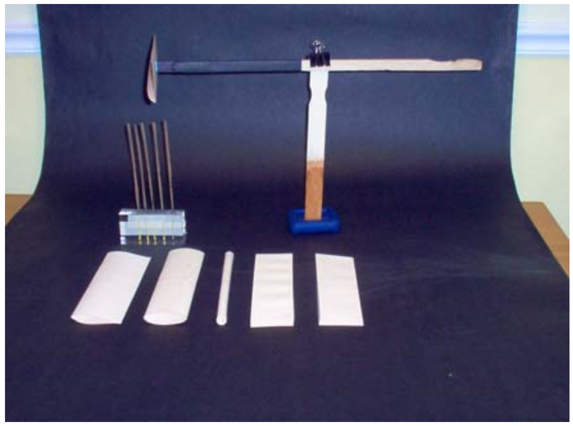
Nr.	Average Distance Flown (m) And Flight Characteristics*
1	Average distance flown: 2.5 meters. "Dead leaf" stalling.
2	Average distance flown: 5 meters. "Wavy" flying, with tendency to stall
3	Average distance flown: 7 meters. Smooth glide with little or no tendency to stall
4	Average distance flown: 1.5 meters. Steep dive.

* Results obtained after my own trials.

Lesson Four. Wing Profile and Air Flow

Air is a fluid and is much more elastic than liquids. This is the very reason why airplanes fly. Indeed, most of the flying is due to lift – the upward force on the lower side of the wing – than because of support under the wing.

One way to actually see the airflow is by building a home-made "wind tunnel," or rather, its equivalent, which posed the first and biggest problem. Several ideas were tried, like using a small fan and chalk powder, but the fan blew the powder out in a cloud. A second idea was to use cigarettes instead of chalk powder, but (apart from the inconvenience of the smell) the smoke was immediately dissipated without showing any airflow lines. A third time I tried to drop chalk powder from a perforated box, but the powder never fell in a continuous stream, and it created too much turbulence and airborne dust as to be useful. The solution was to position the airfoil profiles above a line of burning incense sticks or “smoke maker,” as shown in the set-up pictured below:



The wing profiles were attached (using sticky tack) perpendicular to the horizon to a “T” structure made of two wooden sticks held together by a metal clip. The metal clip allowed the T horizontal beam to be tilted up or down to an angle so as to test different angles of incidence for the wings.

The “smoke maker” line of incense sticks was placed just beneath the wing profile, at a short distance in order to observe the smoke lines flow over both sides of the profile before they broadened and dissipated.

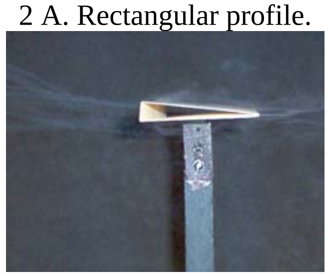
Six basic profile shapes were constructed using stock card. They were tested for linear (smooth) or turbulent airflow. The results are shown below. For convenience, the pictures are shown horizontally and the air flow going from left to right.

Turbulent airflow at the trailing edge is observed for the round and rectangular profiles (1, 2A, and 2B), as well as for the triangular profile when its base is at the trailing edge (3A). On the other hand, laminar airflow occurs as the air leaves the trailing edge for the double and single airfoil shapes (5A and 6A), as well as for the triangle when its tip is at the trailing edge (3B).

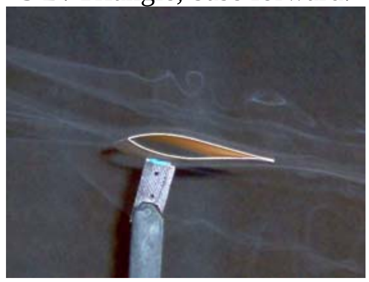
1. Round profile.

2 A. Rectangular profile.

2B Rectangle perpendicular



3 A. Triangle, tip forward. 3 B. Triangle, base forward. 4 A. Oval


4 B. Oval, perpendicular. 5 A. Double airfoil. 5 B. Double airfoil nose up.



6 A. Single airfoil. 6 B. Single airfoil nose up. 6C Single airfoil nose down

The turbulence can be understood if we visualize the air being split into two "sheets" as it hits the leading edge, but later, when the two sheets reach the trailing edge they meet an abrupt ending, finding a "void" to be filled up. This creates turbulence in the form of eddies and induces drag. On the other hand, for the shapes showing laminar airflow, what happens is that the air sheets flow along the upper and lower surfaces until they reunite at the trailing edge smoothly. But even airfoil profiles can create turbulence if their angle of attack, or angle at which the profile meets the airflow, is too pronounced as can be seen in pictures 5B, 6B, and 6C.

The oval profile produces airflow almost as laminar as the airfoil profiles, but there is a small "pocket" of still air behind it as can be seen in picture 4A; when the oval profile is perpendicular to the airflow (4B), it is as turbulent as the perpendicular rectangle (2B).

And now, why do airplanes fly? An airplane wing has generally a teardrop shaped, more pronounced curvature at the top surface and a less pronounced one in the under side. The amount of air that starts its flow and is split in two at the leading edge is the same amount of air that must leave at the trailing edge; therefore, the sheet of air that flows on the top surface has a longer distance to go through than the air in the surface under, and so, the first must flow faster – and stretch itself – in order to reach end of the wing simultaneously with the lower sheet of air. Both the higher speed of the airflow and its stretching (or rarefaction) create a lower air pressure as compared to the air flowing at the under side of the wing. This phenomenon was first explained by Bernoulli through his equation which demonstrates that "the particular path that a volume of fluid takes is called a streamline, and the energy-per-volume of fluid along a streamline is constant" (Bloomfield 155):

$$\frac{\text{energy}}{\text{volume}} = \frac{\text{pressure potential energy}}{\text{volume}} + \frac{\text{kinetic energy}}{\text{volume}}$$

$$= \text{pressure} + \tfrac{1}{2} \cdot \text{density} \cdot \text{speed}^2$$

$$= \text{constant } (\textit{along a streamline}) \qquad \text{(Bloomfield 155)}$$

This is finally what creates the airlift that make possible for an airplane to fly. Finally, it must be clarified that for paper airplanes like the ones used in this unit, airfoil is not critical as it is for real airplanes, and they can glide relatively well mainly due to their light weight which enables the under-wing support to have an effect.

LESSON PLANS

Lesson 1. Changing Density

Objectives

5.2 A. Define a scientific question and plan an investigation in order to answer it.
5.5 B. Investigate the effect of modifying one variable in the experiment.
5.2 D. Communicate valid conclusions after the results of the experiment
5.7 C. Identify and understand some changes in the physical properties of matter

Introduction

Have you ever wondered why some materials sink and some others float in water? It is certainly not because of their weight as is commonly (and erroneously) assumed because a heavy tree trunk will float in a lake, whereas the small pebble you throw will sink. The answer is density.

Concept Development

Density is the amount of mass in a known volume of an object or substance (Kellman, et al. 245). An easy rule of thumb, let's say that all objects float if they are less dense than water (like wood of Styrofoam) and all objects sink because they are more dense (denser) than water (like stones or metals), regardless of their size and weight. In this experiment you will be able to change the density of a solid by compressing it with your hands and experience its change in density by seeing it floating or sinking.

Student Practice

<u>Materials</u>

- Two sandwich white bread slices (do not use the very first and last slices)
- Hand lens
- Scissors or cookie cutters
- Double pan balance
- Bowl filled with water, wide and deep enough to accommodate the bread slice cut-outs.

<u>Procedures</u>

1. Put one bread slice on top of the other; with the scissors cut a square of approximately five centimeters per side from the middle of the bread slices (don't use the edges). You can also use your cookie cutter instead. Both cut-outs must, therefore, be identical in size and shape. Using the double pan balance, verify that they have the same weight. Discard the surrounding bread left over.

2.While keeping one of the bread pieces uncompressed, take the second bread cut out and using your fingers compress it (crush it) more and more until you can shape it like a small cube or sphere (the shape is not critical in itself, but it helps you to prevent crumbs from falling loose). Using the hand lens observe the differences between both bread pieces. Using the double pan balance check them again.

3. Take the uncompressed bread and sit it flat on the water. Then take the compressed piece of bread and sit it on the water beside (not on top) of the first one.

NOTE: Watch that both bread slices are free of holes, as this can make a difference in the mass of the bread pieces.

Assessment

Make a drawing of the experiment with labels. Answer the questions:

Are both, uncompressed and compressed pieces the same weight? Why?
What is the difference in both bread pieces when you observe them with the hand lens?
What happens to the uncompressed and compressed bread in water?
Which bread is less dense than water and which is more dense?

Closure

Density is different from weight because in density you are dealing with a property of matter, whereas weight depends on the object. If matter becomes more compact, it increases in density, and that is why the same amount of material (in this case bread) changed from less dense to more dense than water when the volume was reduced.

Resources

Houston Independent School District. *Project Clear Curriculum, Grade 5 Science, Unit 5: What's the Matter?*
Moyer, Richard, et al. *Science (5th grade)* pp 295 – 299.

Lesson 2. Growing with Heat

Objectives

5.2 A Define a scientific question and plan an investigation in order to answer it.
5.2 D Communicate valid conclusions after the results from the experiment.
5.3 C Use models in order to investigate a physical phenomenon.
5.7 C Identify and understand some changes in the physical properties of matter.

Introduction

How can you notice if something actually grows or shrinks with temperature changes? You can make a toy submarine that responds to the temperature in the surrounding water. The principle behind is that all mater expands (grows) with the addition of heat, and contracts (shrinks) with the loss of heat.

Concept Development

The molecules that make matter are not perfectly still, rather they move (vibrate) in place; they have a certain kinetic energy. So, as heat is a form of energy, if you heat matter, you are providing energy to the molecules, or increasing their kinetic energy, and they will move more, taking more space and, therefore, making the object expand.

When matter expands with heat, its density changes because you have the same mass (as before adding heat) spread in a larger volume. Using common tools and instruments, this change in density is not measurable, or even noticeable, for most of the materials. Nevertheless, if you use objects whose density is slightly higher than that of water, you can observe it floating or sinking as it gains or loses heat.

Student Practice

<u>Materials</u>

- One penny
- Two tea candles (1 ½ inch diameter X ½ inch tall)
- A small paper cup (2 ounces is the best size, but other sizes are useful too).

- A plastic knife
- Hot plate
- A clear plastic container, approximately 1 L capacity.
- Water (approximately four liters or one gallon)
- A 250 ml heat-resistant beaker for heating water
- Iced water
- One thermometer

<u>Procedure</u>

1. Take the candles out of their aluminum tins and remove the wick and metal roundel to which the wick is attached. Put one candle in the paper cup and place the penny on top of it. Put the other candle inside its aluminum tin and put it to melt on the hot plate.

2. Pour the melted wax on top of the candle with the penny inside the paper cup, so as to bury the penny in wax. Make sure you don't lose any wax as this is just a little more than the exact amount of wax we need. (You can speed up the cooling down of the wax by putting the paper cup in a water bath).

3. Fill your cut plastic bottle to a half with water at room temperature and put your submarine in it. Your submarine must barely float. NOTE: sometimes the submarine stays on the surface by surface tension. In order to make sure that the submarine is not "hanging" on top by surface tension, give it a gentle push down the water; it must come up slowly. If it sinks, dry it and add melted wax until it stays afloat.

4. Now comes the delicate part of the experiment. Once you have your submarine barely floating, carefully trim off some wax (little by little) with the plastic knife until it barely sinks (this may take several trials). Again, every time you put it in the water, check that it does not "hang" on top by surface tension.

5. Now your submarine is ready to emerge and will submerge by itself: with the submarine in the bottom of the plastic bottle filled up to a half with water, add hot water – at a temperature between 50 or 60 degrees Celsius – to the container up to three quarts of its capacity. Observe the submarine surface after a couple of minutes. If you wait for enough time for your water to cool down to room temperature, you will see your submarine submerge; you can avoid waiting so long if you add ice cubes to the water.

Assessment

1. Make a drawing of the submarine in cold and in hot water. Answer the questions:
2. What is the effect of cold water on the volume and density of the wax?
3. What is the effect of hot water on the volume and density of the wax?
4. Between the water and the wax, which one changes its volume and density more with the temperature changes?
5. Oceans have hot and cold water currents: Which one do you think is at the bottom and which at the surface?

Closure

Objects expand or contract depending on temperature: heat makes them grow and the loss of heat makes them shrink. Changing volume means changing density and in cases where the density is close to that of water, floatability can shift from negative to positive floatability. By adding or losing heat, you change several of the physical properties of matter. This is the secret behind the submarine you just built.

Resources

Houston Independent School District. *Project Clear Curriculum, Grade 5 Science, Unit 5: What's the Matter ?*
Moyer, Richard et al. *Science (5th grade)* pp 375-377.

Lesson 3. Wings: 2X8 is Different from 4X4

Objectives

5.2 A Plan and implement descriptive and simple investigations, including asking well-defined questions, formulating hypotheses.
5.2 B Collect information by observing and measuring.
5.2 C Analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
5.2 D Communicate valid conclusions.
5.4 D Demonstrate that repeated investigations increase the reliability of the results.

Introduction

The title may be puzzling, but somehow it is true. Have you ever wondered why airplanes and gliders do not have the wings shorter and wider, or longer and thinner? In this experiment you will test these questions.

Concept Development

Airplanes and gliders have a specific wing area depending on several characteristics like total mass (weight), expected cruise speed or – in the case of motorized airplanes – engine power. The wing area is the length or wingspan times the width or cord. But in flight, some proportions work better than others even though the area is the same (like the title suggests); so there is an optimum ratio length/width, or wingspan/cord. The purpose of this experiment is to find the best ratio wingspan/cord for a wing by measuring the distance flown by gliders with different wings, whereas all the other characteristics remain the same, and searching an explanation of these results.

In this lesson four gliders are used, all with a wing area equal to 54 square centimeters, but each with a different wingspan/chord ratio (from short and thick to long and thin), and, as mentioned above, all other characteristics of the gliders are identical: fuselage shape and length of 21.5 cm, V tail configuration total mass of 2.8 grams and center of gravity of the glider; these are your constants. So, the independent variable, the wingspan/cord ratio must be tested in a scientific way, and the dependent variable or results, the distance flown in meters, must be carefully recorded and presented in order to draw valid conclusions.

Student Practice

<u>Materials</u>

- Glider construction instruction and templates
- Ruler
- Scissors
- Glue

<u>Procedures</u>

1. Build the four gliders according to the instructions and templates provided by the teacher. Be neat during construction, as a straight glider will make good flights.
NOTE: It is recommended to build the gliders before the lesson.

2. Now that you can see them, make a prediction on which glider will fly the longest and which the shortest distance.

3. The best flying conditions are indoors, because this prevents air drafts interference. Choose one glider for testing. Practice your flights holding your glider slightly behind the center of the wing and throw it straight and horizontal, always with the same hand, from the same place and height and in the same direction. This is known as consistent experimental procedures.

4. Select a glider and throw it consistently at least five times (multiple trials), measure the distance flown at each trial, and tabulate your results. Observe that the distance flown at the five trials falls within a certain range, but in the event that a flight is abnormally short or long, discard (cross out) this or these extreme values from your experiment.

5. Repeat step 3 with the other three gliders.

6. Using the results reported in your table, calculate the average distance in meters flown by each glider.

Assessment

1. Present a table in which you report the wingspan/cord ratio and the average distance flown by each glider.
2. Make a line graph of your results and explain: Which variable goes in the X axis? Which one goes on the Y axis? Why?
3. Was your prediction correct? Why?
4. Which gliders do not perform well? Which have intermediate performance? Why?
5. Which glider flies the longest distance? Why?

Closure

Do you think you can still improve the glider? What will you do to the ratio wingspan/chord? Keep in mind that you cannot modify anything else from the glider, that is, you must keep your constants (wing area, fuselage length, V tail, and total mass). Certainly you can fine-tune the glider, and a good way is testing small variations in the wing ratio around the best known ratio; this is known as trial and error. Try it!

Resources

Lennon, Andy. *Basics of R/C Model Aircraft Design*, pp. 21-24.
Moyer, Richard et al. Science (5th grade), pp. R 11, R 21 and R 23.

Lesson 4. Wing Profile and Air Flow

Objectives

5.2 A Plan and implement descriptive and simple investigations, including asking well-defined questions, formulating hypotheses.
5.2 B Collect information by observing and measuring.
5.2 C Analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
5.2 D Communicate valid conclusions.
5.3 C Use models in order to investigate a physical phenomenon.
5.4 D Demonstrate that repeated investigations increase the reliability of the results.

Introduction

Why do airplanes (and birds) fly? The most immediate answer is “because they have wings” That is true in that without wings even an airplane with a powerful engine would not fly. But the wings of real airplanes and gliders, and of most flying model airplanes, have a special profile that gives them upward lift.

Concept Development

If you could see the cross section of an airplane's (or bird's) wing, you will notice that it is curved like a teardrop on top and flatter in the bottom (airfoil shape). When the airplane is moving forward, the air that passes on top of the wing has a longer distance to go through (because this surface is curved, and longer in comparison with the flatter surface in the bottom), and, therefore, it must flow faster, and when air flows faster, its pressure decreases, creating in this case an upward lift which holds the airplane airborne. This principle was described by a Swiss mathematician named Daniel Bernoulli (1700-1782) (Bloomfield 155).

Thanks to this airfoil shape, the air flows smoothly through the wing, which is known as laminar flow, and it leaves the wing practically without creating turbulence. Turbulence is not desirable because it creates drag, which slows down the airplane, hindering flight. But it must be also said that even the best wing can create turbulence and stop lifting an airplane if its angle of incidence respect to the wind is too big.

In this activity you will be able to test different shapes or wing cross sections, parallel to the air stream and at different incidence angles for laminar flow and for drag, and you will actually be able to see the air flowing through the wing surface and the drag or no-drag at the trailing edge of the wing. Follow your teacher!

Student Practice

NOTE: In order to save time, it is important that the teacher prepares the "wind tunnel," and the students make their wing profiles before the lesson. Apart from the one-sided airfoil shape, the number of wings and their shapes can be determined freely, and they must not necessarily be the ones presented in the teacher background section.

<u>Materials</u>

- Construction paper
- Ruler, regular pencil and one color pencil or marker
- Scissors
- Glue

<u>Procedures</u>

1. Using construction paper build the wing shapes, also called profiles, to be tested. A convenient size for your construction paper is a half of a regular sheet of paper.

2. Before putting the wings on the "wind tunnel," make a drawing of each profile and predict the way the air is going to flow, and if it will create turbulence and where. Trace in pencil the airflow arrows and turbulences (if any) on each drawing. NOTE: for convenience draw your wing profiles horizontally, with the wing leading edge to the left and the wind flowing from left to right.

3. Draw each profile "nose up" and "nose down" (respect to the airflow) at an angle of 45 degrees and predict the way the air is going to flow, and if it will create turbulence and where. Trace in pencil the airflow arrows and turbulences (if any) on each drawing.

4. This step requires still air, so avoid disturbing the air as much as possible. Place the first profile in the wind tunnel (with the smoke makers lit by the teacher) and observe the airflow and turbulence. Modify the incidence angle of the wind, nose up (tilted to the left) and nose down (tilted to the right) by approximately 45 degrees.

5. Repeat the wind tunnel test for every profile you made.

Assessment

Make a small poster showing the different profiles in three positions: horizontal, nose up and nose down, showing both, the predicted and observed airflow and turbulences if any. Use pencil lines for the predicted airflow and color lines for the observed airflow. Answer the following questions:

1. Which shape is the best for an airplane? Why?
2. After the best profile, how would you rank the profiles you tested?
3. When there is drag, where does it appear? Why?
4. Do you observe "pockets" of still air in some of your profiles? Where? Why do you think this happens?

Closure

As you can observe, airfoil shapes provide lift towards the side that is rounded, or more rounded in the wing, and also eliminates turbulence. Because of this property, the airfoil shape is applied not only to the wings, but to all other external structures in the airplane, like the horizontal stabilizers (the small wing-like structures in the tail), the vertical stabilizer, the propeller or turbine blades and the fuselage itself. The difference with the wing profile is that in the fuselage, the airfoil shape is symmetrical. This is known as aerodynamic shape or profile.

As air, water is a fluid and the same airfoil shape applies to the parts of boats and ships that are submerged, and of course to the entire shape of submarines, but in this case it is called hydrodynamic shape or profile, by which the resistance to moving forward is diminished.

Resources

Rogers, Kirsteen, et al. *The Usborne Internet-Linked Science Encyclopedia. 2002*, pp 142-143.
http://en.wikipedia.org/wiki/Bernoulli

APPENDICES

Appendix 1: Texas Essential Knowledge and Skills (TEKS)

5.2 A. Plan and implement descriptive and simple investigations, including asking well-defined questions, formulating hypotheses, and selecting and using equipment and technology.
5.2 B. Collect information by observing and measuring.
5.2 C. Analyze and interpret information to construct reasonable explanations from direct and indirect evidence.
5.2 D. Communicate valid conclusions.
5.3 C. Represent the natural world using models and identify their limitations.
5.4 B Demonstrate that repeated investigations increase the reliability of the results.
5.5 B. Describe some interactions that occur in a simple system.
5.7 C. Identify changes that occur in the physical properties of the ingredients of solutions such as dissolving sugar in water.

Appendix 2: Glider Construction Instructions

Photocopy the templates in tag mark cardboard, or any cardboard with the thickness of regular folders. Neat construction of the gliders is important in order to get best glides and obtain reliable results. The templates come as two pages, one for the fuselages and the other for the wings, V tails, and nose weights.

Fuselage: Each fuselage strip is made of four one-centimeter wide bands. Cut the fuselage strip and score along the lines; then fold the lines and make a triangular prism (not a squared prism) by overlapping and gluing the fourth band over the first band.

Tail: Cut the tail piece and fold it in V along the center line. Glue it at the end of the fuselage marked “tail,” making sure that both edges (fuselage end and V tail trailing edge) match in order to not affect the center of gravity of the glider.

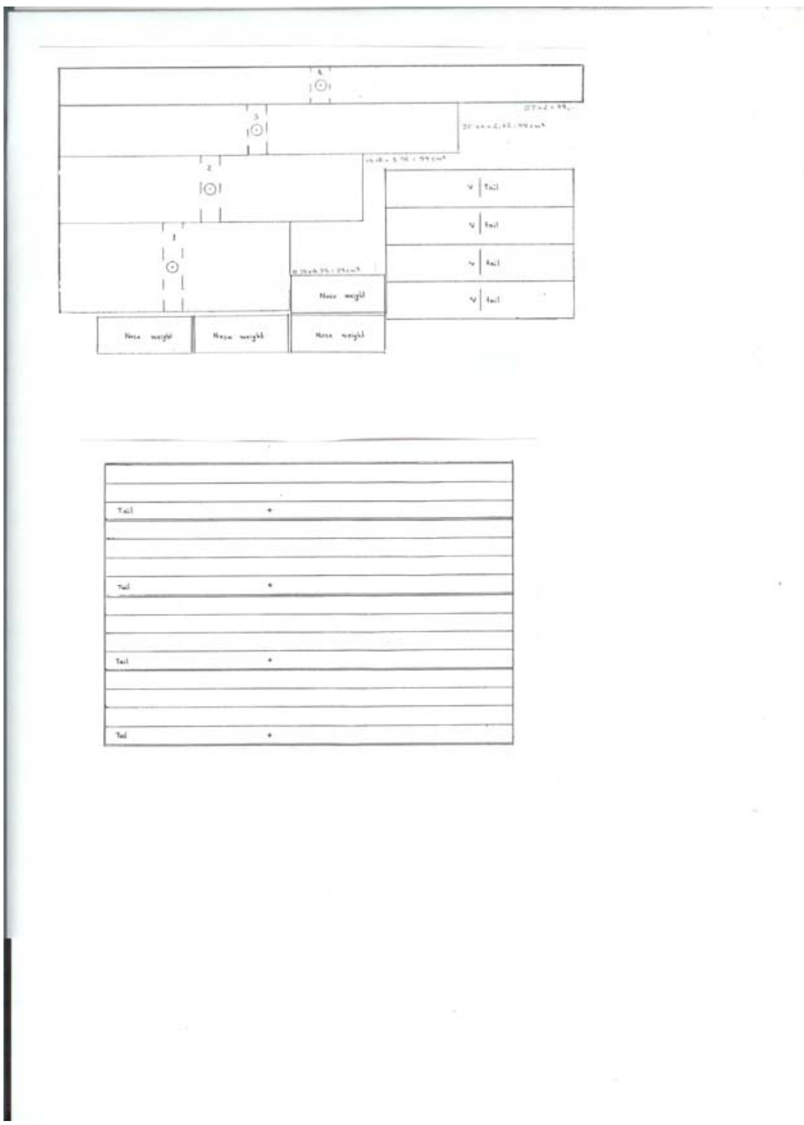
Wing: Cut one wing and punch a hole where the circle at the center of the wing is located; this is the center of gravity of the wing. Glue the wing on top of the center of gravity of the fuselage, indicated by the cross in the C + G mark, or in other words, overlap the hole with the cross. Use the broken lines on the wing in order to position them perpendicular to the fuselage.

Nose weight: Cut one strip marked “nose weight,” roll it, and insert it (no glue needed) inside the nose of the glider, matching both edges.

Repeat the assembly steps for the other three gliders.

Appendix 3: Glider Templates

The templates provided below were reduced for convenience; therefore, you must enlarge them a 200 % in order to obtain the original dimensions of the glider parts.



ANNOTATED BIBLIOGRAPHY

Works Cited

"Bernoulli, Bernoulli's Principal." *Wikipedia*. April 13, 2008. <http://en.wikipedia.org/wiki/Bernoulli>.
General consultation site in which a vast number of articles, pictures and animations can be found on scientific and other kind of topics. The information presented is up-to-date and at different grades of depth.

Bloomfield, Louis. *How Things Work: The Physics of Everyday Life*. New York: John Wiley & Sons, Inc. 1996.
This book explains most of the physical phenomena and laws providing explanations in common sense language as well as formulae. It is really useful for the both, the middle or high school students, as well as for the general public.

Houston Independent School District. *Project Clear Curriculum, Grade 5 Science, Unit 5: What's the Matter? And Unit 7: N-R-G*. Houston: HISD, 2003.
They contain the lessons outline, prompts and questions, vocabulary, hands-on activities and resources to be used when teaching the subjects of matter and energy respectively.

Kellman, Kathy, *et al* (editors). *Sciencesaurus*. Wilmington, MA: Great Source Education Group Inc, Houghton Mifflin Company, 2005.
Elementary science condensed encyclopedia, excellent illustrations; very useful in understanding and presenting information in a succinct way.

Lennon, Andy. *Basics of R/C Model Aircraft Design: Practical Techniques for Building Better Models.* Wilton, CT: Air Age Media, 1996.

Moyer, Richard et al. *Science (5th grade)*. New York: McGraw Hill, 2000.
Text book for science, fifth grade. It develops the concepts introduced in the fourth grade level edition and presents new ones, as well as definitions and laboratory experiments suitable for science at such grade level.

Rogers, Kirsteen, et al. *The Usborne Internet-Linked Science Encyclopedia*. London: Usborne Publishing Ltd. 2002.
Elementary to middle school level, contains multiple illustrations; explains over 2,500 terms; useful for presenting complex concepts in simple words.

Supplemental Resources

Barnhart, Robert. *The American Heritage Dictionary of Science*. Boston: Houghton Mifflin Company, 1986.
Useful resource for precise definition of scientific terms in all fields. 16000 entries.

Churchill, E. R., L. V. Loeschnig, and M. Mandell, *730 Easy Science Experiments with Everyday Materials*. New York: Tess Press, Black Dog & Leventhal Publishers Inc. 1997.
The book covers all subjects in the elementary science curriculum through simple hands-on activities, explaining in diagrams and text, for each one of the experiments, the what to do, what happens, why and what next.