STEM Curriculum Planning Guide

This instructional design guide serves as the template for the design and development of STEM units of instruction at the Dayton Regional STEM Center in Dayton, Ohio. The guide is anchored to the *STEM Education Quality Framework* also developed at the Dayton Regional STEM Center.

STEM Unit Title	**Nature of Flight**
Economic Cluster	Air Vehicles
Targeted Grades	5, 6, 7, 8
STEM Disciplines	Science Technology Engineering Mathematics
Non-STEM Disciplines	English Language Arts

Section I: STEM Unit Overview

Unit Overview

The lesson focuses on how the principles of flight are demonstrated in nature and how nature can provide models for man-made air vehicles. Mankind has learned (and is learning) a great deal by observing living organisms in attempt to replicate their physical abilities. The intent of this lesson is to leverage the students' interest and appreciation of nature, to introduce the physics involved with flight, as well as the engineering design process.
The introduction will involve a multimedia presentation featuring various living things in flight. Examples include: A flying tree squirrel gliding from one tree to another, an albatross flying on an extremely long flight, an eagle plucking a trout out of a stream, an owl swooping down to snatch a field mouse, a hummingbird and/or a bumble bee flying at tremendous speeds with frequent quick turns, a maple seed "whirlybird", etc.
Students complete a series of inquiries in order to gain a deeper understanding of the principles of flight as they make connections between living organisms and man-made air vehicles.
After the students have connected form and function of natural systems with the structure and motion of different air vehicles, they will design an air vehicle to meet certain specifications. Students will work in design teams to engineer, test, and redesign their air vehicles in order to meet specifications for speed, distance, duration, height, etc.

Essential Question

How can natural flight inform the design of air vehicles for specific functions?

Enduring Understanding

Biomimicry can be used to model the characteristics, adaptations, form, and function of living things to create innovative solutions to problems.

Engineering Design Challenge

Students become engineers, selected to design gliders for use in surveillance. Each team must design a glider based on biomimicry of influences from nature and other individual parameters. Teams of students work collaboratively to research, design, plan testing methods, hypothesize, test, and redesign their aircraft.

Time and Activity Overview

Day	Time Allotment	Actvities
1	50 minutes	Pre test Video Hook Pre activity discussion Air Resistance (short activity)
2	50 minutes	Lift and Bernoulli's Principle (short activity) Camber and Lift (short activity)
3	50 minutes	Angle of Attack (short activity) Drag (short activity)
4	50 minutes	Design, Build, Test Redesign, Test
5	50 minutes	Complete Redesigns, Test Post Activity Discussion Prepare Presentations
6	50 minutes	Finish Presentation Preparation Presentations
7	50 minutes	Post Test

Pre-requisite Knowledge & Skill

Students should understand that there are structural differences between living things “in flight” and man-made aircraft.

Students should be familiar with calculating the area of regular shapes.

Students should have a basic understanding of the 4 main principles of flight: lift; weight; thrust; and drag.

Students should understand that many species of plants and animals have adapted to their varied environments to enhance their chances for reproduction and survival.

Students should be able to make predictions and be able to support their predictions with scientific reasoning.

Students should be able to make and carefully record scientific observations.

Academic Content Standards

Add Standard	Mathematics	Ohio
Grade/Conceptual Category	8	
Domain	Statistics and Probability	
Cluster	Investigate patterns of association in bivariate data.	
Standards	2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.	

Add Standard	Mathematics	Ohio
Grade/Conceptual Category	7	
Domain	Ratios and Proportional Relationships	
Cluster	Analyze proportional relationships and use them to solve real-world and mathematical problems.	
Standards	1. Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. For example, if a person walks 1/2 mile in each 1/4 hour, compute the unit rate as the complex fraction 1/2/1/4 miles per hour, equivalently 2 miles per hour.	

Add Standard	English Language Arts	Ohio
Grade	8	
Strand	Writing	
Topic	Research to Build and Present Knowledge	
Standard	7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	

Add Standard	English Language Arts	Ohio
Grade	8	
Strand	Speaking and Listening	
Topic	Comprehension and Collaboration	
Standard	1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. a. Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion. b. Follow rules for collegial discussions and decision-making, track progress toward specific goals and deadlines, and define individual roles as needed. c. Pose questions that connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas. d. Acknowledge new information expressed by others, and, when warranted, qualify or justify their own views in light of the evidence presented.	

Add Standard	English Language Arts	Ohio
Grade	8	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. 5. Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	

Add Standard	English Language Arts	Ohio
Grade	7	
Strand	Writing	
Topic	Research to Build and Present Knowledge	
Standard	7. Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.	

Add Standard	English Language Arts	Ohio
Grade	7	
Strand	Speaking and Listening	
Topic	Comprehension and Collaboration	
Standard	1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacherled) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly. a. Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion. b. Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed. c. Pose questions that elicit elaboration and respond to others' questions and comments with relevant observations and ideas that bring the discussion back on topic as needed. d. Acknowledge new information expressed by others and, when warranted, modify their own views.	

Add Standard	English Language Arts	Ohio
Grade	7	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	4. Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation. 5. Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.	

Add Standard	English Language Arts	Ohio
Grade	6	
Strand	Writing	
Topic	Research to Build and Present Knowledge	
Standard	7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.	

Add Standard	English Language Arts	Ohio
Grade	6	
Strand	Speaking and Listening	
Topic	Comprehension and Collaboration	
Standard	1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacherled) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. a. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion. b. Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed. c. Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion. d. Review the key ideas expressed and demonstrate understanding of multiple perspectives through reflection and paraphrasing.	

Add Standard	English Language Arts	Ohio
Grade	6	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	4. Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. 5. Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.	

Add Standard	English Language Arts	Ohio
Grade	5	
Strand	Writing	
Topic	Research to Build and Present Knowledge	
Standard	7. Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.	

Add Standard	English Language Arts	Ohio
Grade	5	
Strand	Speaking and Listening	
Topic	Comprehension and Collaboration	
Standard	1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacherled) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly. a. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion. b. Follow agreed-upon rules for discussions and carry out assigned roles. c. Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others. d. Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.	

Add Standard	English Language Arts	Ohio
Grade	5	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	4. Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. 5. Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.	

Add Standard	Social Studies	Ohio
Grade		
Theme		
Strand (pk-8 only)		
Topic		
Content Standard		

Add Standard	Science	Ohio
Grade	8	
Theme	Order and Organization	
Topic	Forces and Motion	
Content Standard	Forces between objects act when the objects are in direct contact or when they are not touching. -Magnetic, electrical and gravitational forces can act at a distance. Forces have magnitude and direction. -The motion of an object is always measured with respect to a reference point. -Forces can be added. The net force on an object is the sum of all of the forces acting on the object. The net force acting on an object can change the object's direction and/or speed. -When the net force is greater than zero, the object's speed and/or direction will change. -When the net force is zero, the object remains at rest or continues to move at a constant speed in a straight line. There are different types of potential energy. -Gravitational potential energy changes in a system as the masses or relative positions of objects are changed. -Objects can have elastic potential energy due to their compression or chemical potential energy due to the nature a and arrangement of the atoms that make up the object.	

Add Standard	Science	Ohio
Grade	7	
Theme	Order and Organization	
Topic	Cycles of Matter and Flow of Energy	
Content Standard	In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors. -The variety of physical (abiotic) conditions that exists on Earth gives rise to diverse environments (biomes) and allows for the existence of a wide variety of organisms (biodiversity).	

Add Standard	Science	Ohio
Grade	6	
Theme	Order and Organization	
Topic	Matter and Motion	
Content Standard	There are two categories of energy: kinetic and potential. -Objects and substances in motion have kinetic energy. -Objects and substances can have energy as a result of their position (potential energy). An object's motion can be described by its speed and the direction in which it is moving. -An object's position and speed can be measured and graphed as a function of time. -Note 1: This begins to quantify student observations using appropriate mathematical skills.	

Add Standard	Science	Ohio
Grade	6	
Theme	Order and Organization	
Topic	Cellular to Multicellular	
Content Standard	Living systems at all levels of organization demonstrate the complementary nature of structure and function. -The level of organization within organisms includes cells, tissues, organs, organ systems and whole organisms. -Whether the organism is single-celled or multicellular, all of its parts function as a whole to perform the tasks necessary for the survival of the organism. -Organisms have diverse body plans, symmetry and internal structures that contribute to their being able to survive in their environments.	

Add Standard	Science	Ohio
Grade	5	
Theme	Interconnections within Systems	
Topic	Light, Sound and Motion	
Content Standard	The amount of change in movement of an object is based on the mass of the object and the amount of force exerted. -Movement can be measured by speed. The speed of an object is calculated by determining the distance (d) traveled in a period of time (t). -Earth pulls down on all objects with a gravitational force. Weight is a measure of the gravitational force between an object and the Earth. -Any change in speed or direction of an object requires a force and is affected by the mass* of the object and the amount of force applied.	

Add Standard	Science	Ohio
Strand		
Course Content		
Content Elaboration		

Add Standard	Fine Arts	Ohio
Grade		
Subject		
Standard		
Benchmark		
Indicator		

Add Standard	Technology	Ohio
Grade	8	
Standard	Design	
Benchmark	C: Understand and apply research, innovation and invention to problem-solving.	
Indicator	1. Explain the design axiom that form follows function. 3. Describe how invention is a process of turning ideas and imagination into devices and systems; and innovation is the process of modifying an existing product or system to improve it. 4. Evaluate a variety of creativity-enhancing techniques.	

Add Standard	**Technology**	
Grade	7	
Standard	Design	
Benchmark	C: Understand and apply research, innovation and invention to problem-solving.	
Indicator	1. Explain that understanding the function of an object requires a higher level of thinking than focusing on the object itself. 3. Describe and complete an experiment to evaluate the solution to a problem. 4. Evaluate the credibility and applicability of information obtained to address a specific problem (e.g., what measurements should be used to build a chair or a piece of clothing?; are they based on the prospective customers?).	

Add Standard	**Technology**	
Grade	6	
Standard	Design	
Benchmark	C: Understand and apply research, innovation and invention to problem-solving.	
Indicator	1. Examine how troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system (e.g., if after installing a switch in a circuit the light does not come on, how would you determine the problem?). 3. Recognize the patterns of the technological evolution of an invention (e.g., steam engines were invented, went through a period of rapid improvement, followed by a period of fine tuning and eventually were replaced by diesel/electric technology). 4. Modify an existing product or system to improve it (e.g., something to improve storage in your locker).	

Add Standard	**Technology**	
Grade	5	
Standard	Design	
Benchmark	C: Understand the role of troubleshooting in problem-solving.	
Indicator	1. Show that invention and innovation are creative ways to turn ideas into real things (e.g., provide examples of multiple solutions to the same problem—many models of cars, varieties of apples, chess set figures).	

Assessment Plan

What evidence will show that students have acquired the enduring understandings for this STEM unit?

Performance Task, Projects	Principals of Flight Short Inquiries Design Challenge
Quizzes, Tests, Academic Prompts	Pre/Post-Test
Other Evidence (e.g. observations, work samples, student artifacts, etc.)	Principles of Flight Inquiry Responses Design Challenge Rubric
Student Self- Assessment	Design Challenge Rubric

Technology Integration

ADISC Technology Integration Model*

	Type of Integration	Application(s) in this STEM Unit
A	Technology tools and resources that support students and teachers in ***adjusting, adapting, or augmenting*** teaching and learning to meet the needs of individual learners or groups of learners.	Internet Research of Flying Organisms
D	Technology tools and resources that support students and teachers in ***dealing effectively with data***, including data management, manipulation, and display.	Stopwatch
I	Technology tools and resources that support students and teachers in conducting ***inquiry***, including the effective use of Internet research methods.	Bioimicry Videos Internet
S	Technology tools and resources that support students and teachers in ***simulating*** real world phenomena including the modeling of physical, social, economic, and mathematical relationships.	Bioimicry Videos Balsa Wood Planes
C	Technology tools and resources that support students and teachers in ***communicating and collaborating*** including the effective use of multimedia tools and online collaboration.	Power Point or Prezi.com
	**The ADISC Model was developed by James Rowley PhD, Executive Director of the Institute for Technology-Enhanced Learning at the University of Dayton*	

Career Connections

Career Description

Aeronautical/ Aerospace Engineers:
study birds, insects, bats and other flying animals to learn and model how they move through the atmosphere. These professionals use their understanding of the physics of flight to help design air vehicles capable of varying tasks.

Mechanical Engineers:
are concerned with performance requirements for machines and vehicles. In-depth understanding of material properties such as tensile strengths allows these professionals to brain-storm, test, and redesign, new technologies necessary for air vehicles to achieve cutting-edge challenges.

Section II: STEM Lesson Plan

Title of Lesson

Day 1: Pre-Test and Air Resistance Inquiry

Time Required

50 minutes

Materials

Appendix A: Pre-Test
Appendix B: Man-Made Vehicles and Living Systems Match Examples
Appendix C: Principles of Flight Inquiry 1: Air Resistance

Objectives

Students will investigate and be able to explain air resistance and its dependence on area.

Instructional Process

Teacher Note:
Principle of flight inquiry student sheets may be completed individually or together with design teams. Pages may be copied for each individual or team and distributed. Or, pages may be projected for the class to view as they work through the investigations. If pages are projected, students may respond in their Science Journals.

1. Administer Pre-test.
2. Display pictures and/or videos of living things "in flight" that highlight design features of man-made aircraft.
3. Group students into design teams of 2-4 students per team. Smaller teams are optimal.
4. Instruct students to look at the pictures and videos of flying organism as they note what each is doing.
   Suggested Videos:
   Human Powered Flight through Mimicry (Video): http://www.youtube.com/watch?v=r4zdaZ_iaCI
   AFRL Video on Micro Air Vehicles: http://www.youtube.com/watch?v=XNENOmI58jM
   Robot Butterfly Means Breakthroughs for Biomimicry in Aviation (Video): http://www.treehugger.com/files/2010/05/flying-mechanical-butterfly-could-mean-new-heights-for-biomimicry-in-aviation.php
5. Ask students how the structure of the organism is related to what it is doing.
6. Have students view pictures of man-made air vehicles and try to match each vehicle with the corresponding living system based on design characteristics/form and function.
7. Ask students to match man-made air vehicle pictures or videos with the living system that has similar characteristics and capabilities and explain their reasoning.
8. Ask students what eventually happens when they throw a ball. (Students should explain that the ball falls because of the gravitational force acting on it, which is the same things as the ball's weight.)
9. Ask the students why a bird and a plane do not fall when they are flying. (Students will say that the wings hold the plane or bird up- they should be lead to think about the wings as part of the plane/bird and as something that needs to be held up too.)
10. Distribute Principles of Flight Inquiry 1: Air Resistance and three half sheets of 8.5x11 paper to each team. Instruct them to crumble the first one up, fold the second one in half, and leave the third one as is. These will represent three various areas.
11. Discuss similarities and differences in the pieces of paper
12. Allow time for students to predict which piece of paper would hit the ground first if you dropped all of them from the same height at the same time. Have them explain their reasons for your prediction.
13. Now have students drop the pieces of paper from the same height at the same time and rank them in order from least to greatest time. Then compare their results to their predictions.
14. Discuss and elicit ideas from the students regarding what causes some pieces of paper to take longer to reach the ground (air resistance).
15. Pose this question to the class for discussion: On what does this force depend? (Depends on the area of the paper- the more area, the more air to push up on the paper, so the larger the force of the air.)

16. After students have done this, instruct them to draw diagrams showing the force of the earth pulling on the paper (the paper's weight) and the force of the air on the paper, as shown below.
*Teacher Note: Students will need this explained to them. The teacher may want to do this together with the class as they discuss how the arrows should look.

*Teacher Note: Students should understand that the arrow for the force of weight should remain the same for each piece of paper since they are all the same size. They only changed the area of the paper, not the weight.

Differentiation

Modify the Pre-Test as necessary to meet the needs of individual students.
Consider homogeneous grouping for this unit, as it allows the teacher opportunity to choose challenge difficulty levels.

Assessments

The Pre-Test should be used as a guide for the teacher to determine unit modifications necessary to meet individual classes.

Discussion

Man-Made and Living System match Activity

Section II: STEM Lesson Plan

Title of Lesson

Day 2: Bernoulli Principle, Camber, and Lift Inquiries

Time Required

50 minutes

Materials

Appendix D: Principles of Flight Inquiry 2: Bernoulli Principle and Lift
Appendix E: Principles of Flight Inquiry 3: Camber and Lift

Objectives

Students will explore and be able to demonstrate lift, camber, and Bernoulli's principle.

Students will investigate and be able to demonstrate how the camber (curve) of an object will affect airflow and that lift is the force exerted by air on an airfoil (wing).

Instructional Process

Principles of Flight Inquiry 2: Bernoulli Principle and Lift:

1. Have students reflect on the video and pictures of birds, animals, and planes.
   Discuss:
   a. How does a bird "take off" from the ground? Can the man in the flying suit do this? Does a plane do this?
   b. How does a plane take off? Watch the video that your teacher shows you and look carefully at the wings and their position as the plane goes down the runway. What do you notice?
2. Distribute Principles of Flight Inquiry 2: Bernoulli Principle and Lift and provide each student a strip of paper (~2"x6")
3. Hold up a strip of the paper from the side and ask students to take note of its shape. Sketch the shape on the board and discuss the forces that act upon it (see: Principles of Flight Inquiry 2: Bernoulli Principle and Lift, Key)
   *Be sure students understand that air is all around us and collides with us all the time. Since air particles are so small, we usually don't feel this unless we're in the wind or near a fan. When the paper is just hanging there, air is pushing on all sides, as well as gravity pulling the paper down (its weight) and you holding it in place. The force of the air on each unit of area of the paper is called air pressure.
4. Instruct students to hold a strip of paper (~ 2"x6") just below their mouth. Challenge them to make the paper go down by blowing over the top of it.
5. Instruct students fold the same piece of paper into a bridge on their desk. Challenge them to blow under it to make the bridge rise.
6. Instruct students put two pieces of paper together. Challenge them to blow between them to make them split a part.
7. Elicit explanations from students for what happened in each challenge.
8. Draw the next picture shown on the Principles of Flight Inquiry 2: Bernoulli Principle and Lift, Key on the board as you elicit explanations from students about why they think the paper was lifted during the first challenge.
   *Be sure students understand that when they blow over the top of the strip, the whole strip moves upward, indicating that the air is pushing up on the paper more than it is pushing down on it. So, the air pressure above the paper is less than the air pressure below it. This is because you blew the air and gave it some speed on the top of the paper.
9. Elicit explanations from the students about why they think they were unable to make the bridge rise.
   *Be sure students understand that when they are blowing air under the bridge the air pressure under the bridge is less, therefore the air pressure above the bridge is pushing down.
10. When you are trying to separate the two papers, you are making the air between them have less air pressure than the air outside of them. Therefore, the air pressure on the outside is greater and pushing them together.
11. Explain to students that what they have witnessed in the three challenges is called Bernoulli's Principle - Air moving at higher speeds has less pressure than air moving at lower speeds.
12. Once students complete the challenges, ask them to explain how forces affect their challenges.

Principles of Flight Inquiry 3: Camber and Lift:

1. Distribute Principles of Flight Inquiry 3: Camber and Lift and ask students to compare the shape of the paper to the shape of an airplane wing. Now compare the shape of a bird's wing in flight to the shape of the paper. Ask: What do you notice? What do you think this shape helps cause?
2. Ask and Discuss: If an airplane is going to "take off" or go upward into the air, the forces on it cannot be balanced- the upward forces have to be bigger than the downward forces. On an airplane, what is the downward force that acts on it? What is the upward force that acts on the airplane?
3. Explain to students that the curve of the airplane wing is called the camber of the wing.
4. Think-Pair-Share: Ask students how they can make the air velocity on the top of an airplane wing higher than on the bottom. Have them discuss their idea with a partner. Then discuss as a class. After the discussion, allow time for them to answer the first question on their student sheet.
5. Test It: Instruct students to build their balsa wood glider or basic plane kit. Then conduct at least three test flights and record their data on the table in the student instructions or on their own created table.
6. Explain that camber is the curve of a wing. Elicit ideas about how this helps a bird or plane fly.
7. Review Bernoulli's Principle.
8. Now students should use what they know about Bernoulli's Principle and camber to redesign their glider for better lift.
   Students should discover that the wing, curved on the top, stays up longer than a flat wing of the same area. This indicates that the wing has more "lift" with the air at the upper surface exerting less pressure on the wing than the air on the lower surface. Due to Bernoulli's effect, this is evidence that the air on top of the wing has a higher speed than the air on the bottom of the wing due to the curved upper surface.
9. In order to connect what they have discover about lift to living organisms and planes, have students complete the questions on the student instruction sheets. With their arrows, they should show that the force of air pressure is greater than the force of weight.
10. Be sure students understand that in both the diagram of the bird taking off and the plane taking off, since they are going to move upward, the force from the air upward must be greater than the weight so that there is a net upward force. This net upward force is the lift force. In both cases, the source of this force is the air. As the bird flaps its wings, it pushes down against the air, so the air pushes back in an upward direction. The air pushing upward on the wing provides the lift force to overcome the bird's weight so it can take off.
    For the airplane, since the top of the wing is curved, as the air moves over and under the wings, the air pressure on top of the wing is less than the air pressure on the bottom of the wing because of the wing's curvature or camber. This means that there is a net force from the air upward, which is the lift force. As the airplane goes faster down the runway, the air pressure on the top keeps decreasing, so the net lift force keeps increasing. When the plane moves fast enough, this lift force will become bigger than the plane's weight, so the plane will go upward and take off.

Differentiation

Data tables included on the appendices may be removed in order to challenge students to create their own method of data collection.

Assessments

Appendix D: Principles of Flight Inquiry 2: Bernoulli Principle and Lift
Appendix E: Principles of Flight Inquiry 3: Camber and Lift

Section II: STEM Lesson Plan

Title of Lesson

Day 3: Angle of Attack and Drag Inquiries

Time Required

50 minutes

Materials

Appendix F: Principles of Flight Inquiry 4: Angle of Attack
Appendix G: Principles of Flight Inquiry 5: Drag
Appendix H: Principles of Flight Inquiry 6: Putting it All Together

Objectives

Students will investigate the effect of the angle of the wing in relation to the relative air flow and understand that this is referred to as the angle of attack.

Students will investigate drag in order to discover that it is the force exerted on a wing or other aerodynamic body and that this force tends to reduce the forward motion of the object.

Instructional Process

Principles of Flight Inquiry 4: Angle of Attack:

1. Distribute Principles of Flight Inquiry 4: Angle of Attack and have students view a plane taking off and a bird taking off. Ask them if they note anything about the orientation of the wing. Students should note that the plane has its "nose up" so that the angle of attack is tipped upward
2. Have students predict the position that they think gives them the best lift. Students should sketch them holding their glider with the nose pointed slightly upward as they prepare for launch.
3. Instruct students to use their gliders from the last activity to test at least three different starting angles. They should record their data on the table provided in the student instructions or create their own.
4. Discuss Angle of Attack.
   *Be sure students understand that the orientation of the wings of a plane with the direction of motion of the plane is called the angle of attack. Zero angle of attack is when the wing is horizontal to the ground when the plane is on the ground. When the angle of attack is zero, all the lift of the plane comes from the camber of the wing and the Bernoulli affect. As the position of the wings is tilted "upward", the lift from the air is increased because of how the air hits the wing.
   There is an optimal (best) angle of attack when a plane is taking off or flying. If you increase the angle of attack too far, the forces from the air don't add to the lift force anymore and the plane either can't take off or "stalls" in the air.

Principles of Flight Inquiry 5: Drag:

1. Distribute Principles of Flight Inquiry 5: Drag and ask students why planes need gas after they have taken off and are already up in the air and flying? To fuel the engines, rockets, or propellers that push it through the air.
2. What is drag?
   Discuss that drag is the force exerted on a wing or other aerodynamic body and that this force tends to reduce the forward motion of the object.

Ask:
What do birds do when they want to go faster? (Recall bird diving for prey) Sweep
What do birds do in flight when they want to go up or down more? Recall tail lift, dip
Why is it difficult for a bird to lift prey and fly with it? More weight so need more lift; difficult to balance
Can birds take off directly upward? Can a man in a flying suit or a flying squirrel take off directly upward? What can take off this way? Helicopter
Why do birds need to flap their wings? To lessen the air pressure since air slows down vehicle/ bird by Drag force
Review:
We've already seen that air can push on things (air pressure), that it can provide a lift force, and that it can resist the motion of an object. Since air is all around us and affects us in every direction, we call forces that are all

caused by the air different things, depending on what the motion of the object is and what the force does. Lift forces are upward and caused by differences in air pressure between the top and the bottom of the object. Resistant forces, like air resistance, are called that because they resist the way the object is moving. So, if the object is moving downward, like the dropped paper, the force of air resistance is upward, opposite the direction of the paper's motion.

3. Ask students what happens when they hold a piece of paper in front of the fan. Which direction does the paper move? Why?
4. Give each design team ½ - 1 stick of modeling clay. Have them explore drag by testing it as instructed on the student instructions sheet.
5. Be sure students understand that the force that the airplane's engines provide is called the thrust of the airplane. The engines push air backward, which makes the air push on the plane forward. The air pushing the plane forward in response to the engines is the thrust. The stronger the engine, the more air it can push, the more the thrust.
6. Instruct them to draw the drag and thrust forces on the diagrams on their student sheet.

Summary of short activities
Students should review the basic forces involved in flight and recognize that forces from the air both cause the plane to stay in the air (lift) and to need thrust to continue forward motion because of resistance. Students may be confused that air can cause two forces in different directions, but should recognize that air is all around us can push in any direction on us. We call the forces "lift" or "drag" relative to which way it is pushing the plane.
Complete the Smithsonian National Air and Space Museum's Forces of Flight interactive individually in a computer lab or as a class projected on a screen. http://www.nasm.edu/exhibitions/gal109/htf/activities/forcesofflight/web/index.html
Complete the Smithsonian National Air and Space Museum's How Wings Work interactive individually in a computer lab or as a class projected on a screen. http://www.nasm.edu/exhibitions/gal109/htf/activities/howwingswork/web/index.html

Principles of Flight Inquiry: Putting it All Together

1. Distribute Principles of Flight Inquiry: Putting it All Together. Students should be able to label the arrows with each type of force on the diagram. After they have labeled each force on the diagram, discuss the forces that oppose each force.

Differentiation

Data tables included on the appendices may be removed in order to challenge students to create their own method of data collection.

Assessments

Appendix F: Principles of Flight Inquiry 4: Angle of Attack
Appendix G: Principles of Flight Inquiry 5: Drag
Appendix H: Principles of Flight Inquiry 6: Putting it All Together

Section II: STEM Lesson Plan

Title of Lesson	**Days 4 and 5: Engineering Challenge: Design, Build, Test, Redesign**
Time Required	110 minutes (2 days)
Materials	Appendix I: Engineering Design Challenge Appendix J: Engineering Design Challenge Rubric

Objectives	Students will use the Engineering Design Process and gained knowledge of lift, Bernoulli's principle, camber, angle of attack, and drag to design an air vehicle using the parameters of their engineering challenge. After testing their design students will redesign to improve their air vehicle.
Instructional Process	1. Provide each design team with the Engineering Design Challenge and Rubric handouts. 2. Instruct students to use common materials to modify the base-airplane design to meet the challenge. Students will need to work collaboratively with their design team to design their aircraft, make a plan to test their aircraft, and hypothesize what the air vehicle's changes in performance will be with design changes. 3. After completing their designing and testing, have students begin work on their presentations as outlined on the Engineering Design Challenge
Differentiation	The teacher may choose to give specific teams of students the more difficult challenges.
Assessments	Engineering Design Challenge Results Engineering Design Challenge Rubric

Section II: STEM Lesson Plan

Title of Lesson	**Day 6 and 7: Presentations and Post-Test**
Time Required	110 minutes (2 days)
Materials	Appendix I: Engineering Design Challenge Appendix J: Engineering Design Challenge Rubric
Objectives	Students will be able to demonstrate understanding of the subject under investigation by presenting a synthesis of their findings.
Instructional Process	1, Instruct students to complete their presentation preparation. 2. Allow time for each team to present. 3. Administer Post-Test.
Differentiation	Modify the Pre-Test as necessary for individually classes or students.
Assessments	Engineering Design Challenge Rubric Post-Test

Section III: Unit Resources

Materials and Resource Master List

* Goggles are recommended for all Inquiry activities involving projectiles.

Pre-Activity Discussion
An overhead or computer projector to share either video or images of both living and man-made things in flight with the class
Student sets of a large variety of pictures of various living things that fly as well as man-made aircraft for sorting and matching.
Ball (optional- to provide visual): Explore and Explain

Design teams should consist of 2-4 students. Smaller teams are optimal.
Principles of Flight Inquiry 1: Air Resistance
3 sheets of 8.5"x11" paper per team
Text book and one sheet of paper the same size as the text book – for teacher
Copies of student instructions

Principles of Flight Inquiry 2: Bernoulli Principal and Lift
3 - 2"x6" strip of paper per person
Copies of student instructions

Principles of Flight Inquiry 3: Camber and Lift
Balsa wood glider or basic plane kit per team
Manila folder - one per group per team
Masking tape
Scissors
Copies of student instructions

Principles of Flight Inquiry 4: Angle of Attack
Gliders used in Inquiry 3
Copies of student instructions

Principles of Flight Inquiry 5: Drag
Electric Fan – one or two per class
Piece of paper
Modeling clay – ½ to a whole stick per team
Transparent, thick liquid – such as glycerin or dish soap
Tall glass cup or graduated cylinder
Stop watch

Engineering Design Challenge
Materials may vary depending on instructor. Some included suggestions:
Per Team of 2-4 students:
Paper
Light Weight Cardboard
Manila Folders
Paper Clips
Straws
Clear Tape
Masking Tape
Styrofoam
Scissors
X-acto Knife
Balsa wood
Pennies (one per team)
Play dough (one gulf ball size per team)
Quarters (one per class)
Egg Cartons (Possible Template: See Appendix J)

Balsa Wood Glider Kits (Possible Template for Balsa or other Mediums: See Appendix II)
Copies of student instructions

Key Vocabulary

Adaptation
a form or structure modified to fit a changed environment.

Air Pressure
the force exerted by air, whether compressed or unconfined, on any surface in contact with it.

Airfoil – any surface, as a wing, aileron, or stabilizer, designed to aid in lifting or controlling an aircraft by making use of the air currents through which it moves.

Angle-of-Attack
angle between the wing and the direction of the relative wind.

Area
the extent of a two-dimensional surface enclosed within a specified boundary or geometric figure.

Aspect Ratio
the ratio of the span of a wing to its mean chord.

Biomimicry
the mimicking of things in nature.

Camber
the rise of the curve of an airfoil, usually expressed as the ratio of the rise to the length of the chord of the airfoil.

Characteristic
a distinguishing feature or quality.

Chord
a straight line joining the trailing and leading edges of an airfoil section.

Drag (Air Resistance)
the aerodynamic force exerted on an airfoil, airplane, or other aerodynamic body that tends to reduce its forward motion.

Force
an influence on a body or system, producing or tending to produce a change in movement or in shape or other effects.

Gravity
the force of attraction by which terrestrial bodies tend to fall toward the center of the earth. earth on an object near earth is the object's weight.

Lift
the component of the aerodynamic force exerted by the air on an airfoil, having a direction perpendicular to the direction of motion and causing an aircraft to stay aloft.

Observation
an act or instance of noticing or perceiving.

Prediction
to declare or tell in advance.

Thrust
to push forcibly; shove; put or drive with force.

Weight
the force that gravitation exerts upon a body.

Winglets
a small wing used mainly to carry external loads or to connect struts or gears to the fuselage.

(All Vocabulary is from www.dictionary.com)

Technical Brief

Historical Biomimicry in Aviation Background: Great Inventors of the past have turned to nature for inspiration. Da Vinci studied bats, Lilienthal watched storks, and the Wright Brothers looked to pigeons to understand how to control an aircraft in flight. Even today, scientists at the AFRL in Dayton Ohio and other places are trying to replicate the flight of many animals and even insects like the bumble bee.
The following are websites that have a great deal of information that could be used when teach aerodynamics at a middle or even high school level. These websites are from NASA, and the first few are very specific to this lesson's content and level. The last website is the general index for the NASA aerodynamics website.

http://www.grc.nasa.gov/WWW/k-12/airplane/airplane.html (Excellent diagram and definitions of airplane parts)

http://www.grc.nasa.gov/WWW/k-12/airplane/geom.html (Excellent diagram and definitions and roles of different parts of the wing)
*At bottom of page is an applet that allows you to change different wing parameters and "test" the wings

http://www.grc.nasa.gov/WWW/k-12/airplane/area.html (Different wing geometries and formulas for calculating)

http://www.grc.nasa.gov/WWW/k-12/airplane/factors.html (Factors that affect lift on an airplane)

http://www.grc.nasa.gov/WWW/k-12/airplane/index.html (The "beginner page" to the awesome aerodynamics references from NASA)

http://www.grc.nasa.gov/WWW/k-12/airplane/short.html (An index of links by NASA for aerodynamics…many of the resources above are from this source. This is an INCREDIBLE resource, with interactive simulations, movies, etc. Make sure you go to the bottom of the pages for next links, other indexes, etc.)

Safety and Disposal

While cutting materials, assure that students are using the tools in a safe and appropriate manner.
Assure that students use goggles when testing projectiles.
The instructor may need to warn students as not to poke each other with the wood skewers.
Please recycle the paper if possible.

References

dictionary.com. (n.d.). www.dictionary.com

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Section IV: Appendices

Appendix A: Pre / Post Test and Key
Appendix B: Man-Made Vehicles and Living Things Match Examples, Teacher's Guide
Appendix C: Principles of Flight Inquiry: Air Resistance and Key
Appendix D: Principles of Flight Inquiry 2: Bernoulli Principle and Lift and Key
Appendix E: Principles of Flight Inquiry 3: Camber and Lift
Appendix F: Principles of Flight Inquiry 4: Angle of Attack
Appendix G: Principles of Flight Inquiry 5: Drag
Appendix H: Principles of Flight Inquiry 6: Putting it All Together
Appendix I: Engineering Design Challenges 1-8
Appendix J: Engineering Design Challenge Rubric
Appendix K: Additional Teacher Resources