AIAA

AEROSPACE MICRO-LESSON

Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee.

THE WRIGHT BROTHERS

At the dawn of the 20th century, the world was gripped by a new craze–aviation fever! People were trying to take to the sky in all manner of aircraft, from airships to airplanes. In these technologically tumultuous times, inventors from around the world clamored to be the first people to master heavier-than-air flight. These people–some of the brightest and most famous inventors from around the world–created all manner of vehicles in all sorts of shapes and sizes in their attempts to get airborne. Yet the first people to successfully take to the sky in a heavier-than-air craft weren't well-funded scientists or wealthy engineers; they were a pair of little-known bicycle makers from Ohio–two brothers called Wilbur and Orville.

Next Generation Science Standards (NGSS):

- Discipline: Engineering, Technology, and Applications of Science.
- Crosscutting Concept: Patterns.
- Science & Engineering Practice: Constructing explanations and designing solutions.

GRADES K-2

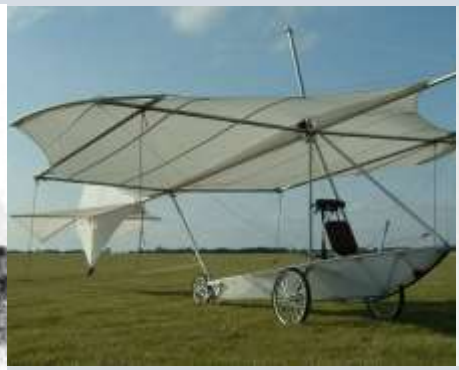
NGSS: Engineering Design: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

Today, we take airplanes for granted. Thousands of people fly across countries and oceans on airliners; military jets keep us safe, and tons and tons of freight are flown all around the world every day. Some airplanes even fly through hurricanes and over wildfires to study weather and fight fire. But 150 years ago, aeronautics–the study of flight–was still in its infancy, and air travel was just a distant dream. However, a lot of intelligent engineers and scientists were able to work together to solve this seemingly-impossible problem. Like any engineering problem, they started by studying the basic science of flight. What did they study? Birds! What do you think these early researchers learned from their studies of birds?

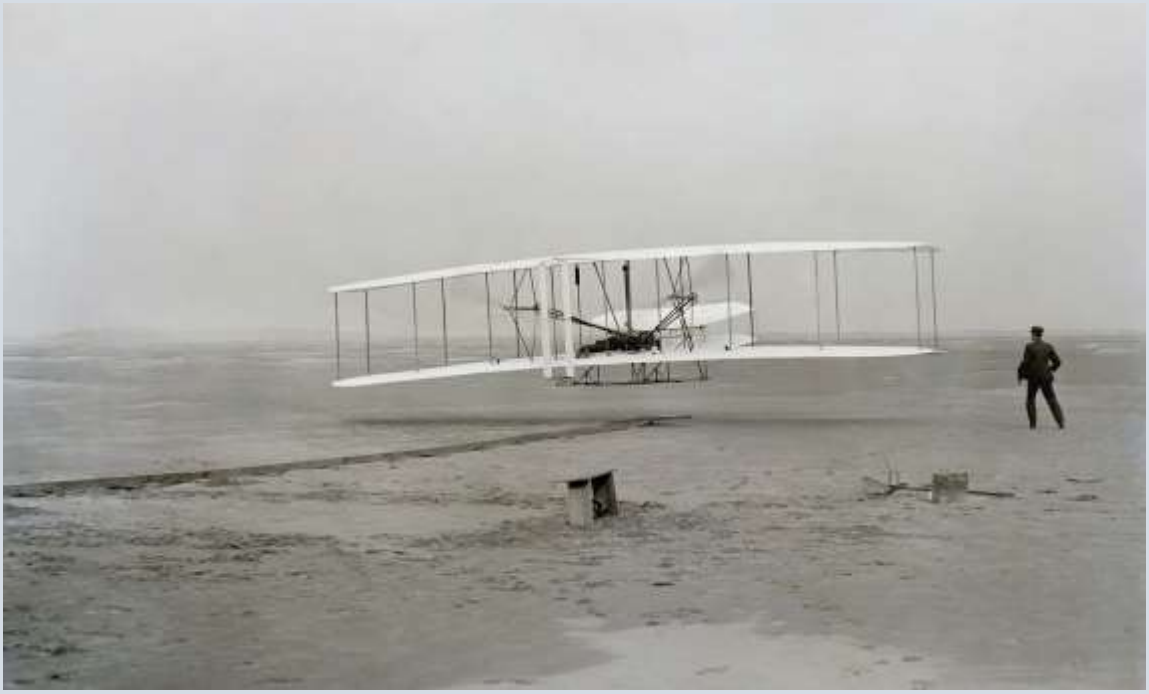
Researchers like George Cayley (England), Octave Chanute (United States), and Otto Lilienthal (Germany) learned a lot of the same lessons from birds that you might do from looking at them yourself. They noticed that birds push themselves forward by flapping their wings, but can fly on the wind without flapping at all. They noticed that birds can change direction by twisting their wings and by bending their tails. They were also able to notice similarities in how the parts of birds–the wings, the body, and the tail–are laid out. These researchers applied all of these lessons and tried to design their own airplanes. A lot of early pioneers tried to build aircraft with flapping wings (we call these *ornithopters*) but Cayley, Chanute, and Lilienthal were some of the first to try building aircraft with fixed wings. This made the challenge easier, as instead of trying to design an aircraft which could both push itself through the sky and fly

GRADES K-2 (CONTINUED)

smoothly, they could focus just on the smooth flying–otherwise called *gliding*. All three of these engineers built aircraft which were capable of gliding short distances under pilot control. Look at some of the pictures below: can you see the similarities between these early gliders and birds?



The work done by these early researchers helped later engineers develop powered aircraft. By the year 1900, engineers had a good working idea of how to build wings; they just needed to figure out how to build lightweight engines to push them through the sky and controls to allow pilots to fly properly. The Wright brothers, Orville and Wilbur, were a pair of bicycle mechanics from Dayton, Ohio. They studied the work of Chanute and Lilienthal and started building their own gliders. They used these gliders to test out their own ideas about aircraft and to develop ways of controlling them. They eventually decided to use the same technique which they saw birds using–twisting the wings in flight–to control the aircraft's direction. They also fitted controls to the other surfaces of the aircraft to allow them to move up and down, pointing the aircraft in different directions. Thanks to their careful research and experimentation, they became the first people to successfully fly a powered airplane on December 17, 1903. The aircraft they tested–the *Flyer*–doesn't look anything like a bird. But the key to their success was their careful study of birds and the flying machines built by their predecessors.



GRADES 3-5

NGSS: Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Believe it or not, there was a time when most people thought that air travel was impossible. However, engineers and scientists earn a living by doing what people think impossible, and as you know, air travel has been no exception. How does the technical community solve problems and invent things? By working together, coming up with new ideas, and testing them scientifically. A lot of early pioneers tried to build aircraft with flapping wings (we call these *ornithopters*) but were unsuccessful. Why? There are a few reasons: crucially, the motion of birds' wings is far more complicated than any machine which these inventors were able to build (even today, it would be difficult to fully replicate); furthermore, the materials available at the time–like wood and steel–were far too heavy to allow this kind of design to work.

However, in the late 1800s, researchers like George Cayley (England), Octave Chanute (United States), and Otto Lilienthal (Germany) focused their efforts instead on aircraft with fixed wings. They studied the way that birds are able to glide without flapping their wings and used this as inspiration. By the year 1900, engineers had a good working idea of how to build wings; they just needed to figure out how to build lightweight engines to push them through the sky and controls to allow pilots to fly properly. It was a hotly-contested challenge and would-be aviators from around the world were all trying to be the first people in flight. Many famous engineers and scientists built and tested many creative aircraft designs, but the two men we remember today as the fathers of flight were a pair of bicycle mechanics from Dayton, Ohio–Wilbur and Orville Wright.

What made the Wright Brothers successful? They diligently followed the engineering design process–they studied the work of Chanute and Lilienthal, and carefully built a series of increasingly-complicated aircraft, starting with kites and working their way up to manned gliders. In addition to testing their ideas in flight, they came up with creative ways to test their theories on the ground. They built a wind tunnel to test wings, and even went so far as to mount parts on the front of a bicycle and study how the air flowed over them as the rider pedaled forwards. Thanks to their hard work, the Wright brothers became the first people to successfully fly a powered airplane on December 17, 1903.

Unlike many of their rivals, the Wrights didn't rush to make any claims about their accomplishments; they kept their progress secret, quietly developing their aircraft and their flying abilities until they were ready to show the world. Sure enough, most people didn't believe them when they first publicized their results. But because of their careful attention to the engineering design process, they were able to consistently demonstrate a reliable aircraft, proving to the world that they had truly mastered the art of flight.

GRADES 6-8

NGSS: Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The development of the airplane is one of the most fascinating chapters in human history. In just a few decades, airplanes went from flimsy machines made of wood and canvas to high-speed jet aircraft capable of reaching the edge of space. Now airplanes are an accepted part of modern life, but the story of how they first came to be is a fascinating tale of secrecy and scandal. What's more, it is a great example of how engineers use the design process to solve seemingly impossible problems.

You can read the above sections to learn about how some of the earliest aviation pioneers studied birds for inspiration. Their work meant that by the turn of the 20th century, engineers had a good working understanding of the most key elements of manned flight–fixed (i.e. non-flapping) wings. However, there were many other problems that had to be solved to create the first successful aircraft. Wings by themselves don't fly very well; they need stabilizers to keep them flying straight; controls to let pilots fly them; and lightweight engines to push them through the sky. Tackling these challenges was no mean feat, and engineers from around the world did their best to find solutions in variously creative ways. The machines that each created looked quite different and each achieved a different level of success.

Perhaps the most famous inventor to create a flying machine was Samuel Langley. Langley was widely regarded as one of the most accomplished physicists in the world; he was the secretary of the prestigious Smithsonian Institution, and after demonstrating the first powered "model" aircraft (which flew successfully but were too small to carry people) in 1896, received $50,000 from the United States government to develop a manned aircraft. However, Langley mistakenly assumed that a successful aircraft would have to be fully stable without pilot input, so he didn't allow for a full set of pilot controls and his vehicle was impossible to fly. More worryingly, his lightweight aircraft was too flimsy and couldn't hold itself together in flight. Langley's manned *aerodrome* never achieved flight, and became something of an embarrassment to the United States government.

Another inventor was also hard at work trying to fly in the United States. Gustav Whitehead, a German immigrant, built several aircraft in his Connecticut workshop. Following testing of an unmanned plane, Whitehead claimed to have achieved sustained, powered flight in his *Number 21* aircraft in 1901. To this day, controversy surrounds his claims as there is no surviving proof of his alleged flight. Other inventors from around the world also claimed to be the first flyers–Clement Ader claimed to have flown a steam-powered aircraft in France; Alberto Santos-Dumont, a Brazilian, was initially credited in Europe with the first powered flights; Karl Jatho of Germany likely made some very short flights.

Despite all of these claims to the title of the first powered and controlled flight, today there is only one name which rightfully possesses that honor–Wright. Wilbur and Orville Wright, a pair of bicycle mechanics from Dayton, Ohio, became the first humans to convincingly demonstrate powered and controlled flight of a heavier-than-air machine on December 17, 1903. Unlike most of their contemporaries, the Wrights kept detailed notes of their experiments and their designs; they saved their correspondence with other aviation pioneers; and most importantly, they took photographs of their first flight. While other pioneers had made short "hops" in their aircraft, the Wrights were able to fly well over

GRADES 6-8 (CONTINUED)

250 meters (850 feet) in their machine, the *Flyer*–an accomplishment far beyond anything which had been demonstrated up to that point.

What made the Wright Brothers successful? They diligently followed the engineering design process–they studied the work of Chanute and Lilienthal, and carefully built a series of increasingly-complicated aircraft, starting with kites and working their way up to manned gliders. In addition to testing their ideas in flight, they came up with creative ways to test their theories on the ground. They built a wind tunnel to test wings, and even went so far as to mount parts on the front of a bicycle and study how the air flowed over them as the rider pedaled forwards. One can even see the development of their designs from looking at their kites and gliders–through scientific trial and error, they discovered what components their aircraft needed to fly–wings, vertical fins, and horizontal stabilizers. Thanks to their hard work, the Wright brothers became the first people to successfully fly a powered airplane on December 17, 1903.

GRADES 9-12

NGSS: Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The development of the first true airplane is a fascinating story which spans over a century of experimentation and adventure. You can read about some of the first pioneers of aeronautical engineering in the sections above, but you have probably already heard of the most famous name in early aviation–Wright. The Wright brothers were a pair of bicycle manufacturers who, despite having little formal education, dazzled the world by becoming the first to demonstrate sustained and controlled flight on December 17, 1903. So, how did a pair of obscure mechanics who hadn't even finished high school manage to accomplish one of the most impressive engineering feats of their time? They applied good problem-solving and diligent engineering testing to make their dreams a reality.

The Wrights began their quest by obtaining all of the information which they could find–they wrote to the Smithsonian Institution, which would eventually become a great rival of theirs–to request any information they could provide. They studied the work of earlier pioneers like Chanute, Cayley and especially Lilienthal. From their studies, they determined that the problem of controlling an aircraft was the biggest unsolved issue in aeronautics and set about finding a solution. Whereas previous aircraft tried to turn using ship-style rudders, the Wrights, inspired by their background in bicycles, noticed that birds were able to turn by angling their wings in the same way that bicycle riders lean into turns. They decided to try and mimic this characteristic by twisting the wings of their aircraft–a technique which came to be known as *wing warping*. This was a revolutionary idea; most of the well-established aeronautical inventors like Langley and Chanute designed their craft to be perfectly stable and to always fly level. Today, we know that this is both impossible and undesirable, but at the time it was thought a logical enough approach. The Wrights tested their unconventional idea using kites; pulling strings would allow the wings of the kite to warp, which caused the kite to roll to one side or another.

GRADES 9-12 (CONTINUED)

Having successfully demonstrated wing-warping, the brothers moved on to their first manned vehicle–an unpowered glider design–in 1901. They combined features from previous designs but designed their own wings to incorporate wing-warping technology. A series of tethered flights with the craft tied to the ground, and few gliding flights from the top of a small tower proved that their design was relatively sound–the craft was able to fly, but the wings produced less lift than expected and their wing-warping technology was not adequate to turn the plane correctly in flight.

Discouraged, the brothers returned to the drawing board. They spent the next year refining their calculations to better predict the amount of lift their plane would generate. They built a novel testing apparatus by mounting a bicycle wheel horizontally on top of one of their bicycles. If they mounted a pair of models on the sides of the wheel, they could see which felt the greater force from the passing airflow by watching which way the wheel turned as they pedaled the bicycle. They also built their own wind tunnel, which they used to study different types of wings and the lift they produced.

When the brothers built their next glider in 1902, the improvements were dramatic. Their new wings produced more lift and less drag, allowing the plane to fly much more effectively. They also added a steerable rudder to help solve the problem of *adverse yaw* which their wing-warping created. The Wrights had noticed that wing-warping caused the aircraft to turn in the opposite direction–this happened because twisting the wing had two effects. The first was to make one wing rise higher than the other–just as the brothers intended, to make the plane "lean" into the turns. The second was that the higher wing would create more drag (due to its twist), literally pulling the airplane back by that wingtip and inducing a turn in the wrong direction. The Wrights solved this problem by mounting a vertical rudder at the back of the plane, which exerted a force to stop the plane rotating in the wrong direction. When the pilot was given control of the rudder, he could balance the yawing (rotation about the vertical axis) and rolling (rotation about the longitudinal axis) of the plane to create stable turns. This was the breakthrough which the brothers needed.

The next year, the brothers took the final step towards creating the modern airplane by adding a lightweight engine driving a pair of propellers. The Wrights created propellers using their new knowledge of wings, and hired a mechanic to build a powerful gasoline engine, which drove the two propellers using bicycle chains. On December 17, 1903, the brothers finally achieved the impossible–they flew their first powered aircraft, the *Flyer* under manual control four times, culminating in a flight of over 250 meters. Finally–after decades of collective research and years of careful engineering development by the Wrights–the airplane had arrived.

Sixty Years Ago in the Space Race:

December 17, 1957: The Atlas ICBM had its first successful test flight (after two failures), reaching 700 miles downrange.