

USING AERONAUTICS TO INCREASE ENGAGEMENT, COMPREHENSION, AND
INTEREST IN AVIATION STEM CAREERS

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

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DEDICATION

To my son, Ennio.

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ABSTRACT

Since the initiation of STEM Education, the need for pilots and aircraft technicians has steadily increased as the number of people entering aviation career fields has been on the decline. The population in general remains unaware of rewarding career opportunities in aviation and aerospace as the focus in STEM careers has been on computers, information technology and healthcare. Will using aviation themes to teach science increase engagement, comprehension, and interest in aviation STEM careers. A unit on force and motion was taught using aviation themed activities. Pre and post assessments were administered to measure comprehension of force and motion concepts for treatment and non-treatment groups. The treatment group completed pre and post treatment surveys to measure their interest and awareness of aviation STEM careers. A post treatment questionnaire, and student interviews were used to determine both student engagement and interest in aviation careers. Data analysis indicated a small, but not significant increase in comprehension for the treatment group. Student awareness in aviation as a STEM career increased, while interest in aviation careers exhibited almost no change. Using aviation themes to teach certain science topics can increase student engagement, if used economically. Unless individual students have had a personal experience with aviation, beyond flying on a commercial airliner, the novelty may wear off quickly. Used strategically, using aviation themed activities can generate a greater interest for some students and certainly make others cognizant of the field.

INTRODUCTION AND BACKGROUND

Context of the Study

North Junior High is the largest of eight junior high schools in the Boise School District in Boise, Idaho and serves students in grades seven through nine. Enrollment is 995 students and the school ranks in the top twenty percent academically of all schools in Idaho. The minority enrollment is eight percent Hispanic, three percent Asian, two percent two or more races, and one percent black. The remaining 86 % of the student population is white. Students qualifying for free and reduced lunch account for 17% of enrollment compared to the state average of 35% (Public School Review, 2019-20). The school is located less than one mile from the Idaho State Capital Building in downtown Boise and less than one-half mile from Boise High School. I have taught for 23 years, 14 years for the Boise School District; this was my second year at North Junior High as a traveling teacher. This year, I taught physical science, life science, and Pathways to Success.

Pathways to Success is a class for seventh graders who may need some guidance dealing with the transition from elementary to junior high school. The curriculum allows teachers to find creative ways to help students understand the need to be organized and responsible while navigating multiple classes and teachers. I did some initial research into planning field trips to work sites, my idea was for them to learn about different careers and see some firsthand. I hoped doing so would compel them to think about a career they might pursue and realize the connection between school success and work.

I remembered reading an article about a shortage of pilots and aircraft technicians. I was surprised to learn a field I always assumed would not have problems attracting motivated and talented participants now found itself in such dire need. I had grown up around aviation, my father was a pilot, aircraft mechanic, aircraft owner, and safety inspector for the Federal Aviation Administration (FAA). Before becoming a teacher, I had worked for a company that provided aircraft ground support at an international airport. I assumed everyone was fascinated with aviation and space, after all I live in a country with a renowned history in both fields. I arranged a field trip to tour the Boise airport control tower, I felt this would be a good way for my Pathway students to see different aspects of the aviation business.

According to the Boeing Aircraft Company, the world's largest aerospace company and leading manufacturer of commercial aircraft, there will be a need for 804,000 civil aviation pilots and 769,000 civil aviation technicians worldwide between the years 2019 and 2038 (Boeing, 2020). Since 1980, according to the FAA, the number of pilot certificates issued has decreased by sixty percent leading to an increasing shortage of pilots. To help meet demand, the Aircraft Owners and Pilots Association (AOPA) the largest civil aviation organization, has created an aviation STEM curriculum focused on aviation careers and introduction to flight, designed for ninth, tenth and eleventh grades. I would like to pilot an elective science course in my district using the AOPA curricula.

I believe students would be more motivated to be successful, learn more about scientific concepts, and applying engineering practices in a science class that explores a

credible career path with many different potential opportunities. A course in aviation careers could fulfill the districts science elective requirement for some students and possibly be the stimulus to pursue a worthwhile career in aviation or aerospace. I wondered how much interest in aviation there was among students and if that interest would translate to higher achievement, especially if they knew opportunities existed.

Focus Question

The focus question for this study was, Will using an aviation theme to teach physics improve student engagement and content mastery?

Sub-questions included the following:

1. Is there already an underlying interest in aerospace careers?
2. Is interest created in aviation careers using aviation themes to teach physics?

CONCEPTUAL FRAMEWORK

STEM Education

STEM is an acronym that stands for the fields of science, technology, engineering, and mathematics. Having a basic knowledge of STEM will be required for most students when they are ready to enter the labor force. To be competitive in an increasingly global labor market, a comprehensive knowledge of STEM will be necessary for careers which require the ability to solve complex problems utilizing an in-depth working knowledge of multiple fields (U.S. Department of Education).

A STEM approach in education refers to offering relevant hands on learning experiences using inquiry. For teachers, “developing an integrated knowledge of STEM is essential in K-12 education, as it lays the foundation for a learner to learn more, solve problems, and innovate” (Krajcik & Delen, 2017, p. 38). An “integrated STEM approach” makes a connection between lessons and uses practices found across many other areas of inquiry. According to the National Research Council STEM learning environments must: 1) support deep learning of key scientific principles; 2) engage students in making sense of phenomena and designing solutions to problems using scientific and engineering practices, 3) create contexts that motivate and challenge learners, 4) build integrated understanding over time, 5) combine the use of scientific ideas and scientific and engineering practices to develop integrated understanding and 6) make students’ thinking visible (Krajcik & Delen, 2017, p. 40).

Students need to practice using a STEM approach to fully utilize and apply all the parts it encompasses. Using STEM practices and ideas to solve problems relating to

experiences that are recognizable helps motivate and challenge students to apply what they have learned with a deeper understanding of the concepts. The classroom environment should be centered around investigating phenomena and solving problems from student experiences in and out of the classroom. A fundamental principle is that learning takes place within authentic contexts, normally occurring activities and environments involving common experience and behavior. “Students develop a deeper understanding when constructing knowledge by working with and using ideas in real-world contexts” (Krajcik & Delen, 2017, p. 47–48).

A principal factor behind the introduction of STEM education was the “rapid increase in demand to fill STEM-related positions” (Ward et al., 2019, p. 9). As teachers were trained and programs initiated many teachers brought with them a bias toward their areas of expertise instead of focusing on a comprehensive approach where questioning and solving problems are meant to advance overall innovation. The Next Generation Science Standards (NGSS) were designed by stake holders to bring greater consistency to the implementation of K-12 STEM curriculum. The standards are designed to allow educators some flexibility when creating interesting and stimulating learning experiences in the classroom. (Ward et al., 2019)

Next Generation Science Standards (NGSS) are made up of three parts incorporated into all the standards. The NGSS website describes the following equally applied but separate dimensions: 1. Crosscutting Concepts enable students to make connections across four dimensions of science, including physical, life, earth and space, and engineering design. Concepts such as cause-effect are made explicit for students to

assist in the development of a coherent and scientifically based view of the world around them. 2. Science and Engineering Practices describe what scientists do to investigate the natural world and what engineers do to design and build systems. This is the inquiry into science, and students design, build, and apply their knowledge in crosscutting concepts. 3. Disciplinary Core Ideas (DCI) are the key ideas in science that have broad importance and are within or across multiple science and engineering disciplines. The core ideas build on each other as a student progresses across the four domains: physical science, life science, earth and space science, and engineering design. (Ward et al., 2019, p. 9–10)

STEM Careers

The Federal Aviation Administration (FAA) has cited a general ignorance of aviation career opportunities among the public while at the same time detailing steeply rising demand for qualified and trained aviation professionals. As the need for aviation professionals continues to grow, the number of qualified specialists has been in decline since the 1980's. The reasons are varied, retirement of baby boomers, an emphasis on safety necessitating rigorous training and certification, the expense involved with meeting substantial job qualifications, intrusive background, and medical checks (Byers, 2016). Having proficient entry level STEM skills is also one component, careers in aviation and aerospace that require a high degree of STEM education include: commercial pilot, flight instructor, military pilot, test pilot, unmanned aircraft systems operator, aircraft control specialist, airway transportation systems specialist, aircraft mechanic, aircraft systems assembler, avionics technician, aerospace engineer, civil engineer, electrical engineer and engineering technician (Ward et al., 2019).

A shift toward a global economy focused on digital technology has created a highly competitive environment for skilled workers and the demand will steadily increase while the number of entry level workers decline overall as the population ages. The international transportation system will continue to grow significantly; even with the implementation of automated Next Generation technologies the demand for flight crews and mechanics will also grow. Opportunities for education and training programs paid by airlines, airports and air traffic control services will also substantially increase as the competition for STEM qualified and capable candidates expands. Ab initio, meaning from the beginning, is an industry term that describes airline-oriented flight training programs that take qualified candidates from zero experience through commercial pilot at no cost, in return for dedicated service to the airline (Byers, 2016).

The motivation behind pursuing a career in aviation is usually initiated by a positive personal experience that inspires an ambition to fly or a fascination with the mechanics of flight. Evidence indicates initial interest “ignites at a young age through active, intentional engagement”. Interest can be maintained through different kinds of interaction with aviation. A pathway, in the context of an aviation career, is a continuum of aviation related activities that begins with a first experience, eventually leading to a career or lifelong interest in aviation or aerospace (Ward et al., 2019, p. 8).

METHODOLOGY

Demographics

This classroom research project based on the action research model evaluated the effects of using aviation themes to teach physics concepts to improve student engagement and content mastery. It also attempted to measure underlying student interest in aviation careers and whether interest increased using aviation themed lessons. A unit on force and motion is part of the districts ninth grade physical science curriculum. The unit was used for this classroom research project during first quarter beginning in September and ending in October 2019. One physical science class of 29 students made up of 15 eighth grade, 14 ninth grade and one seventh grade student was selected to receive the treatment. The treatment class had four students on Individual Learning Plans (IEP) including two English Language Learners (ELL). The nontreatment class consisted of 30 students, eight eighth grade and 22 ninth grade. The nontreatment class had six students on IEPs including three ELLs. Some eighth grade, and a small number of seventh grade students choose to take physical science before their ninth-grade year with parent approval in preparation for advanced placement (AP) classes in high school. Traveling teachers move between rooms each period; the nontreatment class was taught second period and the treatment class fourth period in a different science classroom. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Treatment

Fundamental concepts of forces and motion were explored using the following aviation themed inquiry activities: Real World Applications: Flying Speed (Appendix B). Aircraft were tracked in real time using an online application; time, distance traveled, and velocity were calculated in flight. Modeling Flight and Motion (Appendix C). Basic engineering practices were incorporated to build and test simple wood airplane models. Students collected data before and after flight test, then analyzed the data to make changes for problems they encountered. Forces of Flight (Appendix D). Balanced and unbalanced forces on airplanes were modeled, then students applied what they learned to keep an airplane level and at constant speed using an online flight simulator. Newton's Laws of Motion and Flight (Appendix E). A sling shot glider and a balloon helicopter were used to provide evidence to verify the three laws of motion. The nontreatment classes explored concepts of force and motion with conventional inquiry activities. The activities contained no reference to aeronautics and were part of the science department lesson collective used before this study.

Data Collection and Analysis Strategies

Student knowledge of force and motion was determined before and after the treatment and nontreatment unit by administering a Force and Motion Pretest and Post Test (Appendix F). Student knowledge and perception of aviation STEM careers was evaluated using an Awareness and Interest Survey, pre and post treatment (Appendix G). Student attitudes and impressions of aviation STEM careers and the aviation themed

lessons were collected using the Post Treatment Questionnaire (Appendix H). The questionnaire was also used to decide which students would be chosen for post treatment interviews.

The Force and Motion Pretest and Post Test was a multiple-choice summative assessment consisting of 40 questions to determine students understanding. (Appendix F). Questions covered all the concepts in the force and motion unit and included the following objectives: identify and measure the speed, velocity, acceleration and momentum of a moving object; identify the types of forces that act on all moving and stationary objects, describe the effect of those forces, apply the laws of motion to all moving and stationary objects and give examples to describe their effects. Mean, median and range of assessment scores were used to compare treatment and nontreatment results on both pre and post summative assessments. Normalized gain was calculated to compare treatment and non-treatment scores on pre and post assessments. Normalized gains of less than 0.3 are considered low gains, 0.3 to 0.7 medium gain, and normalized gains greater than 0.7 are considered high gains (Hake, 1998). A T-test for two independent means was used to determine if differences were not due to random chance.

The Awareness and Interest Survey consisted of 25 statements designed to determine student knowledge and interest in aviation careers, general attitudes toward science, and student understanding of aviation as a STEM career. Students were asked to read and respond to each statement by circling one number on a five-point scale. Circling five indicated they strongly agreed with the statement, four indicated there was some agreement, three indicated they were unsure, two meant they somewhat disagreed with

the statement and circling one indicated strong disagreement (Appendix G). Responses to each statement on the survey were totaled. Strongly disagree and somewhat disagree answers were combined as were strongly agree and somewhat agree to simplify comparison of pre and post treatment results. The percentage of disagree, unsure and agree for each statement was calculated and compared to establish meaningful changes in awareness and interest in aeronautics.

The Post Treatment Questionnaire consisted of five questions designed to discover students' impressions of the activities used during the treatment and their thoughts on the connection to aeronautics (Appendix H). The first question asked if students liked the aviation themed activities and to explain why they did or did not. The second question asked which activity they liked most and why they liked that activity. The third question asked what was learned from lessons using aviation topics. Question number four asked students' which activities helped them gain the best understanding of the concepts. The final question asked if they were interested in aviation careers after taking part in the aviation themed activities. The questions were used to identify unexpected or irregular student responses to the treatment and recognize patterns based on similar answers.

To get varied responses, eight students were selected to do interviews based on their ambiguous or decisive answers to questions on the Post Treatment Questionnaire. The interviews took place outside of class during lunch. Some students were unable to attend the scheduled interview time; six students participated in two groups of three. The interviews took about ten minutes to complete and were recorded. The interviews focused

on exploring student attitudes regarding aeronautics in general and whether the treatment produced a desire to learn more about different aviation career paths. They were also asked to identify and discuss their most positive and negative experience during the treatment period. At the end of the session, students were asked if they would like to comment on anything they believed should be known about the study and their participation.

The quantitative data collected from the surveys and the summative assessment were triangulated with the post treatment questionnaire and interviews to qualitatively support the focus questions (Table 1).

Table 1

Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Will using an aviation theme to teach physics concepts improve student engagement and content mastery?	Pre and Post Force and Motion Assessment	Pre and Post Treatment Awareness and Interest Survey	Post Treatment Questionnaire
Sub-questions			
1. Is there already an underlying interest in aerospace careers?	Pre and Post Treatment Awareness and Interest Survey	Post Treatment Questionnaire	Post Treatment Interviews
2. Is interest created in aviation careers using aviation themes to teach physics?	Pre and Post Treatment Awareness and Interest Survey	Post Treatment Questionnaire	Post Treatment Interviews

DATA ANALYSIS

Results

The non-treatment Force and Motion Pretest (Appendix F) scores exhibited a lower quartile below 50.6%. The median score was 56.3% and interquartile range, representing half of the non-treatment student scores was between 50.6% and 66.9%. The remainder of non-treatment scores were in the upper quartile ($N=30$). Force and Motion Post Test (Appendix F) scores for the non-treatment unit exhibited a lower quartile below 70.6%. The interquartile range was between 70.6% and 85% and the median score was 77.5% resulting in a 37.7% increase from preassessment to post assessment scores (Figure 1).

The treatment Force and Motion Pretest scores exhibited a lower quartile below 50%. The median score was 55% and interquartile range, representing half of the treatment scores was between 50% and 65%. Seventy-five percent of pretest treatment scores were below the upper quartile at 65% ($N=29$). Force and Motion Post Test scores for the treatment unit exhibited a lower quartile below 70.%. The interquartile range was between 70% and 90% and median score was 82.5% resulting in a 50% increase from pre to post assessment scores (Figure 1).

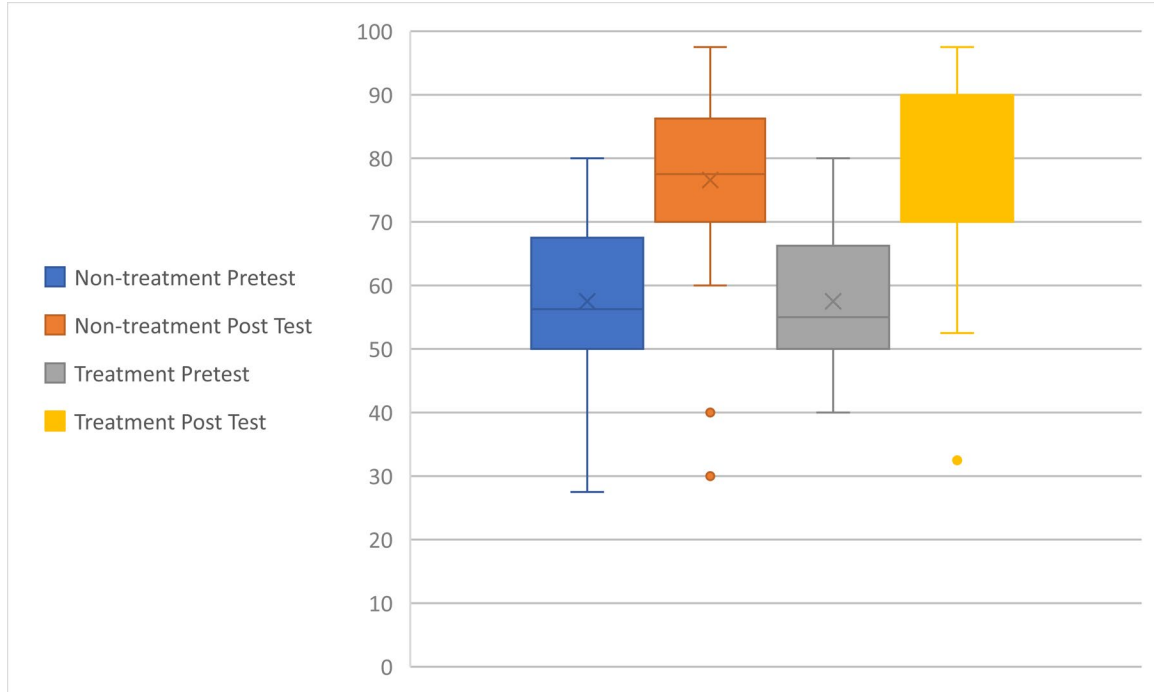


Figure 1. Assessment Scores: Non-treatment, (N=30) versus Treatment, (N=29).

The average normalized gain for the non-treatment Force and Motion Assessment was 0.47 which is considered a medium gain. The averaged normalized gain for the treatment Force and Motion Assessment was 0.51, also considered a medium gain, but resulting in an increase of 8.5% from pre to post average normalized gain (Hake, 1998). The difference between treatment and non-treatment normalized gain was analyzed for statistical significance using a t-test. Calculations determined the t -value to be 0.61 and p -value .55, the result was not significant at $p < .05$. Two students from the treatment group and no students from the nontreatment group had normalized gains below zero (Figure 2).

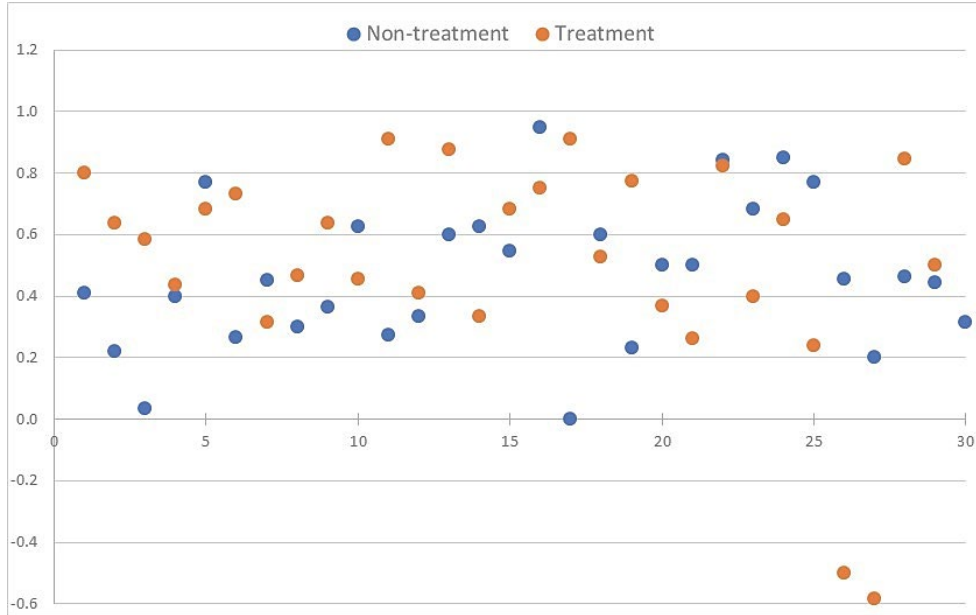


Figure 2. Normalized Gains: Treatment, (N=29) versus Non-treatment, (N=30).

Some differences were found in comparing certain statements on the pre and post treatment Awareness and Interest Survey (Appendix G). The statement, “I understand the science of how airplanes fly.” (Question 11) had the largest change with 43% of students agreeing before the treatment and 80% after the treatment, an increase of 86%. Students agreeing with the statement “Being a professional pilot is a STEM career.” (Question 8) changed from 28.6% pretreatment to 44% post treatment on the survey, an increase of 53.8%. Students agreeing with the statement “I think designing airplanes would be interesting.” (Question 5) decreased by 25.3% from 75% pretreatment to 56% post treatment. Finally, agreement with “I know the career I want to pursue after high school” (Question 1) changed from 60.7% pretreatment to 80% post treatment, an increase of 31.8%. All other responses to the post-treatment Interest and Awareness Survey were similar when compared to pretreatment responses (Figures 3 & 4).

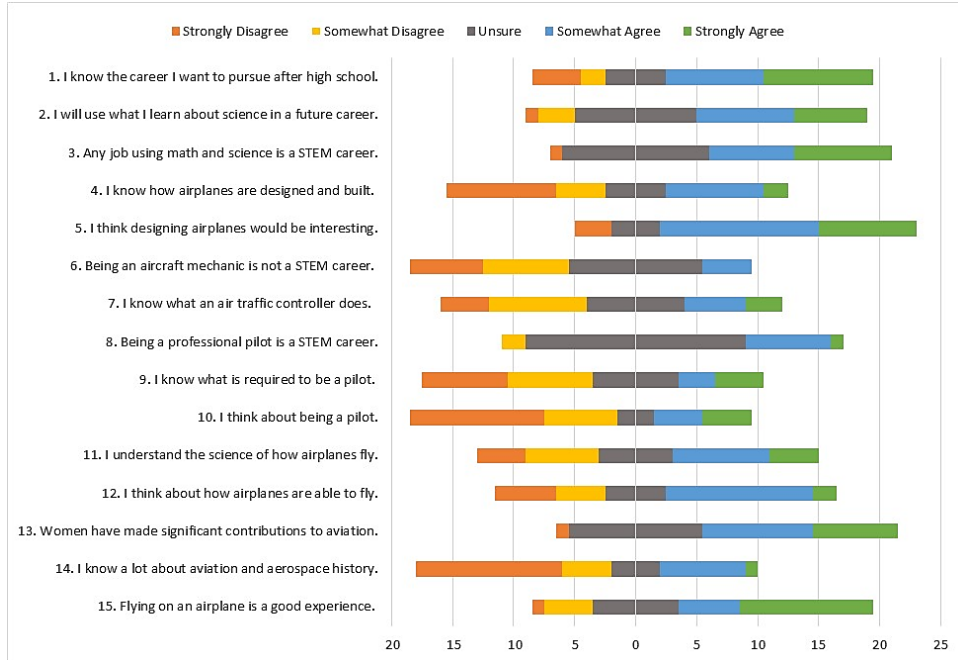


Figure 3. Pretreatment Awareness and Interest Survey, (N=28).

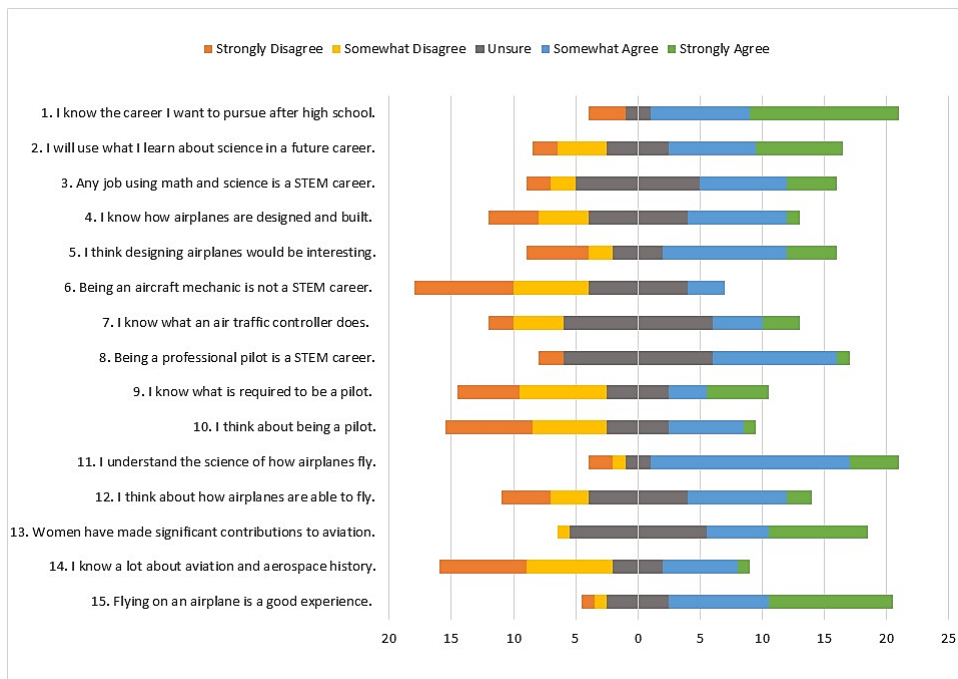


Figure 4. Post Treatment Awareness and Interest Survey, (N=25).

Most responses on the Post Treatment Questionnaire indicated students liked participating in the treatment activities (Appendix H). When asked “Did you like doing classroom activities using aviation themes?” (Question 1), one student wrote “I’ve never been on a plane so doing plane related stuff is cool for me”. Many students specifically mentioned building the model and performing test flights. One student wrote, “I liked building the paper airplane with balsawood. It was cool we got to fly it too”. One of the activities asked students to fly an airplane simulator after a short tutorial on the forces that enable flight. Some students liked the challenge of keeping an airplane level at constant speed, while others thought it was too difficult. When asked “Which activities helped you gain the best understanding of the concepts?” (Question 4), one student wrote, “I did not enjoy the simulation on the computer because it was more difficult to learn and understand,” On the same question another student wrote, “The plane simulation because I learned about drag, lift, weight and thrust.” When asked “Are you more, or less interested in aviation careers after taking part in these activities?” (Question 5) a typical response was, “I see why people would be more interested in aviation careers, but personally, it is not for me”. However, one student responded, “More, because I have a better understanding of what is needed to do”.

The students participating in the post treatment interviews were asked specifically about their individual responses on the post treatment questionnaire. Each question was reviewed to gain more in-depth explanations beyond what was written by asking students if they would like to change their responses or add additional comments. Follow up

questions focused primarily on how the aviation activities that made up the treatment affected student attitudes and interest concerning aviation careers.

Most students liked building the airplane model because it was “hands on” and involved working cooperatively within a group, making it the most engaging activity. Several students mentioned The Real-World Applications: Flying Speed (Appendix B) activity as being the least engaging. They liked the novelty of tracking real airplanes in real time but found that it was too open ended, they didn’t know which airplane to track or how to apply what they had learned about determining velocity. All the students who took part in the interview admitted the treatment had caused them to think about aviation more than they had before, but it did not change their level of interest in an aviation career. When both groups were asked if they thought being a pilot was a STEM career, all students agreed that it was, with only one student saying they were not sure. When the discussion moved to their interest in learning more about aviation careers through an elective science class, most were not interested. One student did express some interest under the right circumstances if the elective science class could be taken simultaneous to the physical science class they were in now because they thought some of the concepts would be similar. One student expressed interest in learning more about how airplanes were designed because they “still didn’t know much about it”.

CLAIM, EVIDENCE AND REASONING

Claims from the Study

Gains made for comprehension by the treatment class were more significant than what the data indicated. Two post treatment scores on the Force and Motion post-test were lower by 25% and 41.9% respectively, than what students had scored on the same assessment pretreatment. Omitting these two normalized gains on a T-test resulted in 95% probability the difference between treatment and non-treatment normalized gain was not due to random chance. Unfortunately, it is difficult to know the precise reasons for the decline in scores from pre to post assessments without a full exploration through individual student interviews which did not take place. Among other contributing factors the cancelation of school due to the Covid-19 pandemic played a part in not having an opportunity to investigate the reasons in detail.

Students became more aware of aviation as a STEM career because of the treatment. Almost all students, except for one individual, had any considerable exposure to aviation beyond flying on a commercial airliner or had ever considered pursuing a career in aviation prior to the treatment. All elements of the treatment including the activities, survey, questionnaire, and interview created a window of opportunity where none had existed for students to learn about aviation and to consider that is was a STEM career.

The survey indicated that a significant number of students were already decided on a career path and that percentage increased after the treatment. Exposure to the aviation themed activities and the questions asked following the treatment may have

motivated some students to discount aviation as a potential career path. Wanting to fly or be involved in aerospace requires a fascination with the field, not having that motivation makes the considerable training and education required difficult to consider or realize. The amount of exposure during this study was inadequate for students to make a fully informed decision about aviation one way or the other.

Value of the Study

Greater awareness of aviation as a STEM career increased because of this study. Interest in aviation careers may not have been achieved, but at least students were presented with an alternative career field they may never have considered. Most students liked having aviation as the focus and engagement increased based on quantitative and qualitative evidence. A larger treatment group would yield better understanding of the extent comprehension of force and motion concepts improved. Based on these outcomes, using an aviation theme in other content areas might also be used to create more engaging lessons and improve comprehension if used economically. Unless individual students have had previous impactful encounters with aviation the novelty may wear off quickly. Used strategically, using aviation themed activities can generate a greater interest for some students and certainly make many more conscious of the field. The lessons developed for this study will continue to be used and modified to enhance effectiveness and student interest.

Impact of Action Research on the Author

The experience gained completing this action research study has benefited me in multiple ways. Learning to use both qualitative and quantitative data to determine how engaging activities are to students has given me insight about what student's value in the lessons and activities I ask them to do. I believe this will help me design activities and structure lessons in the future students will find more engaging and will lead to higher classroom participation and student comprehension of concepts in all my classes.

Through my participation in this action research study I have become proficient at looking for answers to the questions I have about what I do in the classroom, either through existing literature or by forming hypotheses that I can test in the classroom. The study has given me a better understanding of student interests regarding future careers and to better understand whether subjects are relevant and authentic to them. I have learned to design data collection tools to gather evidence, developed an understanding of how research data is evaluated and become familiar with the tools of data analysis to determine the significance of study results. Finally, I have learned to use evidence gathered and its analysis to reflect on additional questions that can be answered through the action research model.

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APPENDICES

APPENDIX A
IRB EXEMPTION



**INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165**

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MEMORANDUM

TO: Michael Giordano and John Graves

FROM: Mark Quinn *Mark Quinn CFP*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 8, 2019

RE: "Using Aeronautics to Increase Engagement, Comprehension and Interest in Aviation STEM Careers"
[MG100819-EX]

The above research, described in your submission of October 7, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).
- _____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- _____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- _____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- _____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

REAL WORLD APPLICATIONS: FLYING SPEED

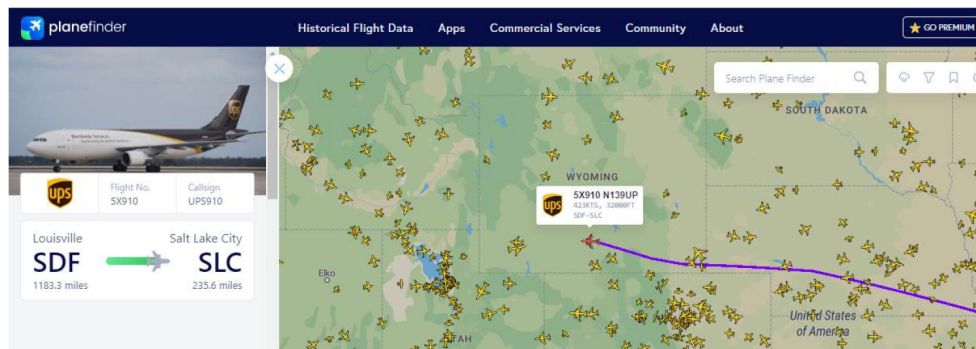
Real-World Applications: Flying Speed

Name _____ Date _____ Class _____

Objective: Estimate the average speed of an airplane as it travels between two points.

There is a significant amount of aircraft in the skies every day of the year. Because these aircraft must be monitored to help pilots get to their destination efficiently, and to avoid in-air collisions, it is possible to track any commercial aircraft around the globe. There are many websites and apps available to help people track specific flights or to browse flights around the world. For this activity, go to <http://planefinder.net/>

1. Which parts of the world experience the least air traffic?
2. Choose one country or region surrounded by little air traffic and explain why you think it does not have a busy airspace. (Consider the economics of these countries, population density, geography, weather, time of day, and the observance of any cultural holidays).
3. Which parts of the world experience the *most* air traffic?
4. Choose one country or region surrounded by lots of air traffic and explain why you think it has a very busy airspace. (Consider the economics of these countries, population density, geography, weather, time of day, and the observance of any cultural holidays).
5. How do you anticipate that the airspace of the future will change? Do you think the skies will get busier or less busy? Why?
6. The goal of this activity is for you to determine the *average speed* of an aircraft during its cruise portion of its flight. Explain what information you will need to determine average speed.
7. Zoom in to an area where there is a regular amount of air traffic. The goal at this point is to identify an aircraft that is moving from one notable location to another (such as a city, interstate intersection, lake, etc.), so that speed may be determined. **Avoid starting or ending at an airport, as aircraft speed changes significantly at those points.**



<https://www.aapt.org/Resources/Aeronautics-for-Introductory-Physics.cfm>

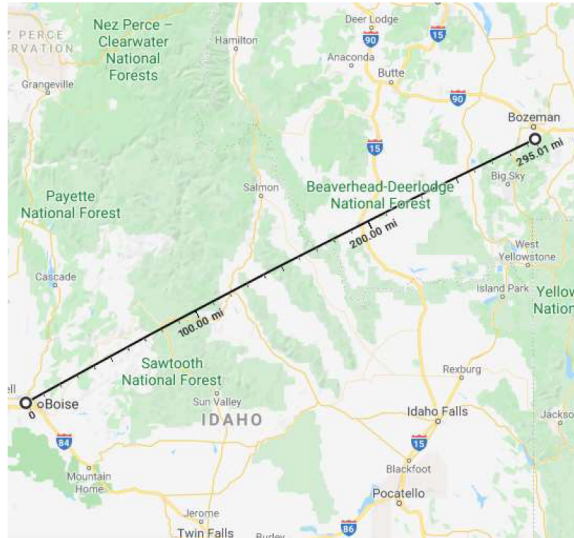
Real-World Applications: Flying Speed

8. Choose one aircraft and record the time it as it flies from one point of interest to the other in a straight line. Choose a range of time somewhere between one and five minutes to ensure that enough time is collected for accurate results. If your airplane significantly changes direction or follows an unclear path, consider choosing a different aircraft. Record the **time** here: _____

9. Measure the distance between the two points of interest by following the example procedure below:

- Go to www.google.com/maps to get to Google Maps
- On Google Maps, find the initial point of the plane's timing.
- Right-click on the initial location to get a menu. Choose "Measure distance." The second point of interest can be clicked, and an estimate given for the distance between the two points.

10. Show your work, and, if appropriate, explain how you can calculate the average velocity of the airplane.



11. For a typical passenger jet, the airplane will cruise at around 500-550 miles per hour. How does your answer compare? You might need to convert your velocity units to make a fair comparison.
12. What aspects of this activity might lead to error in your measurements and calculations? Provide three specific examples and explain if this would increase or decrease your calculated value.
13. Compare your results to that of your peers. Why might your peers have calculated different values?
14. Take a broader look at the flight paths across the United States.
- What patterns do you notice for eastward or westward flights?
 - How do flight paths change upon entering or leaving airports? Why do you think this is the case?

Real-World Applications: Flying Speed

Problem Set: Comparative Velocities

Background

Airplanes were developed with a primary goal: to take their occupants across the skies at speeds never before imagined. For thousands of years, before the invention of the wheel, humans were limited by the speed of their legs. Using a mathematical model (equation) you developed in your regular class activities to represent the relationship between position and time for an object moving at a constant velocity, perform these very simple calculations to get a sense for how fast and far we can now easily travel because of aircraft.

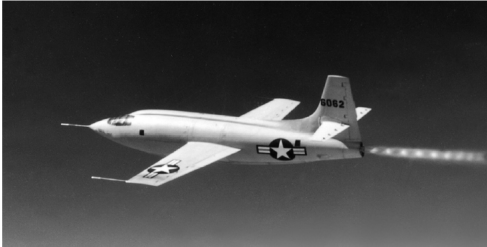
Problem Set

1. Determine *your* average walking speed. Explain how you accomplished this:
2. Convert your speed in meters per second (m/s) to kilometers per hour (km/hr), then use that speed to solve the following problems. How much time would it take **you** to walk the following routes, assuming you never stopped along the way?

Land Routes	Distance to Walk	Time to Walk (Show work)	Time to Fly Non-Stop on Commercial Aircraft
Oregon Trail (MO to OR) 	3,219 km (2,000 miles) Immigration route used from 1830s to 1860s for settlers heading west for new land.		3 hours
Silk Road (Western China to Constantinople) 	6,437 km (4,000 miles) Cultural and commercial trade route used from 200 BCE to 1450s CE to connect culture and trade between the East and West.		8 hours
Early Land Migration (Northern Russia to Tierra del Fuego) 	17,703 km (11,000 miles) Possible route taken by early civilizations from the Asian continent, beginning about 30,000 years ago to their arrival at the southernmost tip of South America about 15,000 years ago.		19 hours

Real-World Applications: Flying Speed

3. How long would it take each of the following NASA planes to travel the exact same routes, assuming they were at their maximum speed for the entire duration of the flight? *Show your work!*

NASA Aircraft	Distance & Flight Time
Bell X-1: (1,127 km/hr) Chuck Yeager was the first person to break the speed of sound in 1947 using rockets in conjunction with traditional jet engines.  https://airandspace.si.edu/collection-objects/bell-x-1-glamorous-glenmis/nasm_A19510007000	Oregon Trail: 3,219 km (2,000 miles)
Douglas D-558: (2,124 km/hr) Scott Crossfield was the first person to fly more than twice the speed of sound (Mach 2) in 1953.  https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-035-DFRC.html	Silk Road: 6,437 km (4,000 miles)
North American X-15: (7,274 km/hr) William J. "Pete" Knight broke the record for the fastest piloted airplane flight speed ever recorded, at 6.7 times the speed of sound (Mach 6.7) in 1967.  https://airandspace.si.edu/collection-objects/north-american-x-15/nasm_A19690360000	Early Land Migration: 17,703 km (11,000 miles)

APPENDIX C
MODELING FLIGHT AND MOTION

Modeling Flight & Motion

Name _____ Date _____ Class: _____

Scaling and Model Airplanes

Objective: Determine the relationship between weight and wing surface area.

Early engineers found that building vehicles for powered flight was a difficult task. In this activity, you will determine the relationship between weight and surface area of the model aircraft wings.



<https://www.pitsco.com/Delta-Dart-Model-1>

1. Estimate the surface area of the wings by identifying the simple geometric shapes that make up the wings.

2. Draw a top-view of your model airplane, identifying the shapes. Describe – in words – how you calculate the total surface area of the tops of the wings.

a. Drawing:

b. Description of calculation of area:

3. The “carrying capacity” of an airplane (or any other object) is calculated:

$$\text{Carrying capacity} = \text{weight} / \text{surface area that carries the weight}$$

To find the carrying capacity of the model aircraft determine its weight. Find its mass in kilograms (kg) and multiply by 9.8 m/s^2 , which is the rate of acceleration for all falling objects. Show your work.

$$\text{Weight (N)} = \text{mass (kg)} \times \text{gravity (m/s}^2\text{)}$$

4. What two variables could be changed to increase the carrying capacity of an airplane?

Modeling Flight & Motion

Flight Test

Flight testing is a branch of aeronautical engineering that collects data on aircraft in flight and analyzes it to evaluate the aerodynamic flight characteristics of the aircraft to show the design works.

1. Pick a spot to launch the plane.
 2. Wind the rubber band, start with 50 turns then adjust, as necessary.
 3. Launch the airplane and write down observations about the distance it traveled and the direction.
-

4. Record all changes made before launching again.
-

5. Record your observations and additional changes you will make
-

Speed and Velocity

Objective: Determine average speed and acceleration of the aircraft model.

1. Use a timer to observe the time from launch to the airplanes final distance. Perform three trials, record distance and time in the table below.
2. Use the distance and time data to calculate the airplanes average speed. Write the formula with the observed variables and correct units in the data table - then calculate average speed for each trial.

Trial	Distance (m)	Average Time (s)	$speed = d/t$	Speed (m/s)	Notes
1					
2					
3					

3. Determine the average velocity for all three trials; do not forget to indicate direction.

Average Velocity: _____

4. Use the mass of your model airplane and calculate its momentum ($p = mv$) - show your work.

Mass (m) _____ kg

Velocity (v) _____ m/s

Momentum (p) _____ kg·m/s

APPENDIX D
FORCES OF FLIGHT

Forces of Flight

Name _____ Date _____ Class _____

Background

At any given time, there are four forces acting upon an aircraft. These forces are lift, weight (or gravity), drag and thrust. **Lift** is the key aerodynamic force that keeps objects in the air. It is the force that opposes weight; thus, lift helps to keep an aircraft in the air. **Weight** is the force that works vertically by pulling all objects, including aircraft, toward the center of the Earth. To fly an aircraft, something (lift) needs to press it in the opposite direction of gravity. The weight of an object controls how strong the pressure (lift) will need to be and lift is that pressure. **Drag** is a force generated by the interaction and contact of a solid body, such as an airplane, with a fluid (liquid or gas). Finally, the **thrust** is the force that is generated by the engines of an aircraft in order for the aircraft to move forward.

Website address: <https://interactives.ck12.org/simulations/physics/airplane/app/>

Procedure A

- a) Google: Ck-12 physics simulations
- b) Search: airplane
- c) Play: What makes an airplane “stall”?

1. Draw the four forces acting on an airplane on the diagram:



2. What makes an airplane accelerate?
3. What is the angle of attack?
4. How does an airplane climb?
5. What affects the magnitude of the lift force?
6. What causes an airplane to stall?

Procedure B

- a) Go to the simulation - Play the tutorial at the top, mute the volume and turn on closed captions (cc).
- b) Complete the table below. To calculate the acceleration of the aircraft, divide the net force by the mass of the aircraft.

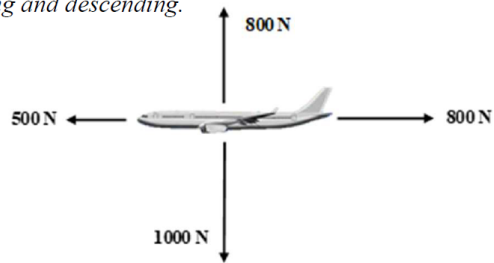
Forces of Flight

Formulaically... $a = F_{net} / m$. Assume the aircraft has a mass of 100 kg.

Setup	Thrust Force (T)	Drag Force (-D)	Lift Force (L)	Weight Force (-W)	Net Force(s)	Acceleration(s)
1	500 N left	800 N right	800 N up	1000 N down	- 300 N right - 200 N down	-300 N / 100 kg = -3 m/s ² right -200 N / 100 kg = -2 m/s ² down
2	500 N left	300 N right	1000 N up	1000 N down		
3	300 N left	500 N right	1100 N up	1000 N down		
4	600 N left	300 N right	1400 N up	1000 N down		
5	100 N left	100 N right	600 N up	1000 N down		

- c) Draw a force diagram for each setup. Use arrows to show the magnitude of the forces and label the arrows. Write one sentence to describe the aircraft's motion.

Setup 1: The aircraft is decelerating and descending.



Setup 2:

Forces of Flight

Setup 3:

Setup 4:

Setup 5:

Procedure C

- a) *Use the simulator and let's fly! Change **airplane size**, **wing profile**, **angle of attack** and **thrust** to maintain level flight at constant speed. Write observations about the effect of each variable.*

1. *Wing Profile* _____

2. *Thrust* _____

3. *Angle of Attack* _____

4. *Airplane Size* _____

APPENDIX E

NEWTON'S LAWS OF MOTION AND FLIGHT

Newton's Laws of Motion & Flight

Name _____

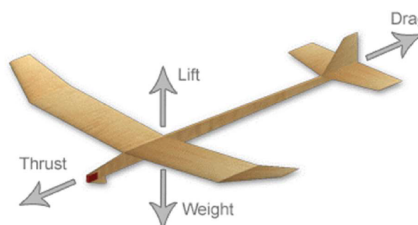
Date _____

Class _____

Background

- Newton's three laws of motion describe the interaction of forces that control movement. The first law states that a body in motion will remain in motion unless acted upon by an **unbalanced force**. The same is true for a body at rest.
- The second law predicts that when an unbalanced force is applied to a body it will produce **acceleration**; while the mass of the body (inertia) resists acceleration.
- The third law explains the result of the interaction of more than one force. Every action has an equal and opposite reaction.

There are four forces that act upon and compete with any airborne object. Thrust and lift produce the force needed for flight, while gravity and drag have the reverse effect. Thrust must exceed drag, and lift must exceed gravity for the flight to continue.



<http://content.whiteboxlearning.com/application/glider/g10102.html>

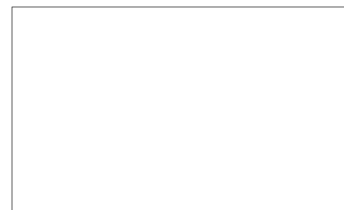
A. Sling-shot Glider

- Place a penny on the wing of the glider as close to the fuselage as possible. Keep the wing and penny parallel with the ground. Launch the glider and observe the motion of the penny.

1. Use the terms friction, gravity, and acceleration to describe this demonstration.

2. Draw a force diagram to show the motion of the penny. Label each arrow with the force acting on the penny.

3. Identify the law(s) of motion you think this demonstrates and explain why.



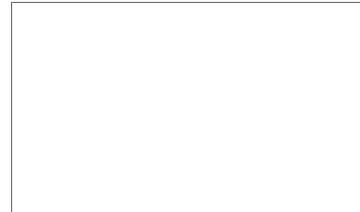
- Launch the just the glider (no penny) with varying amounts of force, measure the length of the band to show how much force is used for each launch. Find the mass of the glider and estimate the time and distance in the table below. Use the variables time and velocity to determine acceleration.

Launch	Length of Band	Distance Traveled	Time	Velocity	Acceleration	Force
#1						
#2						
#3						

- The mass of the glider in kilograms _____
3. Determine the force applied to the glider for each launch.

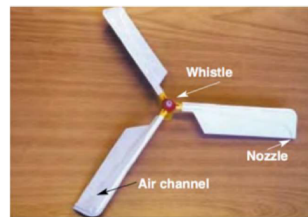
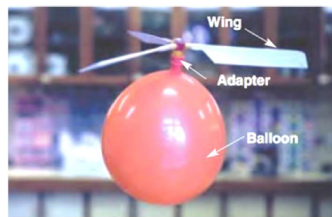
Newton's Laws of Motion & Flight

4. Describe this demonstration using the terms mass, acceleration, and force.
5. Draw a force diagram to show the gliders motion. Label each arrow with the force acting on the glider.
6. Identify the law(s) of motion you think this demonstrates and explain why.

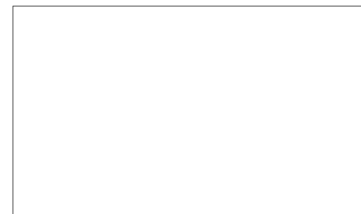


B. Balloon Helicopter

- Follow instructions provided to assemble the Balloon Helicopter. Observe what happens when launched.



1. Describe the balloon helicopters motion using the words thrust and lift. What makes the helicopters wing rotate?
2. Draw a force diagram to show the helicopters motion. Label each arrow with the force acting on it. Identify two forces that are equal and act in opposite directions.



3. Identify the law(s) of motion you think this demonstrates and explain why.

APPENDIX F

FORCE AND MOTION PRETEST AND POST TEST

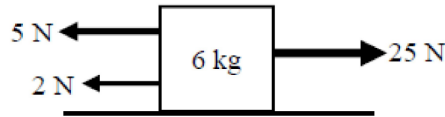
Force and Motion Assessment

Multiple Choice: Pick one answer for each question.

1. If you know the distance an object has traveled in a certain amount of time, you can determine
 - a. the size of the object.
 - b. the speed of the object.
 - c. the location of the object.
 - d. the velocity of the object.
2. Speed equals distance divided by
 - a. time.
 - b. velocity.
 - c. size.
 - d. motion.
3. If the speed of an object does NOT change, the object is traveling at a(n)
 - a. constant speed.
 - b. average speed.
 - c. increasing speed.
 - d. decreasing speed.
4. If a bicyclist travels 30 kilometers in two hours, her average speed is
 - a. 30 km/h.
 - b. 60 km/h.
 - c. 15 km/h.
 - d. 2 km/h.
5. If an object moves in the same direction and at a constant speed for 4 hours, which of the following is true?
 - a. The object decelerated during the 4 hours.
 - b. The object's velocity did not change.
 - c. The object accelerated during the 4 hours.
 - d. The object's speed changed during the 4 hours.
6. A train that travels 100 kilometers in 4 hours is traveling at what average speed?
 - a. 50 km/h
 - b. 100 km/h
 - c. 2 km/h
 - d. 25 km/h
7. When you know both the speed and the direction of an object's motion, you know the
 - a. average speed of the object.
 - b. acceleration of the object.
 - c. distance the object has traveled.
 - d. velocity of the object.
8. You can show the motion of an object on a line graph in which you plot distance against
 - a. velocity.
 - b. time.
 - c. speed.
 - d. direction.
9. In graphing motion, the steepness of the slope depends on
 - a. how quickly or slowly the object is moving.
 - b. how far the object has moved.
 - c. when the object began moving.
 - d. the direction the object is moving.
10. A place or object used for comparison to determine if something is in motion is called
 - a. a position.
 - b. a reference point.
 - c. a constant.
 - d. velocity.

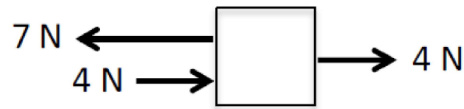
11. On a graph showing distance versus time, a horizontal line represents an object that is
 - a. moving at a constant speed.
 - b. increasing its speed.
 - c. decreasing its speed.
 - d. not moving at all.
12. Velocity is a vector quantity because
 - a. it only indicates magnitude.
 - b. it only indicates direction.
 - c. it is both magnitude and direction.
 - d. distance over time.
13. The moon accelerates because it is
 - a. in the vacuum of space.
 - b. continuously changing direction as it orbits the Earth.
 - c. a very large sphere.
 - d. constantly increasing its speed of orbit.
14. To determine the acceleration of an object, you must calculate the change in velocity during each unit of
 - a. speed.
 - b. time.
 - c. motion.
 - d. deceleration.
15. If velocity is measured in kilometers per hour and time is measured in hours, the unit of acceleration is
 - a. hours.
 - b. kilometers per hour.
 - c. kilometers per hour per hour.
 - d. kilometers.
16. In an acceleration graph showing speed versus time, a straight line shows the acceleration is
 - a. decreasing.
 - b. increasing.
 - c. changing.
 - d. constant.
17. The tendency of an object to resist any change in its motion is known as
 - a. mass.
 - b. inertia.
 - c. force.
 - d. balance.
18. If you know a car traveled 300 kilometers in 3 hours, you can find its
 - a. acceleration.
 - b. direction.
 - c. average speed.
 - d. velocity.
19. Changing direction is an example of a kind of
 - a. acceleration.
 - b. speed.
 - c. velocity.
 - d. constant rate.
20. The greater the mass of an object,
 - a. the easier the object starts moving.
 - b. the greater its inertia.
 - c. the more balanced it is.
 - d. the more space it takes up.
21. Which of these is an example of deceleration?
 - a. a bird taking off for flight
 - b. a baseball released by a pitcher
 - c. a car approaching a red light
 - d. an airplane following a straight flight path
22. Force equals mass times
 - a. speed.
 - b. motion.
 - c. acceleration.
 - d. inertia.

23. Calculate the acceleration of the object below.



- a. 5.3 m/s^2
 - b. 3 m/s^2
 - c. 4.5 m/s^2
 - d. 3.7 m/s^2
24. What net force is required to accelerate a car at a rate of 2 m/s^2 if the car has a mass of 3,000 kg?
 - a. 1500 N
 - b. 3000 N
 - c. 4500 N
 - d. 6000 N
 25. One way to increase acceleration is by
 - a. increasing mass.
 - b. decreasing mass.
 - c. decreasing force.
 - d. increasing both force and mass proportionally.
 26. According to Newton's third law of motion, when a hammer strikes and exerts force on a nail, the nail
 - a. creates a friction with the hammer.
 - b. disappears into the wood.
 - c. exerts an equal force back on the hammer.
 - d. moves at a constant speed.
 27. Two figure skaters who push off of each other will move at the same speed if
 - a. they push with the same force.
 - b. the ice does not cause any friction.
 - c. there is no air resistance.
 - d. they have the same mass.
 28. According to Newton's first law, an object in motion will stay in motion unless:
 - a. An opposing force acts on it.
 - b. It's in outer space.
 - c. It stops.
 - d. It remains at rest.
 29. Which law can explain how gases released from burning fuel in a rocket produce thrust?
 - a. Newton's first law of motion
 - b. Newton's second law of motion
 - c. Newton's third law of motion
 - d. the law of conservation of momentum
 30. What is required for a rocket to lift off into space?
 - a. thrust that is greater than Earth's gravity
 - b. mass that is greater than Earth's mass
 - c. very little air resistance
 - d. more velocity than friction
 31. When two equal forces act on the same object in opposite directions, the net force is
 - a. smaller than either force.
 - b. equal to each of the forces.
 - c. zero.
 - d. greater than either force.

32. What is the net force of the object below and what direction is it accelerating?



- a. 7 Newtons, accelerating to the left
 - b. 7 Newtons, accelerating to right
 - c. 1 Newton, accelerating to the left
 - d. 1 Newton, accelerating to the right
33. What happens when two forces act in the same direction?
- a. They cancel each other out.
 - b. The stronger one prevails.
 - c. They add together.
 - d. Their sum divided by two is the total force.
34. The force that one surface exerts on another when the two rub against each other is called
- a. friction.
 - b. acceleration.
 - c. inertia.
 - d. gravity.
35. The force of gravity on a person or object at the surface of a planet is known as
- a. mass.
 - b. inertia.
 - c. air resistance.
 - d. weight.
36. If you kick a bowling ball and a tennis ball with the same amount of force, according to Newton's Second Law of Motion, what will happen?
- a. The tennis ball will travel farther than the bowling ball.
 - b. The bowling ball will travel farther than the tennis ball.
 - c. The bowling ball will travel faster, but cover a shorter distance.
 - d. The balls will travel the same distance.
37. A 16 kg object experiences a 5 m/s^2 acceleration? Find the force that caused this acceleration.
- a. 3.2 N
 - b. 8 kg
 - c. 21 N
 - d. 80 N
38. What is the weight of a 15 kg rock.
- a. 150 N
 - b. 15 N
 - c. 1.5 N
 - d. 15 pounds
39. If an object falls from rest, how fast will it be going after 5 seconds?
- a. 25 m/s^2
 - b. 10 m/s^2
 - c. 50 m/s^2
 - d. 125 m/s^2
40. Bernoulli's principle helps to explain
- a. hydraulic brakes.
 - b. buoyancy.
 - c. momentum.
 - d. flight.

APPENDIX G
LIKERT SURVEY

Participation in this research is voluntary and participation or non-participation will not affect a student's grades.

Directions: Read the following statements, HONESTLY respond to each by circling the number that corresponds to the scale Strongly Agree-5, Somewhat Agree-4, Unsure-3, Somewhat Disagree-2 and Strongly Disagree-1. *Circle one number for each statement.*

Student Awareness and Interest Evaluation	Strongly Agree	Somewhat Agree	Unsure	Somewhat Disagree	Strongly Disagree
1. I like science more than other subjects.	5	4	3	2	1
2. Math is an important part of science.	5	4	3	2	1
3. I like to do lab activities in science.	5	4	3	2	1
4. I understand the purpose of science lab activities.	5	4	3	2	1
5. I learn more from doing science lab activities.	5	4	3	2	1
6. I often use math in science lab activities.	5	4	3	2	1
7. Science labs simulate what is done in a STEM career.	5	4	3	2	1
8. I have learned about STEM careers from science labs.	5	4	3	2	1
9. Flying on an airplane is a good experience.	5	4	3	2	1
10. I know a lot about aviation and aerospace history.	5	4	3	2	1
11. Women have made significant contributions to aviation.	5	4	3	2	1
12. I think about how airplanes are able to fly.	5	4	3	2	1
13. I understand the science of how airplanes fly.	5	4	3	2	1
14. I think about being a pilot.	5	4	3	2	1
15. I know what is required to be a pilot.	5	4	3	2	1
16. Being a professional pilot is a STEM career.	5	4	3	2	1
17. I know what an air traffic controller does.	5	4	3	2	1
18. Being an aircraft mechanic is not a STEM career.	5	4	3	2	1
19. I think designing airplanes would be interesting.	5	4	3	2	1
20. I know how airplanes are designed and built.	5	4	3	2	1
21. Most aircraft are designed for the same purpose.	5	4	3	2	1
22. My science teacher discusses STEM careers.	5	4	3	2	1
23. Any job using math and science is a STEM career.	5	4	3	2	1
24. I will use what I learn about science in a future career.	5	4	3	2	1
25. I know the career I want to pursue after high school.	5	4	3	2	1

APPENDIX H
POST TREATMENT QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. Did you like doing classroom activities using aviation topics? Explain why or why not.

2. Which activities using aviation topics do you like most? Explain why.

3. What did you learn from lessons using aviation topics?

4. Which activities helped you gain the best understanding of the concepts? Explain why.

5. Are you interested in aviation careers after taking part in these activities? Explain why or why not.
