Lesson Seed

STEM Onboard a Carrier: Catapulting Aircraft & Connecting Math Concepts

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Abstract

This article connects math concepts found within middle school and high school curriculums to the work involved with the deployment of combat-ready naval aviation from a United States Aircraft Carrier. Problems and activities presented in the lesson are inspired by the author's experience as a math educator embarking on an aircraft carrier, specifically USS Theodore Roosevelt, as a Distinguished Visitor and U.S. Navy Community Ambassador. By incorporating various scenarios associated with catapulting aircraft along with a wide range of problems involving simple arithmetic operations, unit conversions, basic measurements, application of coordinates, basic geometry knowledge, and graphing of scatterplots, this paper strives to make math lessons and problems more meaningful for students. As such, real-life connections can highlight math concepts and world issues as well as potential careers, opportunities, and pathways which not only aim to introduce topics, apply knowledge, and reinforce and build math skills but also aim to increase student interest in learning and applying math skills.

Introduction

With 70% of the World covered by water and aircraft carriers able to provide "on-call global airpower" (Commander of Naval Air Forces, 2023), "aircraft carriers are the centerpiece of America's Naval forces" (U.S. Navy, 2021). In June 2023, I had the great privilege to embark on the USS Theodore Roosevelt Aircraft Carrier, located somewhere in the Pacific Ocean, tour the carrier, dine with crew members, observe flight operations, and learn more about the roles and responsibilities of carrier crew. Wanting to share my experience with others and understanding the need to better educate students on the work being done by the men and women of our Navy, as well as highlight math connections in the real-world, I formulated scenarios involving math concepts inspired by the experience I encountered while on the carrier.

The USS Theodore Roosevelt, like the other ten aircraft carriers operated by the United States Navy, are powered by onboard nuclear reactors that boil seawater creating steam leading to pressure that provides power (Low, 2016) for electricity onboard the carrier, propellers to move the ship forward, and catapults that launch planes off a runway only 300 feet, a fraction of a traditional runway (U.S. Navy, 2021). Focusing on the roles and responsibilities of those involved with the launching of aircraft with catapults, this article provides examples of scenarios that connect math concepts found within middle school and high school mathematics curriculum to the work involved with the deployment of combat-ready naval aviation.

With the National Council of Teachers of Mathematics (2000) sharing that workplace learning experiences are "effective in motivating students who are at risk of becoming disengaged from school" (p. 374), this article focuses on the math connections and associated careers related to the launching of aircraft. While this article addresses just a few of the roles and responsibilities needed to be served on a carrier, there are 2000 air wing crew members and 2800 ship crew members onboard a carrier (Commander Naval Air Forces, 2023) and the scenarios presented in this article are just a glimpse of the careers, math connections, and STEM principles that could be highlighted within middle school or high school mathematics curriculum.

Scenario 1

Being powered by nuclear reactors, an aircraft carrier does not need fuel to operate; however, the aircraft in which they transport require jet fuel to fly. This fuel, the plane itself, the pilot, and any other payload such as weapons and ammunition, determines the gross weight of the aircraft and the amount of steam that is needed to catapult a fighter jet off the deck of a carrier.

Scenario 1 Problems (solutions at the end of the article)

a. Aircraft crew with purple shirts (known as "Grapes" or "Fuelies") move, monitor, and test fuel as well as refuel aircraft (US Navy, n.d.-a). If an empty Super Hornet is known to weigh 32,100 pounds (Boeing, n.d.) and "Grapes" are told to load the plane with 4,440 gallons of jet fuel, where fuel is known to weigh 6.7 pounds per gallon, what will be the gross weight of the aircraft, if the pilot flying the plane is 200 pounds?
b. Aircraft crew with red shirts (known as "Ordies") build, maintain, and mount all ordnance on aircraft (US Navy, n.d.-b). If the maximum takeoff weight for a Super Hornet is 66,000 pounds (Boeing, n.d.) how many pounds of ordnance in the form of weapons or ammunition could be mounted onto the Super Hornet mentioned in part A?

Scenario 2

In addition to the weight of an aircraft playing a factor in how much steam is needed to catapult an aircraft, wind speed and wind direction must also be taken into consideration. Aerographers, also known as AG's, collect, interpret, and report various weather data using satellites, radar, and other instruments such as with the anemometer (Figure 1) which measures wind speed. While AG's may not be found on the flight deck of a carrier, the information they provide, with wind reports updated every 30 minutes, is crucial for flight operation (US Navy, n.d.-f).

Figure 1

A handheld anemometer

Note. An aerographer using a handheld anemometer to measure wind on a carrier (Stanton, 2022).

Scenario 2 Problems (solutions at the end of the article)

a. Research the internet on how to build a handmade anemometer, then build your own.
b. Determine how many revolutions your handmade anemometer will spin in front of a fan for 1 minute.
c. What is the distance across your anemometer?
d. Determine the circumference or distance the anemometer traveled in 1 revolution.
e. Determine the speed of the wind using: circumference x revolutions per minute

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Scenario 3

Aircraft Directors and Handlers, those with yellow shirts on board an aircraft carrier, are responsible for the moving of aircraft on the flight deck. (US Navy, n.d.-c). To coordinate the timely movement of aircraft to certain places, the Aircraft Handling Officer, also known as "The Handler," oversees all movement (US Navy, n.d.-d) using a physical scale model known as the "Ouija Board" (Figure 2).

Figure 2

Ouija Board located in the Flight Deck Control Operations Center of a Carrier

Note. The picture shown is of the author with the "Handler" onboard the USS Theodore Roosevelt learning how the Handler uses the "Ouija Board" to coordinate and track movement of every aircraft on the carrier (Remijan, 2023a).

Scenario 3 Problem (solutions at the end of the article)

If the "Ouija Board" uses a scale of 1/16 in = 1 ft (Wolverton, 2008) and the USS Theodore Roosevelt has a flight deck that is 1,092 feet long x 252 feet wide (Commander of Naval Air Forces, 2023), what are the dimensions of the flight deck on the Ouija Board?

Scenario 4

Catapult crew members, identified by wearing green shirts, have various responsibilities that are crucial in operating and maintaining launch equipment such as jet blast deflectors (US Navy, n.d.-e). Jet blast deflectors, also known as JBDs lay flush with the flight deck until raised remotely by a Jet Blast Deflector Operator who sits to the side of a JBD (Figure 3). The purpose of a raised JBD is to redirect high temperature jet blast exhaust, created by full throttled aircraft in the final stages of the catapult process, away from flight deck personnel and equipment.

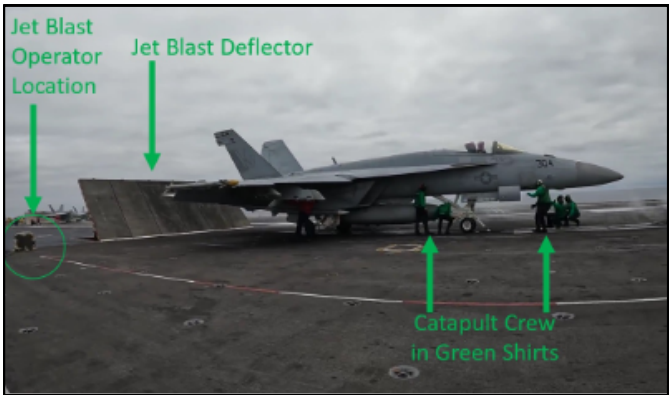
Scenario 4 Problems (solutions at the end of the article)

a. If a jet blast deflector consists of 6 rectangular panels that are each 14ft x 6ft each (Wallace, 2002), determine the area of one JBD.
b. Using Desmos, measure the angle in which a jet blast deflector is raised using the image found at https://www.desmos.com/geometry/nnkln2vidx.

c. Jet blast deflectors are raised and lowered with the help of hydraulic arms, also known as linear actuators. Build a hydraulic arm following the steps provided by the US Naval Academy STEM Center at https://usna.edu/STEM/hydraulics.php, build a modified version, or make your own version of a hydraulic arm.

Figure 3

Jet Blast Deflector Remotely Raised by a Jet Blast Deflector Operator



Note. Left image showing a JBD being raised in video found at https://youtu.be/sOodVA_cDI8 (Blumer, 2023). Right image showing a closeup of a JBD Operator (Murray, 2007).

Scenario 5

After an aircraft moves in front of a jet blast deflector, an Aircraft Director, identified in a yellow shirt, directs the pilot to move the aircraft into place at the back of a catapult using various hand signals. Next, the Catapult Crew, in green, attaches the aircraft to the shuttle of the catapult located in a trough of the flight deck runway.During this time, the Catapult Officer, better known as the "Shooter", also designated with a yellow shirt, reviews the aircraft's weight provided by the Weight Board Operator as well as the wind speed reported by an Aerographer.Using this information, the Shooter then refers to a table (Gateau, 2002) to find a code that is communicated to the catapult crew below deck on how much steam is needed to launch the plane (PBS, 1996). Once the "Shooter" confirms that the aircraft, catapult, and surrounding crew are all in position, the "Shooter" will give the final signal for launching the aircraft by touching the ground and pointing down the runway (US Navy, n.d.-g).

Scenario 5 Problems (solutions at the end of the article)

a. Watch and reflect on video of the catapult process found at https://youtu.be/5d4dJaV-9V0. What do you notice? What do you wonder?
b. Using the rate of the launch process shown in the video above, how many aircraft could hypothetically be launched from one catapult in 1 hour?

Scenario 6

To prepare catapults or to ensure that catapults are working properly, operational carriers will periodically conduct "no-load" catapults with no aircraft attached (Chakraborthy, 2016). A "no-load" catapult simulation can be conducted in a school setting as shown at https://youtu.be/4k9MeMS2hVY where a plastic straw

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represents a shuttle, a string represents the trough found on the runway of the flight deck, and a "rocket-type" balloon pumped with air represent the cylindrical pistons of a steam-filled catapult.

Scenario 6 Problems (solutions at the end of the article)

a. Conduct 3 no-load launch simulations involving a rocket balloon pumped with air by a hand-pump, a straw, and a string connected to two chairs that are 25 feet apart. After each launch, complete the chart in Figure 4.
b. What do you notice from the results found in your chart of data?
c. Create a scatterplot graph comparing the number of pumps of air to balloon length. Then, use the graph to predict the length of a balloon with 5 pumps of air.
d. Create a scatterplot graph comparing the number of pumps of air to balloon width. Then, use the graph to predict the width of a balloon after 5 pumps of air.
e. Create a scatterplot graph comparing the number of pumps of air to distance the straw traveled along the string. Then, use the graph with a regression to predict how far the straw will travel using a balloon with 5 pumps of air.
f. Conduct a final no-load launch simulation experiment using a balloon with 5 pumps of air and test your predictions for balloon length (part C), balloon width (part D), and distance the straw traveled (part E).

Figure 4

Chart for Collecting Data

# of Pumps of Air	Balloon Length	Balloon Width	Balloon Volume (Cylinder) V = (π r^2)h	Distance Straw Traveled
2				
3				
4				

Conclusion

Educators must teach and reach all students, make connections in the real world, incorporate timely connections of what is happening in the world around them, and provide connections on potential careers and pathways whether that be college, technical school, or the military. Problems related to "task and talk" aim to transform interest in learning mathematics related to aircraft carriers, careers, or current events into interest in learning mathematics itself.With many middle-school and high school teachers encountering students who find mathematics "uninteresting and irrelevant" or students who lack the motivation to learn mathematics (NCTM, 2000, p. 371), scenarios addressing math concepts with real-life connections and work relevance can make math more meaningful & motivating for all students (NCTM, 2000).

When teachers can integrate contextual problems, have students engage with problems where they build something or conduct an experiment to collect data, students are more likely to take an interest in what they are learning and/or what is being discussed. Discussions related to current events, relatives in the Navy, opportunities related to the Navy (enlistment, ROTC, collegiate programs, or the Naval Academy), or our country having a volunteer military compared to other countries that require young people to serve may help to build student interest, especially when some students may "dislike" math but like talking about the "non-math" connections related to the problems. Finally, when math students from various ethnicities & socioeconomic backgrounds experience quality instruction & are informed of the pathways & opportunities available w/ STEM, such as with the Military, specifically in this case showcasing the catapult on a carrier, "a culture of equity (can be developed) where each and every person has access to and is empowered by the opportunities mathematics affords" (NCTM Strategic Framework, 2017).

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Scenario Solutions

Scenario 1

a. 32,100 + 4440(6.7) + 200 = 62,048 pounds
b. 66,000-62,048 = 3,952 pounds

Scenario 2

a. Results may vary.See an example of a handmade anemometer (Figure 2) with directions found at https://youtu.be/BtbjmBH5Xuc.
b. I placed the anemometer in front of a fan and turned on the fan. Filming the anemometer, I replayed the video in slow motion and counted the number of times that the red cup, shown in figure 5, went around in 20 seconds. Determining that the cup went around 33 times in 20 seconds, I then took 33 and multiplied it by 3 to determine the number of revolutions in 60 seconds, or 1 minute, to be 99 times.
c. Answers will vary. I suggest working with an anemometer that is 1ft across like I did to make calculations more math friendly.
d. Answers may vary based on the size of the anemometer, but since I used an anemometer with a diameter of 1 ft, the circumference would be C = π • 1ft = π ft or 3.14 ft as an approximation.
e. Answers may vary based on the anemometer used, but using the circumference or distance traveled in one revolution by my anemometer, I determined wind speed: π feet • 99 revolutions per minute = 310.86 ft/minute. Next, I converted the speed of the wind to miles per hour:

$$\frac{310.86\text{ ft}}{1\text{ minute}} \times \frac{60\text{ minutes}}{1\text{ hour}} \times \frac{1\text{ mile}}{5280\text{ ft}} = 3.5\text{ mph}$$

Scenario 3

Length = 1092 x 1/16 = 68.25 inches or 5′ 8 ¼″
Width = 252 x 1/16 = 15.75 inches or 1′ 3 ¾″

Scenario 4

a. Answer = 6 (14 x 6) = 504 sq feet
b. Answer: The result should be close to 50°, the angle most JBDs are raised (Wallace, 2002)
c. Answer: Results may vary. See an example of my hydraulic arm found at https://youtu.be/Mj0znKheMQk.

Scenario 5

a. Answers will vary.
b. Answer:It took 1 minute 43 seconds (103 seconds) for the aircraft in the video to be launched. If 1 hour equals 60 minutes (3600 seconds), we can take 3600/103 to determine that 34 planes could theoretically be launched in 1 hour from one catapult if the wind, condition of the sea, type of aircraft remained constant, and all aircraft were prepped and ready to go for all those launches.However, with four catapults on a carrier, all four catapults can work in a coordinated manner to take turns launching aircraft and could, if needed in a critical situation, launch 90 aircraft on the carrier in about 20 minutes (Navy Production, 2023b).

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Scenario 6

a. Results may vary from group to group. See example below.

# of Pumps of Air	Balloon Length	Balloon Width	Balloon Volume (Cylinder) $V = \pi(r^2)h$	Distance Straw Traveled
2	4.5 in	3 in	$V = \pi(1.5)^2 \cdot (4.5) \approx 31.79$ in^3	48.5 in
3	6 in	3 in	$V = \pi(1.5)^2 \cdot (6) \approx 42.39$ in^3	95 in
4	8 in	3 in	$V = \pi(1.5)^2 \cdot (8) \approx 56.52$ in^3	220 in

Note. To determine the distance the straw traveled, one could mark a point on the floor that lies underneath the front of the straw before the balloon fires, fire the balloon, mark a point on the floor underneath the front of the straw after the balloon is fired, and then measure the distance between the two points on the floor using a tape measure.

b. As the number of pumps increases, the balloon length will increase, the balloon width remains the same, the amount of air (or volume) increases, and the distance the straw travels increases.

c. Results will vary, but an example of a graph made with Desmos can be found at https://www.desmos.com/calculator/9nj2qtra7l. Using the graph, one might use their eyes only to estimate the length of a balloon after 5 pumps of air to be 10 inches and someone else might use a linear regression and estimate the length to be 9.5 inches as shown at https://www.desmos.com/calculator/rz0hxdk8ti.

d. Results will vary, but an example of a graph made with Desmos can be found at https://www.desmos.com/calculator/enmcahars9. Using the graph, one might use their eyes to predict that the width of the balloon after 5 pumps of air to be 3 inches. While it may not be necessary to create a scatterplot in this case, the measurements may be slightly different in other cases and a scatterplot or linear regression may be helpful.

e. Results will vary based on the data collected.An example of a scatterplot graph made with Desmos can be found at https://www.desmos.com/calculator/aav1d0cqvh. Using the graph and performing a linear regression within Desmos, one could formulate a linear function of to predict the distance the balloon would travel to be approximately 295 inches (or approximately 25 ft) as shown at https://www.desmos.com/calculator/wrhbvz7hi4. However, if someone else used the graph and an exponential regression to formulate an exponential function of , one would predict the distance traveled to be 496 inches (or approximately 41ft), as shown at https://www.desmos.com/calculator/b43bxo7jpa.

f. Results will vary.

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