Endeavor STEM Teaching Certificate Project
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5E Integrated STEM Lesson Plan – Template

Lesson Title: Compressed Air Rocket Launch

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Topic: Quadratic Functions, Energy

Targeted Grade Level: High School (10-12)

Time Needed: 8 days

Subject Integration: Mathematics, Engineering, and Science

Justification: In this lesson students will model the height of a compressed air rocket as a function of time. To help students better understand why a vertical launch of a rocket creates a quadratic model, students will learn about the different types of energy (potential, kinetic, and gravitational potential energy) and the transfer of energy involved in a rocket launch. Students will use the model they create for their rocket to determine the maximum height that the rocket reaches when launched. Students will then use this data to engineer their own rocket design to try to maximize the height that a rocket can reach when launched at a specific PSI. Through integrating the mathematics and science standards with the engineering design process, students will be able to create connections among the content. Students will be able to see a purpose in the mathematics and calculations that they usually learn with no context, and the mathematical modeling will provide students a visual representation that will allow them to make better sense of the transfer of energy and better understand the forces acting on a rocket. Through the design process, students will analyze the data and make observations to develop their own designs and test those designs to maximize effectiveness.

Standards:

NGSS Performance Expectations

HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ***Using Mathematics and Computational Thinking*** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Use mathematical representations of phenomena to describe explanations.	***PS2.A: Forces and Motion*** ● Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) ***PS3.A: Definitions of Energy*** ● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. ***PS3.B: Conservation of Energy and Energy Transfer*** ● Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. ● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. ● Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. ● The availability of energy limits what can occur in any system.	***Cause and Effect*** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects ***Systems and System Models*** ● Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Common Core State Standards:
Math: MP.2 Reason abstractly and quantitatively MP.4 Model with mathematics MP.5 Use appropriate tools strategically KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems. KY.HS.A.18 Solve linear equations and inequalities in one variable, including literal equations with coefficients represented by letters. KY.HS.A.13 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator). KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
ITEEA Standards
Other Standards

Measurable Student Learning Objectives:

- Students will be able to model the height of a compressed air rocket as a function of time (algebraically and graphically).
- Students will be able to calculate the vertex of a quadratic function and interpret its meaning in context.
- Students will be able to describe how the forces of thrust and gravity affect the travel of the rocket.

- Students will be able to describe the transfer of energy in the vertical launch of a compressed air rocket and label the types of energy present at different points on the model of the rocket launch (Height(time)).

Nature of STEM: This lesson addresses the nature of mathematics by allowing students to model real-world phenomena with mathematics then use that model to reason abstractly and quantitatively to solve problems and make decisions in design and engineering. These practices are two of the 8 mathematical practices that define the nature of mathematics. This lesson also addresses the nature of science since science assumes the universe is a vast single system in which basic laws are consistent, and students will be connecting Newton's second law of force the laws of energy to the real-world phenomena of a rocket launch. Students will also see how science is empirical and based on observations and interpretations of the world around us. Students will use data to make interpretations and compare their interpretations to their classmates to see that not all conclusions may be the same- science can be influenced by bias. Lastly, this lesson also incorporated the engineering design process in that students will be asked to design a rocket that will reach a maximum height when launched, will test their design, compare their results to the results and designs of their classmates, then describe changes that they would make to their design to repeat the process.

Engaging Context/Phenomena: In order to engage students, I plan to show a video of a rocket launch and have students discuss the uses for rockets that launch satellites and other objects into space for orbit. Our high school also has a rocket team that competed nationally in the Team America Rocketry Challenge 2019. I would like to show a video of one of their rocket launches at the national competition and maybe even have a student on the team share their experience with my class.

Data Integration: Students will be collecting their own data for analysis through launching compressed air rockets using an air compressor and a PVC launch device. Students will use stopwatches to time the moment from launch to landing, then use the vertical motion formula for data analysis and modeling.

Differentiation of Instruction: Students will be working in teams throughout the lesson to collect, analyze, and interpret data as students address the learning targets of this lesson. There are also levels of scaffolding that I can provide to students that are struggling at any point during the lesson through questioning/explaining. Students will also be provided with technology resources such as graphing calculators to assist with graphing and analyzing their function. In an effort to limit behavioral disruptions, the teacher will group students into teams of four. Students will be assigned roles within their group in an effort to ensure each student participates.

Real-life Connection: In this lesson, students will be experiencing a simplified version of what real space and aeronautic engineers do daily to launch real rockets and their cargo into space. During the engagement of this lesson, I hope to lead students in a discussion of how rockets and what they launch into space (such as satellites) affects students' daily life (such as providing internet, cell service, surveillance/security, etc...).

Possible Misconceptions: Due to the primarily straight up, then down path of the rocket, students may assume that the model of the rocket launch (height as a function of time) would look more like an absolute value function with a constant rate of increase, then rate of decrease. By teaching the science of forces and energy with this lesson, I hope that students will better understand why the model that is produced by the rocket launch is quadratic.

Lesson Procedure:

5E Model	5E Objectives
Engage	**Procedure:** Teacher will show a video of the Falcon Heavy rocket launched into space to release a Tesla Roadster into orbit as a test launch, then watch its return to earth. Teacher will lead discussion of why rockets that launch satellites into space are important to society. Students will brainstorm and provide answers for how rocket launched like the one viewed would relate to them (satellites for cell service, internet, TV, national security, surveillance, etc…). Teacher will then lead discussion on what key factors would be important to consider when designing such a rocket. Students will brainstorm and provide answers (such as tip to minimize air resistance, force needed for lift off, fins shape, etc…). Teacher will explain to students that we are going to be exploring some of the science and mathematics that engineers must consider when designing rockets by constructing and launching our own compressed air rockets. The goal will be for the students to construct a rocket that will reach the maximum height when launched at 90 PSI. **Modifications** Students will be participating in whole-group discussion. In a class where many students don't often feel confident sharing out loud, teacher may have students write 1-2 ides on a post it that students then place on a white board and the teacher reads off different ideas for students to discuss. **Standards Addressed** N/A **Formative/Summative Assessments** Whole group discussion/questioning to engage students by relating to real-world and assess prior knowledge

	Resources https://www.youtube.com/watch?v=sX1Y2JMK6g8, https://docs.google.com/document/d/1fX_nj3w6CfK6aE6TJMy1vgedeekZeE-sFAOV7r0tglA/edit?usp=sharing
Explore	**Procedure:** Students will work in teams to construct a rocket following provided guidelines. Students will follow instructions and materials provided to create a rocket that they will use to launch and collect data. Once student rockets are constructed, students will launch all of their rockets using a PVC rocket launch device and stopwatches. Students will time the launch from the moment of launch to the time it hits the ground. Students will collect all times for all rockets for data analysis in the explain portion of the lesson. Students will draw a rough sketch what they think the graph of their rocket's height in terms of time would look like and explain why. Students will make predictions for the height their rocket reached and which rocket flew the highest. **Modifications** Students will work in teams to collect data. Each student will fill one of 4 roles: rocket launcher (count down and launch rocket), timer (records time from launch to landing), data recorder (records time and analysis of group), and videographer (records team launch with cell phone or teacher provided camera). Scaffolding will be provided as needed through questioning/explanation. **Standards Addressed** MP. 5 Use appropriate tools strategically **Formative/Summative Assessments** Students will share their predictions with the class and justify their reasoning for their model and height predictions. This will allow teacher to assess prior knowledge. **Resources** https://drive.google.com/open?id=1GazuILIMjmNrcLlL4f4sAbUeDjv1ULTbVE35GRqqX8o
Explain	**Procedure:** Teacher will lead students through analysis of the data and an explanation of the concepts that result in the model of the data. Teacher will show students the formula for vertical motion and guide students in using their team's data to calculate the initial velocity of their rocket and creating an algebraic model for the height of their rocket as a function of time. Students will then graph their model. Teacher will lead discussion to get students to understand why the vertical motion of the rocket results in a quadratic model by discussing the forces acting on the rocket and the transfer of different types of energy transferred along the rocket's flight. Students will then use their model to locate the vertex of their rocket's flight and use it to interpret the maximum height that the rocket reached on its launch. **Modifications** Students will still be working in teams to create their models and analyze their data. Scaffolding

	from the teacher will be provided as needed if students get stuck in the process. Students will be able to use technology (graphing calculators) to assist in making models and calculating the vertex of the quadratic model. **Standards Addressed** ● KY.HS.A.18 Solve linear equations and inequalities in one variable, including literal equations with coefficients represented by letters. ● MP.4 Model with mathematics ● KY.HS.A.13 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. ● KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator). ● HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. ● KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems. ● KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented. **Formative/Summative Assessments** Student created models and calculations, as well as classroom discussion from students will serve as formative assessment during this portion of the lesson. **Resources** https://docs.google.com/presentation/d/1XayB2Guc_Ne3cyzEFdr66B4zumU4sISgZ41lD5zhVF0/edit?usp=sharing
Elaborate	**Procedure:** Students will use the concepts that they learned and practiced in the exploration and explanations portions of the lesson to design their own rocket. The goal will be to design a rocket that will reach the maximum height (teacher may even offer a reward for the team that is most successful). Students will develop a design based on prior knowledge and that gained earlier in this lesson to use the provided materials and create their own rocket design. Students will then launch their rockets and collect data as they did in the exploration phase of the lesson to be analyzed in the evaluation portion of the lesson. **Modifications** Students will again work in teams to develop and construct a new rocket design to launch. Team roles will be as they were in the previous phases of the lesson. Scaffolding will be provided by the teacher for

	groups struggling as needed. Students will be provided the original construction instructions as a starting point. **Standards Addressed** ● Engineering design process ● MP. 5 Use appropriate tools strategically **Formative/Summative Assessments** Teacher will formatively assess the engineering design process through observation and through student reflection in the next phase of the lesson. **Resources** https://docs.google.com/document/d/131RG3tHJMaCBQnah4rG93oMfEFvS-MJnisUCJ9cW0ow/edit?usp=sharing
Evaluate	**Procedure:** Students will repeat the data analysis process modeled by the teacher in the exploration phase to model and analyze the effectiveness of their rocket design (did the design effectively combat gravity/air resistance/other factors to produce the maximum height during flight possible?). Students will use their model to answer questions and compare their results to those of their classmates to make further modifications to their design. **Modifications** Students will remain working within their team to collaborate on data analysis and interpretation. Teacher scaffolding will be provided as needed. Students will be provided with graphing calculators to assist in modeling and calculations. **Standards Addressed** ● KY.HS.A.18 Solve linear equations and inequalities in one variable, including literal equations with coefficients represented by letters. ● MP.4 Model with mathematics ● KY.HS.A.13 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. ● KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator). ● HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. ● KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems. ● KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be

	represented. **Formative/Summative Assessments** Students will complete their final data analysis and use their data to re-evaluate the effectiveness of their rocket design and describe additional modifications that they may make to further improve their design. Students will turn in their data model, calculations, and design analysis as a formative assessment of the students' achievement of the learning targets. **Resources** https://docs.google.com/document/d/1qBcAuG8Es5gN5Gd93CT8sFMnZ12UFPx6lZPWYDbvWeg/edit?usp=sharing **https://docs.google.com/document/d/13vGX61rj-QK1Snyif2AyDb2MO2ge6pWEA_x0vlVRRM0/edit?usp=sharing**

Teacher Background:

Topics that would be important for the teacher to understand:

- Quadratic Functions
- Substitution of variables and solving an equation for a given variable
- Graphing a function with/without technology
- Calculating the vertex of a quadratic function with/without technology
- Force https://www.nasa.gov/pdf/544863main_E2_Spacecraft_Structures_C3_Final.pdf, https://www.grc.nasa.gov/www/k-12/rocket/TRCRocket/rocket_principles.html
  - Thrust
  - Gravity
- Energy http://sciencing.com/forms-launching-water-bottle-rocket-8286884.html
  - Potential
  - Kinetic
  - Gravitational Potential Energy

Students would need a basic knowledge of:

- Quadratic Functions
- Substitution of variables and solving an equation for a given variable
- Graphing a function with/without technology
- Calculating the vertex of a quadratic function with/without technology