Endeavor
STEM Teaching Certificate Project

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5E Integrated STEM Lesson Plan – Template

This template serves as a guide for developing a lesson that integrates across subject areas and includes the components of a quality STEM lesson. Please use it to support your work and engage in discussions with your instructors and peers when you have questions.

Lesson Title: Thrillsville

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Topic(s): *Making sense of Newton's Laws of motion*

Targeted Grade Level(s): *7th grade*

Time Needed: *3 class periods (55 min each) - 1 class period to research/plan, 1 class period to build and test & 1 class period to reflect and analyze data.*

Subject Integration: *Science, Math, Engineering & Literacy*

Justification:

Science- Understanding Newton's laws will help the students understand how a roller coaster works and what is needed to complete the task.

Engineering- Understanding the Engineering Design Process will allow the students to work through the project. Students will understand and be expected to use each step of the engineering design process to complete this project. The students will be expected to understand that the "plan" portion of the process will be the most important.

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Math- The students will collect data when they test their roller coaster. They will use the data to compute the speed and acceleration. Once the time trials have been completed, the students will graph their data so they can explain their findings to their classmates. Also, the students will have to complete a budget and a purchase order to buy products to build their roller coaster.

Literacy/ELA - The students will read various articles about the science of roller coasters. They will practice the concept of annotation during this process. The project requires that students has to write a letter to the city council, explaining why the town needs to build this roller coaster. This letter will require the students to explain their budget to the council.

Standards:

NGSS Performance Expectations **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (Grades 6 - 8)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	*Models of all kinds are important for testing solutions.* *The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.*	

NGSS Performance Expectations **MS-PS3-2.** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. (Grades 6 - 8)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
• *Develop a model to describe unobservable mechanisms.*	• *A system of objects may also contain stored (potential) energy, depending on their relative positions.* • *When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.*	• *Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.*

NGSS Performance Expectations **MS-PS3-5.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. (Grades 6 - 8)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:

• *Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.* • *Science knowledge is based upon logical and conceptual connections between evidence and explanations.*	• *When the motion energy of an object changes, there is inevitably some other change in energy at the same time.*	• *Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).*

Common Core State Standards:

Math: 6.NS.2- Fluently divide multi-digit numbers using the standard algorithm. (Grade 6).

8.SP.1- Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association and nonlinear association (Grade 8).

ELA: *RL.7.1- Cite several pieces of textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.*

C.7.1- Compose arguments to support claims with clear reasons and relevant evidence.

a. Produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience.

b. Introduce claim(s), acknowledge opposing claims and counter/refute them and organize the reasons and evidence logically.

c. Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.

d. Use transitions to create cohesion and clarify the relationships among claims.

e. Establish and maintain a task appropriate writing style.

f. Provide a concluding statement or section that supports the argument presented.

g. With some guidance, develop and strengthen writing as needed by planning, revising, editing, rewriting or trying a new approach, focusing on how well purpose and audience have been addressed.

ITEEA Standards

Students will develop an understanding of engineering design. (Grades K-12)

Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. (Grades K-12)

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Design is a creative planning process that leads to useful products and systems. (Grade 6-8) Energy is the capacity to do work. (Grade 6-8).
Other Standards

Measurable Student Learning Objectives:

- *Student's will be able to explain why it is important for engineers to understand how roller coasters work.*
- *Student's will be able to explain in physics terms how their model roller coasters work.*
- *Student's will be able to discuss the effects of gravity and friction in the context of their roller coaster designs.*
- *Student's will be able to identify points in a roller coaster track at which a car has maximum kinetic and potential energy.*

Nature of STEM:

This lesson addresses the "nature of" STEM by allowing the students to learn by doing. This activity incorporates science, technology, engineering and math as key components of this project. This project allows students to become thinkers and innovators. It allows them to be able to research the type of roller coaster that they want to build a model of with the constraints given. The students were allowed to go through the engineering process to guide them step by step through the project. During the plan process, the students had to design the roller coaster with measurements and accuracy (the students were told that another group should be able to build their roller coaster through the design that they worked on).

Through collaboration with other students, the students would be able to learn about Newton's Laws and how they apply to real world situations. Overall, the student will be allowed to learn as a whole instead of just the parts.

Engaging Context/Phenomena:

STEMonstrations: Kinetic and Potential Energy

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Data Integration:

Once the roller coaster is built, the students will be collecting data as they test the roller coaster. They will conduct trials to be able to calculate the speed of the marble through the roller coaster. The data will be collected at different parts of the roller coaster. When the data is analyzed, they will be able to explain what laws of motion were acting upon the marble at what given section. They will have to do 3 separate trials and put the data into a table. Once the table is created, they will have to create a graph to show their reasoning.

Differentiation of Instruction:

- *For lower level students, have the students find "YouTube" videos to explain the physics of a roller coaster. When they build their own roller coasters allow them to discover the concepts of energy conservation, friction and gravity.*
- *For higher level students, introduce equations for potential and kinetic energy so students can calculate both forms of energy and verify the law of conservation of energy. Have students explore loops along with the concept of critical velocity. Have students find the starting height of a roller coaster necessary to complete a loop of a given height.*

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Real-life Connection:

The real-life connection is that almost every student has seen or rode on a roller coaster. They have felt or heard of the "weightlessness" they get when they ride one. For those that have never experienced a roller coaster, use an example of driving down a road and going over a short hill. The feeling you feel in your stomach is similar to what you feel on a roller coaster. Once the project starts, the student should understand how important the planning process can be in everyday lives. The student will understand that the engineering process can be used in everyday life, not just in science class.

Possible Misconceptions:

A misconception that students seem to have about Newton's first law of motion is that force is needed to keep an object in motion and that a moving object stops when its force is used up.

Lesson Procedure:

5E Model	5E Lesson Elements
Engage *Introduce the lesson with an anchoring phenomenon. Facilitate student questions, discussion, etc. as appropriate. Elicit students' ideas about the phenomenon with goal of making the*	**Procedure:** *Did you know that there are many science principles around the design of a roller coaster?* *Show the video of* STEMonstrations: Kinetic and Potential Energy *STEMonstrations: Kinetic and Potential Energy. After the video, open up the floor for discussion about student knowledge of roller coasters.* **Modifications** *Students will explain their history of roller coasters, either as a viewer or a participant. The teacher will make sure that the students can explain in detail for those that have not had the opportunity to be either.*

lesson responsive to students lives and knowledge.	**Standards Addressed** *ITEEA Standard:* Design is a creative planning process that leads to useful products and systems **Formative/Summative Assessments** *Students will be assessed by their explanations of their knowledge of roller coasters. The Q&A session will determine students' understanding of Newton's Laws of Motion.* **Resources** *STEMonstrations: Kinetic and Potential Energy*
Explore *Plan for students to engage in hands-on activities that are designed to facilitate conceptual change.*	**Procedure:** *Day 1* 1. *The students will begin the day with the phenomena. After the video, the students will participate in a Q&A session to discuss the video.* 2. *The project "Thrillsville" will be explained to the students.* 3. *To understand the science behind the roller coaster, the students will work independently on the Energy Skate Park activity and do the accompanying worksheet that goes with the lesson. This activity will help the students understand conservation of Mechanical Energy using kinetic, gravitational potential, and thermal energy.* *Day 2* 1. *The students will review the previous lesson.* 2. *The students will be reminded of the project that they are beginning to work on together.* 3. *The students will be provided instructions on how to work on the Gizmo: Roller Coaster Physics - with accompanying worksheet.* 4. *The students will be allowed to work in pairs to complete this activity.* *Day 3*

	1. *Students will work in groups.* 2. *The groups will design the leadership roles for the group. These include: Facilitator, Scribe, Spokesperson, Time-keeper, Group Rater and Affirmer.* 3. *The students will begin researching roller coasters. They are* 4. *They will assign group roles for each student in the group.Students will work in groups to build a roller coaster. The criteria/constraints for the roller coaster will be explained.* 5. *The students will focus on brainstorming/researching on roller coaster design today.* *Day 4* 1. *The students will begin the planning process of their roller coaster. The students will make sure that their design meets the criteria for the project. Also, their design must include measurements as accurate as possible. This is to ensure that building the roller coaster will be as close to their plan as possible.* 2. *The students will be responsible for making out a supply list and creating a budget of materials that they would need to build the roller coaster.* *Day 5* 1. *The students will begin the process of building the roller coaster. Once the roller coaster is built to specifications from their plan they can test their roller coaster.* 2. *If the roller coaster works, they can start working on their time trials to find the speed of their marble. The students need to record their findings on the data table.* 3. *If the roller coaster doesnt work, they need to go back to the plan process and work improving their roller coaster so that the marble does go through the roller coaster.* *Day 6* 1. *The students will analyze their data and calculate acceleration and speed.* 2. *The students will use their data and create a graph per position on the roller coaster.* 3. *The students will report their findings to the class.*

	Day 7 1. *The students will use their data and graphs to write a letter to the city council proposing that they build a roller coaster for the community.* **Modifications** *The worksheets will be modified according to the students ability. The groups the students will be put in will be differentiated according to the student's different ability levels.* **Standards Addressed** *MS-ETS 1-4* *MS-PS3-2* *MS-PS3-5* *6.NS.2* *8.SP.1* **Formative/Summative Assessments** *see attached Rubric* **Resources** ● *Energy Skate Park Activity - https://phet.colorado.edu/en/simulations/energy-skate-park* ● *Gizmo: Roller Coaster Physics - https://gizmos.explorelearning.com/* ● *Roller Coaster Lab: http://www.monroe.k12.ky.us/userfiles/1186/Classes/30797/Roller%20Coaster%20Lab.pdf*

Explain

Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.

Procedure:

Newton's First Law – An object at rest tends to stay at rest, and an object in motion stays in motion unless acted upon by an unbalanced force. Inertia is the tendency of an object to keep doing whatever it is currently doing.

Newton's Second Law – The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, and inversely proportional to the mass of an object. or

$$F = ma$$

Newton's Third Law – For every action, there is an equal and opposite reaction.

Newton's Laws Examples		
First Law	Second Law	Third Law
Why we wear a seat belt (when in a moving car that abruptly stops we continue moving, seat belt is the unbalanced force that keeps us from flying into windshield) On the rollercoaster (or car), during a sudden turn our body will continue in a straight line while the car turns. We 'feel' pulled to the outside of the turn,	The greater the force when swinging a bat, the greater the acceleration (and distance) of the ball It is easier to push an empty shopping cart than a full one It takes more force to stop a semi-truck than a car	Rocket propulsion Letting go of an inflated balloon Skateboard or scooter push foot backward to move forward

	but that is just inertia | |

Vocabulary

Force – a push or a pull
Inertia – the tendency of an object to keep doing whatever it is currently doing
Mass – the amount of matter in an object
Acceleration – rate of change of velocity per unit time, change in speed, a slowing down or speeding up
Velocity – rate of change of position per unit time, speed

Modifications

Students will take notes on Newton's Laws. Notes will be provided for those that have trouble.

Standards Addressed

MS-ETS 1-4

MS-PS3-2

MS-PS3-5

Formative/Summative Assessments *Students will be assessed as they finish their Nearpod activity.*

Resources *www.nearpod.com*

Elaborate *Provide applications of concepts and*	**Procedure:** *During this procedure, the students will learn by building the roller coaster. They will experience failures and success as they drop the marble through their tubing. If there is a failure,*

opportunities to challenge and deep ideas; build on or extend understanding and skills.	*they will need to understand the science behind the reason their marble failed. This is where student conversation is so important. The teacher must not give the students the answer but direct them to where each group can find the answer through conversation and trials.* *Once the project is completed, if a group is finished before others, they must modify their roller coaster and make either more loops or more curves. If multiple groups are complete, then they must attach the two roller coasters together and test their tracks. They must work together as a group to modify the two tracks to make it work.* **Modifications** *The worksheets will be modified according to the students ability. The groups the students will be put in will be differentiated according to the student's different ability levels.* **Standards Addressed** *MS-ETS 1-4* *MS-PS3-2* *MS-PS3-5* **Formative/Summative Assessments** *see attached rubric* **Resources** ● *Energy Skate Park Activity - https://phet.colorado.edu/en/simulations/energy-skate-park* ● *Gizmo: Roller Coaster Physics - https://gizmos.explorelearning.com/* ● *Roller Coaster Lab: http://www.monroe.k12.ky.us/userfiles/1186/Classes/30797/Roller%20Coaster%20Lab.pdf*
Evaluate	**Procedure:** *During this phase the teacher will evaluate the student's knowledge and skills by engaging students in classroom discussion along with individual discussions in the group setting. The teacher will direct students in the right direction when a student asks a question, instead of answering the questions directly. The teacher will use the "ask 2 then me" approach. The students*

Assess student's knowledge, skills, and abilities.	*will also be assessed as they are building their project. The teacher will walk around the room paying close attention to the conversations that are happening during their groups.* *The student's mathematical abilities will be assessed during the calculating and graphing of the speed and acceleration of their roller coasters.* *The student's ELA abilities will be assessed using a rubric from the persuasive letter they have to write to the city council.* *After the project is complete, the students will take a brief reflection survey on how well they worked as a group member and rate their group members as well.* **Modifications** *Students with special needs will be prompted for answers to the questions.* **Standards Addressed** *MS-ETS 1-4* *MS-PS3-2* *MS-PS3-5* *6.NS.2* *8.SP.1* *ELA - C.7.1* **Formative/Summative Assessments** *Formative: Questioning & Discussion* *Summative: Final Project Letter to the City Council which includes all aspects of the roller coaster project.* **Resources** *Listed below*

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Teacher Background:

Roller coasters rely on two types of energy to operate: gravitational potential energy and kinetic energy. Gravitational potential energy is the energy an object has stored because of its mass and its height off the ground. Kinetic energy is the energy an object has because of its mass and its velocity.

When a roller-coaster car reaches the very top of its first big hill it has a lot of potential energy because it is very high off the ground. It moves over the top of the hill very slowly, so it has almost no kinetic energy. Then it drops down the other side of the hill and starts going very fast as its height rapidly decreases. The potential energy is converted to kinetic energy. This process repeats as the car goes through hills, loops, twists and turns. Whenever it goes up it gains more potential energy with height but loses kinetic energy as it slows down. Energy is never created or destroyed—it just converts from one form to another. This principle is known as conservation of energy.

We know from experience, however, that a roller coaster doesn't keep going forever. Eventually it slows down because of friction (a combination of air resistance and contact with the track). If energy isn't created or destroyed, where does that energy go? It is converted into heat. This is why you can rub your hands together to warm them up—friction converts energy from your moving hands into heat!

Resources:

These resources were used to build the lesson on "Thrillsville."

https://www.nextgenscience.org/search-standards?keys=&tid%5B%5D=106&tid_2%5B%5D=85

https://www.teachengineering.org/activities/view/duk_rollercoaster_music_act

https://physicsworld.com/a/twists-turns-thrills-and-spills-the-physics-of-rollercoasters/

https://www.stem-inventions.com/sfg-roller-coaster

https://raft.net/wp-content/uploads/2020/08/PGS-Roller-Coaster-Math.pdf

https://www.scientificamerican.com/article/make-a-marble-roller-coaster/

https://gizmos.explorelearning.com/

https://nearpod.com/

http://www.monroe.k12.ky.us/userfiles/1186/Classes/30797/Roller%20Coaster%20Lab.pdf

Persuasive Letter Rubric:
https://www.readwritethink.org/sites/default/files/resources/lesson_images/lesson875/PersuasiveLetterRubric.pdf

Self Reflection/Group Reflection

https://www.northwestern.edu/searle/docs/History%20and%20Philosphy%20Self%20and%20Peer%20Evaulation.pdf

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Roller Coaster Rubric

	Poor 5 pts	Fair 10 pts	Good 15 pts	Excellent 20 pts
Appearance	Poor Looks ok, not neat, no name	Fair Looks ok, neat, has name	Good Looks good, neat, hasname	Excellent Looks great, neat, has name
Marble Run and Stability	Poor Marble stays on track, completes at least 1/4 of the track.	Fair Marble stays on track completes at least 1/2 of the track.	Good Marble stays on track, completes at least 3/4 of the track	Excellent Marble stays on track, completes entire track, is brought to a stop.
Design Elements/Thrill	Poor Contains at least 2 design elements such as loop, wide turn, camel back, jumps	Fair Contains at least 3 design elements such as loop, wide turn, camel back, jumps	Good Contains at least 4 design elements such as loop, wide turn, camel back, jumps	Excellent Contains 5 design elements such as loop, wide turn, camel back, jumps
Building	Poor Needs a lot of secondary support The structure sways without the marble on it.	Fair Needs a small amount of secondary support The structure sways noticeably in places as the	Good Needs minimal secondary support The structure wiggles a little while the marble travels on it.	Excellent Needs no secondary support:stable The structure does not shake while the marble travels on it.

		marble travels on it.		
Newton's Laws of Motion	Poor Did not explain laws well. Did not explain Potential or Kinetic Energy points well.	Fair Newton's laws were mentioned but not explained well. Showed some understanding of Kinetic and Potential Energy.	Good Explained some of Newton's laws and showed where Potential and Kinetic energy points were.	Excellent Clearly explained how Newtons Laws of Motion come into play. Showed points of Potential and Kinetic Energy.
Plan	Poor Fair plan, some detail, a little vocabulary	Fair Good detail, labels with pictures. Energy points shown. Some good use of vocabulary	Good Poor plan, very little detail	Excellent Great detail, pictures are labeled clearly. Laws are shown. Energy points shown Lots of vocabulary
Teamwork	Poor A fair amount of good teamwork was shown.	Fair Good teamwork, most members actively engaged.	Good Did not work together well	Excellent Great Teamwork, all members engaged and actively helping.