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.

Learning Experience Title: *Teach Ms. Lee how to roller skate with Newton's Laws of Motion*

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Topic: Forces & Motions, *Newton's 3 Laws of Motion*

- **Newton's First Law of Motion**: An object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force.
- **Newton's Second Law of Motion:** The acceleration of an object depends on the mass of the object and the amount of force applied. [F=ma]
- **Newton's Third Law of Motion:** Whenever one object exerts a force on another object, the second object exerts an equal and opposite on the first.

    Source: NASA Glenn Research Center

Targeted Grade Level: Middle School / 7th Grade

Time Needed: *5-7 Days*

Subject Integration: Science, Engineering, Math, History

Justification:

This learning experience integrates science, math, engineering, and history. The goal of this learning experience is to introduce key physical concepts of forces and motion. Naturally, math is a critical component because it is the language that we use to describe forces and motion so that we can analyze it or make predictions. Students will use numbers and units to quantify forces and motions. Students will also practice using equations such as Newton's Second Law of Motion (F=ma) to determine or examine the relationship between different variables.

Since physics helps us understand how things happens by studying the interactions between matter and energy, it is also important to provide students the opportunity to apply their knowledge to solve real world examples through an engineering challenge. Students will design solutions while considering the needs and constraints. The application of their scientific knowledge to a real-world scenario will help students realize that what they are learning matters outside of the science classroom.

Lastly, roller skates have evolved over time to improve its functions, ease of mass-production, styles, safety, and other essential properties that make them a safe product that is available to the average consumers. By bringing the history of roller skates, students can gain a more comprehensive understanding of how roller skates work, which enables them to make more informed decisions when designing their skating solutions in the summative assessment. History helps us evaluate past failures and successes and analyze our ever-evolving needs so that we can build upon this knowledge to design solutions for the future. By integrating history into this learning experience, it also emphasizes the dynamic nature of science as new evidence or information becomes available.

Standards: *NGSS, Common Core, or related State standards. Write out (or copy and paste) standards completely. Please identify the point when each standard is addressed in the 5E template below. Each standard should be explicitly addressed within the lesson if it is to be included. Example: Reading aloud a non-fiction text does not solely qualify for ELA integration. Making a graph does not solely qualify for math integration. What concept is explicitly being taught?*

NGSS Performance Expectations

NGSS:

- **MS-PS2-2.** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- **MS-PS2-1.** Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Using and Developing Models	**PS2.A: Forces and Motion**	**Cause and Effect**

- Develop and/or use a model to predict and/or describe phenomena.

Analyzing and Interpreting Data

- Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events.

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Common Core State Standards:

Math:

- **MP.2** Reason abstractly and quantitatively.

- **6.NS.C.5** Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1)

ELA:

- **WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research.

ITEEA Standards *(If applicable)*

Other Standards *(as needed)*

Measurable Student Learning Objectives: *Write the learning objectives as "students will be able to" statements. Be sure that your objectives are measurable and connect to the standards listed above.*

You are encouraged to use Webb's Depth of Knowledge to create action oriented objectives.

I can...

- Ask scientific questions that can help us understand how roller skates work based on observations and personal experiences.
- Model the relationships between force and motion with common objects to determine any trends/patterns.
- Explain Newton's Laws of motion and apply them to real-world scenarios.
- Explain how Newton's Laws of Motion helps NASA scientists design rocket ascents.
- Create a roller-skating guide based on Newton's Laws of Motion / Invent a device that makes roller-skating safer / Re-invent roller skating to make it safer/easier

Nature of STEM: *Summarize how your lesson addresses the "nature of" science, technology, engineering, math, etc. as discussed in the Methods of STEM course.*

This lesson models how scientific knowledge evolve over time as new information/evidence arise Students have multiple opportunities revise their thinking/explanations over time to mimic this process. This lesson also shows how scientific knowledge goes hand in hand with technology. In the Elaborate phase, students learn that Newton's Laws of Motion are critical to NASA scientists as they design a rocket ascent. Without this knowledge, predicting how a rocket will behave under different conditions will be impossible. Students are also introduced to mathematic exercises in this learning experience because math is the language of physics. Being able to quantify a measurement is an integral part of sscience.

Engaging Context/Phenomena: *What are your engaging phenomena or your "hook" for the lesson? Be sure whatever you choose is appropriate for the subject area and grade level you are addressing.* Several example phenomena are shared in course. Consider how observations of the natural world serve as phenomena to engage students in the content. *You must utilize a NASA resource in your lesson (please discuss with your instructors if you need assistance).*

- Roller skating:
  - What made your teacher fall when roller skating? – Show short clips of roller skaters falling in different ways.
  - How do roller skates work? – What makes it accelerate?
  - This robot makes roller skating look easy!

- Newton's Laws of Motion demonstrations in space from NASA Johnson:
  - First Law: STEMonstrations: Newton's First Law of Motion
  - Second Law: STEMonstrations: Newton's Second Law of Motion
  - Third Law: STEMonstrations: Newton's Third Law of Motion
- Rocket Ascent

Data Integration:

Students will apply their understanding of Newton's Laws of Motion by analyzing NASA data of a rocket ascent to predict what is happening to the rocket after liftoff. Students examine authentic NASA data, practice visualizing the data by constructing a graph, and calculate forces acting on the rocket throughout the ascent.

https://www.nasa.gov/pdf/466711main_AP_ST_ShuttleAscent.pdf

https://www.nasa.gov/pdf/523195main_ALG_ST_SSA-Mass_Nspire.pdf

<u>Differentiation of Instruction:</u> *How can you adjust this lesson to meet the unique needs of students in your classes? What needs should be addressed? Think about and make these modifications PRIOR to the lesson so all students have the greatest ability to participate.*

- The hands-on explore activity provide entry points for all students. It also allows them to make connections with Newton's Laws of Motion in the Explain phase.
- Some students require sentence starters and vocabulary banks to assist them with expressing their ideas verbally or in written form. Students should have access to these resources during the Explain, Elaborate, and Evaluate phases.
- Students will need adequate time to explore and make sense of each phase of the learning experience. Pacing is important.
- Students may benefit from seeing what exemplar work looks like.

<u>Real-life Connection:</u> *Is there a real-life connection to this lesson? If so, what is it? How have you considered culturally responsive teaching practices? How will students connect to the lesson in their everyday lives?*

The principles of physics are present everywhere in our lives. Physics helps us understand how the world work and why things happen the way they do. Therefore, it naturally lends itself to building real-life connections in the classroom. In this learning experience, students can apply what they have learned about forces and motion to phenomena both inside and outside of the classroom, from scientific application such as rocket ascents to everyday life examples such as roller skating, seat belts, or even magic tricks. Students are also encouraged to identify these physics principles surrounding forces and motion they can observe in their own lives.

<u>Possible Misconceptions:</u> *Are there any previous ideas or thoughts you anticipate students having about this concept? List them here as it will help you consider ideas to include in your lesson.*

- If an object is moving, a force must be acting on it. Motion implies force.

Source: https://www.cpp.edu/respect/resources/documents_3rd/forces/gr3.forces_common_student_ideas.pdf

<u>Lesson Procedure:</u> *This is where you include each phase of the 5E. They should be extremely clear, well organized, and ready to be used by another educator. Be sure that each learning experience meets the guidelines for each "E". The template below will help you.*

5E Model	5E Objectives

Engage
 	
Introduce the lesson with an anchoring phenomenon. Facilitate student questions, discussion, etc. as appropriate. Learn about what students already know and want to know.
	Procedure:
	
	• Do Now: Ask students to think about a time they have fallen/tripped. How did it happen? Students can sketch/describe (or both!) to <u>model</u> their experience.
	• Debrief: Invite students to share out their examples. Ask what do all these examples have in common? Ask students if they think people are more likely to fall while skating or walking. Push students to support their answers with reasoning.
	• Mini Lesson:
	    ○ Begin by sharing my painful personal experience with roller skating to introduce the performance task (designing solutions for roller skating). Inform students that we are about to learn important concepts in physics that can help make their teacher a better skater.
	    ○ Show a short videoclip of roller-skating falls. Students record any observation that can help them answer the question – what makes people fall when they roller skate? Consider showing the videoclip at slower speeds.
	    ○ Students frame their guesses in question form. (Ex: Do skaters fall on their knees more often than on their behinds?)
	• Driving Question Gallery Walk: Students add their questions to a Padlet or physical poster. Students can also vote on the best question.
	• Exit Ticket: Students complete this task independently to demonstrate their understanding.
	
	Modifications:
	
	• Students might struggle with framing their guesses in question form. Provide sentence starters.

	• Not all questions can be investigated. Provide a checklist for testable science question for students to refer to as they are coming up with their questions or doing the gallery walk. **Standards Addressed MS-PS2-2.** **Formative/Summative Assessments:** • Exit Ticket: Students complete a K-W-L chart based on the roller-skating problem. **Resources:** • Lesson Slides • Interactive handout • Video clip of roller skate falls • Padlet (students would need devices to post on the Padlet) or Chart Paper & Post-Its
Explore *Plan for students to engage in hands-on activities that are designed to facilitate conceptual change.*	**Procedure:** Students work in small teams of 2-4. Each team is provided a toy car and a ball, which they can manipulate to carry out all the tasks specified on their interactive handout. Students will record their methods in their handout. Students are not limited to using just materials provided. They just need to include accurate and specific procedures in their handout to document how they manipulate these objects to carry out the tasks. **Modifications** • All students will be provided an interactive handout that will guide them through the investigation. • Heterogeneous grouping allows students to collaborate in a meaningful way. • Students may use a combination of sketches and words to record their ideas/findings. • Clear and precise directions that all students can follow. • Room for creativity – use of additional materials in the investigation. **Standards Addressed*: MS-PS2-2.** **Formative/Summative Assessments**

	• Exit Ticket: Students evaluate claims based on the evidence they have gathered from today's investigation. Students must provide evidence to support their evaluations. **Resources:** • Simple toy cars (with no built-in motor, students can also construct out of Legos) • Small bouncy balls • Interactive handout with directions and guiding questions
Explain *Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.*	**Procedure:** In this activity, students will be introduced to the scientific concepts (Newton's 3 Laws of Motion) that will help them explain what they experienced in the Explore portion. If time permits, set aside 1 day for each law so that students have time to process the new information by making connections with the Explore activity and applying it to the roller skate phenomenon. Students will perform the activity in this order: • Watch a NASA STEMonstration video to learn about each of the Newton's Laws of Motion (see Resources below). • Complete guided notes based on the video. • Whole Class discussion: Give examples of when the law was evident in the toy car/bouncy ball activity (from Explore). • Team Discussion: How does this law apply to roller skates? Students come up with specific examples by sketching/describing their ideas. • Share Out/Gallery Walk **Modifications:** • Provide interactive handout to assist with notetaking. • Play the video twice. Remind students to focus on watching the first time, taking notes the second time. • Allow students to express their ideas in different formats: sketches/words/both. **Standards Addressed*:* MS-PS2-2. MS-PS2-1.**

	Formative/Summative Assessments:
	
	• Exit Ticket: What's the gist? – Students explain what Newton's # Law of Motion is about in 10 words or fewer.
	
	Resources:
	
	  o First Law: STEMonstrations: Newton's First Law of Motion
	  o Second Law: STEMonstrations: Newton's Second Law of Motion
	  o Third Law: STEMonstrations: Newton's Third Law of Motion

Elaborate *Provide applications of concepts and opportunities to challenge and deep ideas; build on or extend understanding and skills.*	**Procedure:** In this activity, student apply their understanding of Newton's Laws of Motion to a new scenario – rocket ascents. Students are provided a data table that includes the following variables: time (after liftoff), mass, altitude, velocity during an ascent.

Table 1: STS-121 Discovery Ascent data (total mass)

Time (s)	Space Shuttle Total Mass (kg)
0	2,051,113
10	1,935,155
20	1,799,290
30	1,681,120
40	1,567,611
50	1,475,282
60	1,376,301
70	1,277,921
80	1,177,704
90	1,075,683
100	991,872
110	913,254
120	880,377

Table 1: STS-121 Ascent Data

Time (s)	Altitude (m)	Velocity (m/s)	Acceleration (m/s^2)
0	-8	0	2.45
20	1244	139	18.62
40	5377	298	16.37
60	11,617	433	19.40
80	19,872	685	24.50
100	31,412	1026	24.01
120	44,726	1279	8.72

Prior to examining the graph, students first make predictions about when they thing the greatest force is acting on the rocket. Student also predicts how force, mass, and velocity of a rocket changes over time. Students should provide reasoning to support their answers.

Students construct a graph to visualize the data. Students then analyze the trends/patterns in acceleration and mass. Students are also asked to calculate the force acting on the rocket by using Newton's 2nd Law of Motion.

Students answer a series of guided question to apply their understanding of Newton's Laws of Motion to this scenario. Examples:

- Describe how acceleration/the amount of force acting on the rocket changes over time.
- What could be causing these changes? Explain why. (Students may use a combination of sketching and describing).

Students also reflect on whether their predictions are supported or rejected by the data.

After the analysis, students watch a [video](#) explaining how rockets are launched into space. Students share out why they think force, mass, and acceleration might change during this process.

Modifications:

- Modified data table (integrate both data tables into a single one)
- Provide vocabulary wall
- Chart paper showing the 3 laws of motion
- Sentence starters for students who struggle with written responses.

Standards Addressed: MS-PS2-2. MS-PS2-1.

Formative/Summative Assessments

- Exit Ticket – Student explain why each of Newton's Laws of Motion is important when launching a space shuttle.

Resources:

Data is available from the following sites:

- https://www.nasa.gov/pdf/466711main_AP_ST_ShuttleAscent.pdf (Velocity, Altitude, Acceleration)
- https://www.nasa.gov/pdf/523195main_ALG_ST_SSA-Mass_Nspire.pdf (Mass)

Evaluate *Assess students knowledge, skills and abilities.*	**Procedure:** In this activity, students are ready to apply what they have learned to our roller skating phenomenon. Students have the option to engineer a solution to one of the following problems: 1) Use Newton's Laws of Motion to create a skater's guidebook 2) Create a device that prevents injury while roller skating 3) Re-invent roller skates

Modifications:

- Student choice
- Provide clear rubric
- Allow students to demonstrate ideas in a variety of formats (written work, presentations, podcast…etc).

Standards Addressed MS-PS2-2. MS-PS2-1.

Formative/Summative Assessments:

This activity is a summative assessment.

Resources *(List all resources and materials used in this part of the lesson.)*

Teacher Background: *What background information does the teacher need to effectively teach this lesson? If you can provide links to resources, please do so.*

Pre-requisites:

- This learning experience is more effective when students are familiar with the different mathematical ways we can describe and measure changes in motions. Students should already be familiar with the following vocabulary:
  - **Position, distance vs displacement, speed vs velocity, acceleration, frame of reference.**
- Students should also be familiar with the concept of forces. It would be helpful if students are able to recognize different types of forces and how they act on an object.
- Students should know how to construct a free-body diagram to determine the net force acting on an object.

Unit 2: Forces & Motion - Summative Assessment

<u>Directions</u>

Demonstrate your mastery of the knowledge and skills we learned in this unit by completing ONE of the following tasks:

Task (CHOOSE ONE)	Audience	Success Criteria
☐ **Create a roller-skater's guidebook using Newton's 3 Laws of Motion.**	Beginner roller-skater	- Your guidebook can be digital or physical. - Must include at least 5 tips that can help someone learn to roller-skate. - Each tip must be supported by one of Newton's Laws of Motion. - Incorporate helpful visual diagrams to make your guidebook more user-friendly.
☐ **Invent a device/tool that can prevent injury while roller-skating.**	Beginner, intermediate, or advanced roller-skaters	- Provide a visual/physical prototype of your device/tool. - Include written and/or visual directions for using this device/tool. - Use Newton's Laws of Motion to explain why your device/tool will prevent roller-skating injury. - Estimate the cost & price of this product.
☐ **Re-invent roller skates to make it better.**	Beginner, intermediate, or advanced roller-skaters	- Modify the designs of existing roller-skates to improve its function, performance, or safety. - Include a visual diagram or prototype to showcase your design. - Use Newton's Laws of Motion to explain why your design improves the function, performance, or safety of roller-skates. - Estimate the cost & price of this product.

Unit 2: Forces & Motion - Summative Assessment Rubric

Task (Check only ONE):
- ☐ Roller-skater's Guidebook
- ☐ Injury-Prevention Device
- ☐ Re-invent Roller-Skates

	Nailed It (4 points)	Almost There (3 points)	On My Way (2 points)	Not Yet (1 point)	Missing (0 point)
Task Completion	All 4 success criteria are met for the chosen task.	3 out of 4 success criteria are met for the chosen task.	2 out of 4 success criteria are met for the chosen task.	1 out of 4 success criteria is met for the chosen task.	Did not meet any success criteria for the chosen task.
Newton's Laws of Motion	All of Newton's Laws of Motion are accurately and effectively used in written explanation.	Most of Newton's Laws of Motion are accurately or effectively used in written explanation.	Written explanation incorporates Newton's Laws of Motion.	Written explanation mentions Newton's Law(s) of Motion, but requires elaboration.	Written explanation is missing or not supported by Newton's Laws of Motion.
Application	Final product reflects full understanding of the task and scientific concepts.	Final product reflects a general understanding of the task and scientific concepts.	Final product reflects partial understanding of the task and scientific concepts.	Final product reflects minimal understanding of the task and scientific concepts.	Final product is missing or has nothing to do with the task or scientific concept.

Total Points: ___ / 12 points

Glows	Grows: