NGSS Lesson Planning Template

Grade/ Grade Band: 3-8	**Topic:** Egg-gineering – 1 Forces	**Lesson # _1__ in a series of __4__ lessons**
Brief Lesson Description: In this lesson students will learn about forces, Newton's Laws of Motion, and the Engineering Design Process (EDP). Students will then apply this knowledge to solve a problem		
Performance Expectation(s): 3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. 3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. 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.		
Specific Learning Outcomes: Making sense of forces and motion		
Narrative / Background Information		
Prior Student Knowledge:		
Science & Engineering Practices: Planning and carrying out investigations Constructing Explanations and Designing Solutions	**Disciplinary Core Ideas:** PS2.A Forces and Motion PS2.B Types of Interactions, Objects in contact exert forces on each other.	**Crosscutting Concepts:** Cause and effect relationships are routinely identified. Models can be used to represent systems and their interactions. Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales
Possible Preconceptions/Misconceptions: -only force is gravity		
LESSON PLAN – 5-E Model		
ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions: Did you know there are rovers traveling Mars, taking pictures, sampling and analyzing rocks, and sending this information back to us? If we ever want to colonize Mars, this information will be useful. How do you think the rovers got to Mars? Discuss. Let's narrow our focus to landing our cargo safely on Mars (or the moon). We need to pre-position supplies for future colonists. We will make models to determine important aspects of the design. Include pictures of rovers, pictures taken by rovers, show video of rovers landing on Mars and deploying. Before we begin our design let's explore forces on objects. Mars rover landing https://www.youtube.com/watch?v=KyktvC7w7Js Images of Mars from Curiosity Rover https://www.nasa.gov/mission_pages/msl/images/index.html		
EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions: Set up Newton's Laws explore stations. Have a Laboratory Notebook (or worksheets) for students to record observations, or series of experiment completed tickets, some way to have your students complete each explore station.		

1st Law – key concept is inertia

Demos: ball in a box, whack a stack, hard-boiled vs. raw egg, coin drop, tablecloth

2nd Law – key concept a = F/m, acceleration is directly proportional to applied force, and inversely proportional to mass

Demos: skateboards, carts, wagons with a light and heavy mass, compare pushing or pulling
throwing a bowling ball vs. basketball
ruler (delivers same force) pushes two cars (or other wheeled items) with two different masses atop

3rd Law – key concept for every action, there is an equal and opposite reaction

Demos: balloon, blow it up and let go
balloon powered car
powering a skateboard or scooter
rockets
standing broad jump
chair with wheels (or skateboard) stand on then push against wall

EXPLAIN: Concepts Explained and Vocabulary Defined:

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.

$$a = \frac{F}{m} \quad \text{or} \quad F = ma$$

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, but that is just inertia	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

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

Additional Hands-on links:

(Note--We do not recommend showing videos, we recommend having students attempt and explore the activity and make first hand observations. The videos are for you if you are unfamiliar with a particular activity or concept)

Newton's First Law Hands on Activities

1. Ball in a box. Place a ball in a box, with the box and ball moving stop the box abruptly.
2. Whack a stack, https://www.youtube.com/watch?v=K4bnp7rSIgo
3. Hard-boiled egg vs. raw egg, https://www.youtube.com/watch?v=dRu6qQbMy4g
4. Coin drop, https://www.youtube.com/watch?v=qq1Whusk8No
5. Tablecloth 'magic' trick, https://www.youtube.com/watch?v=PcGIUZzWoVc, in classroom use plastic cups and wax paper

Newton's Second Law Hands on Activities

1. Batting a playground ball vs. a bowling ball, https://www.youtube.com/watch?v=pgH-4P73e0A
2. Skateboards, or some sort of cart with different masses, test pushing and pulling, amount of effort is force, https://www.youtube.com/watch?v=UhCG0qoY9Dc
3. https://www.youtube.com/watch?v=cEhFmbehhco
4. Use a ruler to deliver same force to two cars, one with less mass, one with more mass. Observe difference in speed and distance (correlates with acceleration)

Newton's Third Law Hands on Activities

1. Rockets, https://www.youtube.com/watch?v=Xx9kiF00rts (stomp rockets, balloon, etc.)
2. I like the part of this video with the motorized car tires moving the cardboard backward, https://www.youtube.com/watch?v=N_V_848AxZM
3. Good thought experiment, https://www.youtube.com/watch?v=8bTdMmNZm2M
4. Balloon powered car, https://www.youtube.com/watch?v=-OENIttg1dU or https://www.youtube.com/watch?v=QzY9RH_JnL0

ELABORATE: Applications and Extensions:

If you haven't done all the explore, hands-on activities, they can be added here as extensions. The balloon car activity can easily be extended to exploring more variables like mass and force, or a class competition.

See lesson 3 of this set for an application. Mission: Egg Lander

EVALUATE:

Formative Monitoring (Questioning / Discussion):

1st Law Q's: When we throw a ball why doesn't it continue forever at the same speed? (Forces of gravity and friction are unbalanced forces bringing it to a stop). Could we go somewhere the ball could continue to travel at the same speed because there is no friction or gravity? (Space)

2nd Law Q's: If we want to increase an object's acceleration, or make it go faster, what could we do? (Increase the applied force or decrease the mass)

3rd Law Q's: If you are riding a skateboard, what makes it move? (When you push backward on the ground, the ground pushes the opposite direction making you move forward. The ground doesn't move since it is so much more massive) Compare with two kids on rolling chairs pushing against each other, they have similar masses, so both will move.

Summative Assessment (Quiz / Project / Report):

Have students record observations in a laboratory notebook or worksheet

Elaborate Further / Reflect: Enrichment:

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
** **Note**** *not all items are required, you can pick and choose explore activities that fit in your classroom or activities you already have materials for.*			
1/student	Composition book or other laboratory notebook		
1 per 4 students	Ball and box		
1 per 4 students	4-5 wooden blocks/PVC pipe or other stick		
1 per 4 students	Raw egg & hard-boiled egg		
1 per 2 students	Cup, card, penny		
1 per 4 students	6 cups, wax paper		
1-2	Inertia demonstrator	Sci-supply.com	$12.95
	2 wagons, skateboards, chairs with wheels		
	Balls of different mass		
	Ruler, small cars, pennies or washers for mass, tape		
	Balloons		
	Recycled materials for lander		

NGSS Lesson Planning Template

Grade/ Grade Band: 3-8	**Topic:** Egg-gineering – 2 Engineering Design Process	**Lesson # _2__ in a series of __4__ lessons**

Brief Lesson Description: In this lesson students will learn about forces, Newton's Laws of Motion, and the Engineering Design Process (EDP). Students will then apply this knowledge to solve a problem

Performance Expectation(s):

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success**.**
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.

Specific Learning Outcomes: Ability to use the Engineering Design Process (EDP) for problem solving

Narrative / Background Information

Prior Student Knowledge:
Complete lesson 1 of 4

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Planning and carrying out investigations Asking questions and defining problems Constructing explanations and designing solutions. Engaging in argument from Evidence Analyzing and interpreting data	ETS1.A Defining and Delimiting Engineering Problems ETS1.B Developing Possible Solutions ETS1.C Optimizing the Design Solution	Cause and effect relationships are routinely identified. Influence of Science, Engineering, and Technology on Society and the Natural World

Possible Preconceptions/Misconceptions:
Scientific method is the only way to solve problems or learn science

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

What is an engineer? Ask students for their ideas and what they know. Who wants to be an engineer?

What is engineering? Engineering is using science and math to solve problems that improve the world around us. Engineers design traffic lights, skateboards, bridges, airplanes, computers, medicine, shampoo, toothpaste, MRI machines, etc.

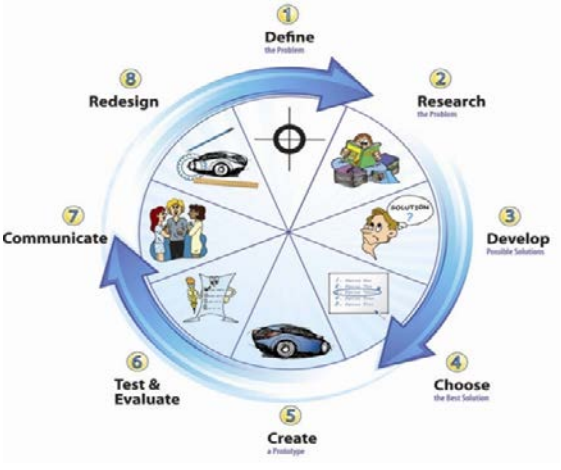
What are some challenges facing today's world that you would like to see solved?

'What is engineering video' https://www.youtube.com/watch?v=bipTWWHya8A

So how do people even start trying to solve these big problems? One tool is the Engineering Design Process (EDP). The EDP can be used to solve all kinds of problems

Useful source of engineering lessons: https://www.teachengineering.org/
Specific to the EDP: https://www.teachengineering.org/lessons/view/umo_challenges_lesson01 or https://www.teachengineering.org/activities/view/usu-1961-everyday-problems-introduction-engineering-design

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:



Example EDP	
1. Identify the need/ Define the problem	Portable communication device
2. Research the problem	First cordless phone was invented in 1965. In 1980's phones were attached to the wall, maybe cordless in the house. First mobile phone was invented by Motorola in 1983. What do you think engineers needed to research and understand?
3. Develop possible solutions	Brainstorm software and hardware ideas amongst your team.
4. Choose best solution	You have to start somewhere!
5. Create & build a prototype	Do the work…
6. Test & evaluate a prototype	Give to friends/co-workers and have them use for a couple weeks, survey and graph the data of their experiences. Dropped calls, voice quality, battery life
7. Communicate	Meet with team and customers, and decide what to improve next
8. Redesign	Make the improvements and keep the cycle going! Back to Step 1 or 2 or 3 or 4

Use this as an example or one of your own choosing.

EXPLAIN: Concepts Explained and Vocabulary Defined:

Vocabulary:

Prototype – an early model or version of a product to test and evaluate a concept or process
Design – art of creating something that does not exist

Additional Hands-on links:

ELABORATE: Applications and Extensions:

Now apply the EDP to a practice scenario. (15 minutes) Design a picnic for your friends (from What is Engineering? What is Design? From TeachEngineering.org.)

Be sure to add question about how to measure the success of your picnic (test & evaluate step of EDP).

EVALUATE:

Formative Monitoring (Questioning / Discussion):

In class discussion, important to ask students about criteria chosen for measuring success of design or re-design.

Summative Assessment (Quiz / Project / Report):

Have students record observations in a laboratory notebook or worksheet

Elaborate Further / Reflect: Enrichment:

See lesson 3: Mission Egg Lander

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
None – continue using laboratory notebooks to record work			

NGSS Lesson Planning Template

Grade/ Grade Band: 3-8	**Topic:** Egg-gineering – 3-Mission Egg Lander	**Lesson # _3__ in a series of __4__ lessons**

Brief Lesson Description: In this lesson students will apply knowledge learned from previous lessons to design the lander and complete the first mission.

Performance Expectation(s):

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

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.

3-5-ETS-1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS-1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS-1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS-1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Specific Learning Outcomes: Applying the design process as well as understanding key concepts previously learned.

Narrative / Background Information

Prior Student Knowledge: Make sure to have done the 1 of 4 lesson and the 2 of 4 lesson prior to this lesson for background knowledge and information.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Planning and carrying out investigations	PS2.A Forces and Motion PS2.B Types of Interactions, Objects in contact exert forces on each other. 3-5-ETS-1-1 Define a simple design problem 3-5-ETS-1-2 Generate and compare 3-5-ETS-1-3 Plan and carry out fair tests MS-ETS1-1 Define the criteria and constraints MS-ETS1-2 Evaluate competing design MS-ETS-1-3 Analyze data	Cause and effect relationships are routinely identified. Influence of Science, Engineering, and Technology on Society and the Natural World

Possible Preconceptions/Misconceptions:

Some students might think this is easy until they see the constraints, budgets and time given to them.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Introduce the mission.

(use worksheet provided)

We need Scientists, Engineers and Mathematicians to help redesign a space lander for AFRL! The space lander is going to be carrying some special equipment to space. We need to ensure the safety of the tools and materials. The budget allowed for the mission is $10.00. Will your team be the ones who help the astronauts get what they need and ensure a successful landing?

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Students will see how the feather bottle and the bottle filled with rocks will fall on the drop zone. The drop zone will be out launching area. If you don't have a drop zone, please use and area where the landers could be dropped from at least 3 meters high to get good readings. Students will see how something so massive could have a different velocity of impact.

Show students the difference of two animals "the hare" and "the tortoise" of how they moved at different velocities.
Get one student to act as the hare and one student to act as the tortoise. Make sure to line up the distances that can be premeasured out. Next start the race between the two students and have another student time them. Show the students the math on the board with your explanation.

It is important to discuss criteria for success. For example, criteria would be different if you are sending astronauts (human life is involved) vs. just cargo. Connect this to variables you would change in the lander and the constraints on your engineering design.

EXPLAIN: Concepts Explained and Vocabulary Defined:

Explain the math with the velocity demonstration. V=distance/time
Students will clearly understand velocity after demo. Next explain the mission again and show the students the store and the free products they are getting. Refer back to worksheet when needed. Students can work in teams of two or more, no more than 4 to a group.

Velocity – rate of change of position per unit time, speed
Flaw – an imperfection or weakness
Constraint – restriction or limitation

ELABORATE: Applications and Extensions:

The students will be given a certain about of time (30 minutes recommended) to design their lander. After students complete their lander with their teams they will all be launched together as a class so everyone could see the design from start to finish. If you want to differentiate instruction, then have the landers launched as soon as groups get done. Once students are finished they can start evaluating their current design flaws. Students can begin lesson number 4 with the redesign.

See the attached math and language arts extensions

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Students will fill out the worksheet that has these questions attached to it. They also will calculate their velocity of their landers.

Evaluate you design. Circle the condition of your lander and cargo after launch.

Survival (no damage)
Living….. with a cracked skull (shell cracked)
Unconscious with brain damage (any part of the inside leaking)
Totally scrambled (everything is broken)

Where did the cargo sustain damage

What does this indicate about the flaws in your design?

How could your group modify your design to make it better?

How did your group work as a team? What was the most difficult part?

Summative Assessment (Quiz / Project / Report):
<u>Ideas:</u>
Fraction worksheet so class could evaluate each other's work
Project report
Poster that shows both designs and the their entire thought process through the engineering design process

Elaborate Further / Reflect: Enrichment:
Follow with lesson 4 of 4 with redesign.

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
** **Note**** *not all items are required, feel free to make substitutions that fit your budget*			
1	Drop Zone	Pittsco W21343	$415.00
	OR		
1 (at least) or 1/group	Metric tape measure, at least 5m		$5 -$50
1 (at least) or 1/group	Timer or stopwatch (can even use phones)		$2-$20
	Recycled materials for lander		
	String		
	Masking tape		

NGSS Lesson Planning Template

Grade/ Grade Band: 3-8	**Topic:** Egg-gineering – 3-Mission Egg Lander Redesign	**Lesson #** 4_ **in a series of** __4__ **lessons**

Brief Lesson Description: In this lesson students will apply knowledge learned from previous lessons to ***redesign*** the lander and complete the second trial mission.

Performance Expectation(s):

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

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.

3-5-ETS-1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS-1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS-1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS-1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Specific Learning Outcomes: Applying the design process as well as understanding key concepts previously learned.

Narrative / Background Information

Prior Student Knowledge: Complete the 1 of 4 lesson, the 2 of 4 lesson and 3 of 4 lesson prior to this lesson for background knowledge and information.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Planning and carrying out investigations	PS2.A Forces and Motion PS2.B Types of Interactions, Objects in contact exert forces on each other. 3-5-ETS-1-1 Define a simple design problem 3-5-ETS-1-2 Generate and compare 3-5-ETS-1-3 Plan and carry out fair tests MS-ETS1-1 Define the criteria and constraints MS-ETS1-2 Evaluate competing design MS-ETS-1-3 Analyze data	Cause and effect relationships are routinely identified. Influence of Science, Engineering, and Technology on Society and the Natural World

Possible Preconceptions/Misconceptions:

Some students might think this is easy until they see the constraints, budgets and time given to them.

Completing a project once is enough.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Show the students the most valuable part of the engineering design process is the redesign because that's how things get better over time. Students can understand why redesign is important just based on the mistakes they may have made with their first design.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Students will evaluate their 1st design and start exploring other materials that will work more efficiently.

EXPLAIN: Concepts Explained and Vocabulary Defined:
Explain the importance of redesign. This video shows a test of voice analog with old phones vs. current models.
Show video to students to reinforce engineer redesign process.

https://youtu.be/0IEPWIESE34

ELABORATE: Applications and Extensions:

The students will be given a certain amout of time (30 minutes recommended) to redesign their lander. After students complete their lander with their teams they will all be launched together as a class so everyone could see the design from start to finish. Use the math and language arts connections. Great place for a writing assignment to compare 1st and 2nd design choices, then make conclusions based on that evidence.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Students will fill out the worksheet that has these questions attached to it. They also will calculate their velocity of their landers.

Evaluate you design. Circle the condition of your lander and cargo after launch.

Survival (no damage)
Living….. with a cracked skull (shell cracked)
Unconscious with brain damage (any part of the inside leaking)
Totally scrambled (everything is broken)

Where did the cargo sustain damage

What does this indicate about the flaws in your design?

How could your group modify your design to make it better?

How did your group work as a team? What was the most difficult part?

Summative Assessment (Quiz / Project / Report):
Ideas:
Fraction worksheet so class could evaluate each other's work
Project report
Poster that shows both designs and the their entire thought process through the engineering design process

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
***** Same as Lesson 3 *****			