Learning Progression: Engineering Design Process

Materials: FOSS Levers & Pulleys **Grade level: 5-6**

Prerequisite skill: Vocabulary

- Criteria 3-5
- Constraints 3-5
- Variables 3-5
- Controlled Variables 3-5
- Similarity/Differences 3-5
- Model 3-5
- Prototype 3-5
- Systematic Process MS
- Iterative Testing MS (test more than once to successfully improve; leads to greater refinement: pg 74 MS ETS1-4 & MS ETS1. C)
- Modification MS
- Optimal MS

Define:
Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or criteria.

Develop Solutions:
Designing solutions to engineering problems begins with generating a number of different possible solutions, then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

Optimize:
Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

Learning Target: A problem's solution(s) will have constraints or criteria.

Success Criteria: I can specify the constraints and criteria of a successful solution to a problem and identify the best solution.

Formative Assessment: Design Challenge #1, #2, #3

Learning Target: Evaluate which solutions meet the criteria and constraints.

Success Criteria: I can generate and evaluate solutions that meet the criteria and constraints.

Formative Assessment: Design Challenge #1, #2, #3

Learning Target: Design and/or develop models of possible solutions.

Success Criteria: I can create models of my solutions.

Formative Assessment: Design Challenge #1, #2, #3

Learning Target: Tests are systematic, should follow criteria & constraints and data needs to be recorded.

Success Criteria: I can design a process to systematically test the solutions.

Formative Assessment: Design Challenge #1, #2, #3

Learning Target: Analyze which solution best solves the problem by looking at data. Communicate other ideas.

Success Criteria: I can evaluate the data from testing to determine how well it met the criteria or constraints of the problem.

Formative Assessment: Design Challenge #1, #2, #3

Learning Target: Refine the designs based on what best meets criteria.

Success Criteria: I can change my solution using the information I gathered to better meet the criteria or know that the optimal solution has been found.

Formative Assessment: Design Challenge #1, #2

Big Idea:

Engineering Design Process

Later big ideas that build on this big idea include:

Northwest Educational Service District 189
Together We Can

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LEVERS & PULLEYS

Challenge Title: Levers Design Challenge 1

Targeted Engineering Practices
☐ Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. ☐ 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 ☐ 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.
Connected Scientific Content Ideas
☐ Force: Machines can change the forces or directions necessary to move an object. ☐ Inquiry: Valid experiments and investigations have specific criteria: asking questions, data collection, analysis and reporting. ☐ Systems: Systems have inputs and outputs. We can predict what will happen if input is changed.
Description of Student Success Criteria:
At the completion of this task students will be able to: ☐ Specify the constraints and criteria of a successful solution to a problem and identify the best solution. ☐ Generate and evaluate solutions that meet the criteria and constraints. ☐ Create models of solutions. ☐ Design a process to systematically test the solutions. ☐ Evaluate the data from testing to determine how well it met the criteria or constraints of the problem. ☐ Change the solution using the information gathered to better meet the criteria or know that the optimal solution has been found.

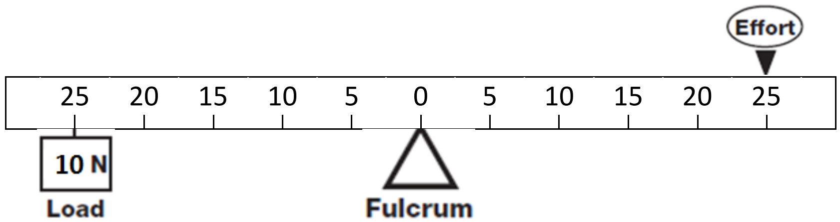
Teacher Instructions: Implementation Support
Timing of the task: Give this design challenge after lesson 1-2 **Required additional materials (not included in the kit):** none **Teacher Instructions:** Do this design challenge in two parts. Have the students analyze Randy and Kevin's lever systems first, discuss as a class and then have them design and test their own.

Name ____ Date ____________________

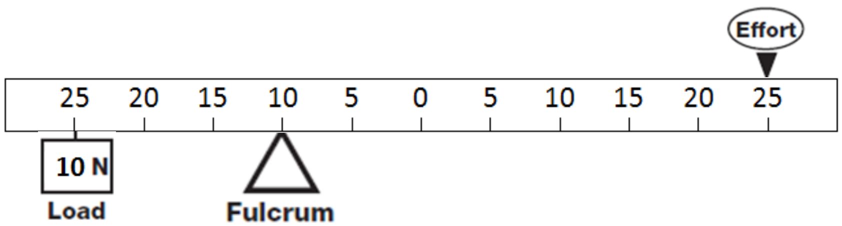
Levers Design Challenge – Investigation 1.2

Randy and Kevin had been working with levers for a couple of days. They were trying new ways to set up levers. They each set up a lever system. Both lever systems had the load hanging at the 25-cm position on one side, and the effort pressing at the 25-cm position on the other side.

Randy's Lever



Kevin's Lever



Randy said, "Our levers are the same. They will both take the same amount of effort to lift the load."

Kevin responded, "I don't think so. One of these systems will require less effort to lift the load."

Which student do you think was right Explain why you think so.

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Name ____ Date ____________________

Criteria: Design a lever system that will have a greater mechanical advantage than Randy and Kevin's lever systems.

Constraints: Use a half-meter stick, 10 N load, dowel, duct tape, a heavy book, binder clip, pencil-cap eraser, rubber bands and a spring scale. Keep the load and effort at 25 cm on opposite sides.

Three Possible Solutions:

1.	2.	3.

Try all three of your possible solutions and record data on the table below:

	Position of fulcrum (cm)	Effort (scale + 0.5 N)	
1			
2			
3			

Circle the solution that provides the greatest advantage and explain why. Support your selection with data from the table.

Name ____ Date ____________________

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LEVERS & PULLEYS

Challenge Title: Levers Design Challenge 2

Targeted Engineering Practices
☐ Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. ☐ 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 ☐ 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.
Connected Scientific Content Ideas
☐ Force: Machines can change the forces or directions necessary to move an object. ☐ Inquiry: Valid experiments and investigations have specific criteria: asking questions, data collection, analysis and reporting. ☐ Systems: Systems have inputs and outputs. We can predict what will happen if input is changed.
Description of Student Success Criteria:
At the completion of this task students will be able to: ☐ Specify the constraints and criteria of a successful solution to a problem and identify the best solution. ☐ Generate and evaluate solutions that meet the criteria and constraints. ☐ Create models of solutions. ☐ Design a process to systematically test the solutions. ☐ Evaluate the data from testing to determine how well it met the criteria or constraints of the problem. ☐ Change the solution using the information gathered to better meet the criteria or know that the optimal solution has been found.

Teacher Instructions: Implementation Support
Timing of the task: Give this design challenge after lesson 3-1 **Required additional materials (not included in the kit):** none **Teacher Instructions:** Be sure to give this design challenge before students are introduced to two-pulley systems. Some students may have difficulty understanding how to attach three loads to one pulley. Allow them to use rubber bands to attach the loads.

Name ______________________________________ Date _________________

Cement Design Challenge 2

Challenge: Design a prototype pulley system to lift an 80 pound bag of cement into a wheelbarrow.

Criteria: Design and create a prototype pulley system to lift **three** 240 gram weights, which represent an 80 pound bag of cement. The **final** design chosen should give the user optimal mechanical advantage.

Constraints: All **three** weights need to be lifted by a single pulley system at the same time. The pulley system must be operated by one person.

Plan Summary: Build a pulley system prototype out of the materials we have in class.

Steps to Do the Plan:

1. Design and build a single pulley system to lift a 720 gram load.
2. Zero the spring scale prior measuring the force (N)!
3. Test and record your data (Newtons of force it took to lift the 720 gram load) in the table.
4. Repeat steps 2 and 3 for design one.
5. Design and build a second single pulley system to lift a 720 gram load.
6. Repeat steps 2 and 3 for design two.
7. Choose the pulley system with the optimal mechanical advantage.
8. Use your test data to write a conclusion.

Name ____ Date __________________

Diagram of Pulley Designs

Design One	Design Two

Test Results

Designs	Newtons Trial #1	Newtons Trial #2	Newtons Trial #3	Newtons Average
One				
Two				

Conclusion: Choose the pulley system that solves the design challenge, and meets the criteria and constraints. Explain your thinking on how your design solves the challenge.

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LEVERS & PULLEYS

Challenge Title: Levers Design Challenge 3

Targeted Engineering Practices
☐ Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. ☐ 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 ☐ 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.
Connected Scientific Content Ideas
☐ Force: Machines can change the forces or directions necessary to move an object. ☐ Inquiry: Valid experiments and investigations have specific criteria: asking questions, data collection, analysis and reporting. ☐ Systems: Systems have inputs and outputs. We can predict what will happen if input is changed.
Description of Student Success Criteria:
At the completion of this task students will be able to: ☐ Specify the constraints and criteria of a successful solution to a problem and identify the best solution. ☐ Generate and evaluate solutions that meet the criteria and constraints. ☐ Create models of solutions. ☐ Design a process to systematically test the solutions. ☐ Evaluate the data from testing to determine how well it met the criteria or constraints of the problem. ☐ Change the solution using the information gathered to better meet the criteria or know that the optimal solution has been found.

Teacher Instructions: Implementation Support
Timing of the task: Give this design challenge after lesson 4-2 **Required additional materials (not included in the kit):** none **Teacher Instructions:** Use checkpoints after part A and B so that students don't move on without the correct information. Allow for students to choose either design as long as they back up their choice with logical evidence.

Name: ____ Date ______________________

Levers & Pulleys - Design Challenge #3

Ted and Jan were working on a search and rescue team that needed to lift an injured climber out of a 20m ravine. Ted was at the top the ravine; Jan was at the bottom of the ravine. The injured climber weighs 720N. They have two pulleys and a rope in their rescue kit.

Scenario A: Jan is going to attach the injured climber to the pulley system and Ted will lift him out of the ravine.

- How should they set up their pulleys so Ted can lift the climber using as little effort as possible? Draw a diagram and set-up the pulley system.

- How much effort will Ted have to use? _______________________________________
- How far will Ted have to pull the rope? _______________________________________
- What is the mechanical advantage? _______________________________________

Note: Mechanical Advantage = $\frac{\text{Load}}{\text{Effort}}$

Name: ____ Date ______________________

Scenario B: Jan is going to attach the injured climber to the pulley system, and she is going to lift the climber from her position at the bottom of the ravine.

- How should they set up their pulleys so Jan can lift the climber using as little effort as possible? Draw a diagram and set-up the pulley system.

- How much effort will Jan have to use? ____
- How far will Jan have to pull the rope? ____
- What is the mechanical advantage? ____

Evaluate: Determine which scenario (A or B) provides the greatest advantage to lift the climber out of the ravine. Write an argument about why you feel this provides the greatest advantage including the following:

- Comparison of the mechanical advantages
- Comparison of the directional advantages
- Comparison of how far the ropes will be pulled
- The reason why you chose that scenario

Note: Mechanical Advantage = $\frac{\text{Load}}{\text{Effort}}$