Pup Prosthetics:

Engineering Mobility for Dogs in Need

Pet: **Dog**	**Class:** **6-9**

Brief Overview:	**Lesson Breakdown**
Students use the engineering design process to design and create a prosthetic leg for a dog that has lost a back leg. They will consider biomechanics, materials, and ethical considerations in their design. *This lesson can be adapted for other pets and for other grades.*	**Lesson 1:** Spot's Missing Leg **Lesson 2:** Building a Leg for Spot **Lesson 3:** Testing and Analyzing the Leg **Lesson 4:** Presentation and Communicating the Results
Essential Question How can we apply our understanding of science and technology to create a solution for a real-world problem faced by animals?	

Subjects	**Stem Connections**
☑ Science ☑ ELA ☑ Math ☑ STEM ☐ Art ☐ Other	**Science:** life science, body as a system of iterating cells **Technology:** prosthetics (option: create with a 3D printer or modeling software) **Engineering:** design, test and refine a prosthetic leg **Math:** create a scale drawing

Performance Expectations/ Standards
NGSS
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.

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells

CCSS
Math 7.G.A.2: Draw two-dimensional figures using coordinates and scale factors**.**

CCSS.ELA-Literacy.W.6.7
Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate
CCSS.ELA-Literacy.SL.8.5. Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.
RST 6.8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

I CAN statements
- identify the challenges faced by a dog with a missing leg.
- research and understand the biomechanics of dog movement.
- use my understanding of science and technology to brainstorm and design a prosthetic leg solution.
- can communicate my design ideas clearly and effectively, both verbally and in writing.
- create a scale drawing of my design
- evaluate the effectiveness of my prosthetic leg prototype and suggest improvements.

Materials

- Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet
- Stuffed dog that has had one of its legs amputated (and sewn up) *(Note: Ideally, each group would have its own altered dog, however, they can also share one per classroom and take turns testing)*
- A variety of building materials - cardboard, tubes, paper, straws, foam,string, etc.
- Tape, glue, hot glue
- Modeling software (optional)

Teacher Background

The field of animal prosthetics, while less commonly discussed than its human counterpart, offers remarkable solutions for overcoming limb loss in creatures great and small. From soaring falcons to prancing ponies, these technological marvels improve mobility, alleviate pain, and restore quality of life.

Beyond Human Applications:

Animal prosthetics differ from human designs in several crucial aspects. Size and weight constraints are paramount, necessitating lightweight materials like carbon fiber or titanium. Mobility demands vary too, requiring flexible joints for nimble squirrels and robust designs for weight-bearing horses. Additionally, materials must withstand environmental demands, be it the abrasive sand of an aviary or the muddy fields of a farm.

Crafting a Second Chance:

Creating an animal prosthetic often involves a multidisciplinary approach. Veterinarians assess the injury, engineers design the appropriate limb based on biomechanical principles, and technicians fabricate the custom-made device. 3D printing technology has revolutionized this process, allowing for precise customization and rapid prototyping.

A Spectrum of Solutions:

- Simple splints and braces: Provide support and stability for healing limbs.
- Partial foot prosthetics: Restore functionality to partially damaged paws.
- Full limb prosthetics: Replace lost limbs, enabling ambulation in birds, reptiles, and mammals.
- Wheels and carts: Offer mobility for animals with severe limb loss or neurological impairments.

Challenges and Advancements:

Durability, long-term tissue integration, and cost are ongoing concerns. Research into bionic limbs with integrated sensors and actuators holds exciting possibilities for even greater functionality.

Impact Beyond Mobility:
The benefits of animal prosthetics extend beyond physical restoration. By regaining mobility, animals experience reduced pain, improved mental well-being, and the potential return to natural habitats. Their stories inspire empathy and raise awareness of animal welfare, fostering a world where even the smallest creature can enjoy a healthy and active life.

As the field of animal prosthetics continues to evolve, one thing remains constant: the dedication to providing second chances, one tiny paw-step at a time.

Lesson 1: Spot's Missing Leg		
Time	**Materials**	**Activity**
10 mins		Introduce the lesson with this story: The crisp autumn air whipped across Spot's fur as she raced through the meadow, ears perked and heart drumming with freedom. Suddenly, the world twisted. A rusted trap, sprung, clamped like a cruel claw on her hind leg. A scream tore from her throat, echoing through the hollow woods. Days bled into nights as Spot weakened and feverish, battled against the gnawing metal. Just when hope had become a distant echo, a lumbering silhouette appeared – Farmer John, his eyes creased with worry. Gently, he freed her, the rusty metal relinquishing its grip with a sickening crunch. The journey to the Animal Haven was a blur of pain and fear. At the Haven, Dr. Lily examined the mangled leg. "The bone is shattered," she said. "We can't save the leg, Spot"
5 mins		Show a video of a dog such as: Slow Motion Dog Run How might the dog's life be affected by a missing leg? Continue with the story: Spot's remaining leg twitched against the soft towel. Fear choked her tiny throat. Would she be forever hobbled, a shadow of her playful self? Then, Dr. Lily said, "we can do something even better." (Show the stuffed dog with the missing leg)

5 mins		Show students a video about a man who creates prosthetics for a variety of animals. Real-Life Doctor Dolittle Creates Life-Saving Prostheti...
25 mins	Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet	Divide students into small groups and have them brainstorm potential solutions for the missing leg. Encourage creativity and diverse ideas, have the students begin to design their prosthetic leg in their student workbook. Allow them to research existing animal prosthetics. (Note: Ideally, each group would have its own altered dog, however, they can also share one per classroom and take turns testing)

Lesson 2: Building a Leg for the Dog		
Time	**Materials**	**Activity**
		Before class: Amputate the dog's leg. (Note: Ideally, each group would have its own altered dog, however, they can also share one per classroom and take turns testing)
45 mins	Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet Stuffed dog that has had one of its legs amputated (and sewn up) A variety of building materials - cardboard, tubes, straws, paper, foam,string, etc. Tape, glue, hot glue Modeling software (optional)	Using readily available materials like cardboard, straws, and tape, allow the students time to build prototypes of their prosthetic legs. OR: Have the students use modeling software to create their designs and/or print them on a 3D printer

Lesson 3: Testing and Analyzing the Leg		
Time	**Materials**	**Activity**
45 mins	Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet	Students test their prototypes on the stuffed dog. They evaluate factors like mobility, comfort, and ease of movement. Students identify areas for improvement in their designs. They can iterate on their designs and create new prototypes based on their evaluations. Optional: Create an obstacle course for the toy dog to traverse. Use materials like bottle caps, craft sticks, and cardboard to create miniature ramps, tunnels, and uneven surfaces. Similar to testing with live hamsters, observe how the toy navigates the obstacle course with the prosthetic leg attached. Focus on mobility, stability, and functionality. Video recording can be helpful for detailed analysis.

Lesson 4: Presentation and Communicating the Results		
Time	**Materials**	**Activity**
20 mins	Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet	Have students calculate the dimensions of the prosthetic leg based on if the dog was an adult yellow Labrador (Ht: 57 cm; Weight: 36 kg)
25 mins	Pup Prosthetics: Engineering Mobility for Dogs in Need Worksheet	Presentation and Communication: Students present their final design solutions to the class, explaining their design choices, challenges overcome, and future considerations.

Differentiation
For students who need additional support:

- Provide scaffolding and additional support for students who need help with research, math calculations, or prototype construction.

For students who need additional challenges:

- Offer enrichment activities for advanced students, such as researching real-world animal prosthetics or exploring 3D design software for more complex prototypes.
- Allow students with different interests to express their creativity through their design choices and presentation formats.

Assessment

Category	**Exemplary (4 points)**	**Proficient (3 points)**	**Developing (2 points)**	**Needs Improvement (1 point)**
Brainstorming	Generates numerous and diverse ideas for prosthetic leg solutions.	Offers several potential solutions with some variety.	Presents limited ideas, mostly relying on common solutions.	Contributes few or unoriginal ideas.
Design	Sketches and blueprints are detailed, clear, and well-labeled. Design demonstrates creativity and originality.	Sketches and blueprints are generally clear, but may lack some details or creativity.	Sketches and blueprints are unclear or incomplete. Design lacks originality.	Design unclear and poorly presented. Minimal creativity shown.
Prototyping	Prototype demonstrates sound biomechanical principles and functions effectively. Materials and construction are appropriate.	Prototype functions with some limitations. Minor issues with biomechanics or material choice.	Prototype has significant functional problems. Design flaws or unsuitable materials hinder performance.	Prototype is poorly constructed and/or non-functional.
Biomechanics & Math	Clearly explains application of biomechanical principles to the design and uses appropriate math calculations (e.g., weight distribution, joint angles).	Demonstrates understanding of biomechanics and attempts to apply math concepts, but calculations may be incomplete or inaccurate.	Shows limited understanding of biomechanics and math concepts. Calculations absent or incorrect.	No evidence of understanding or application of biomechanics or math concepts.

Communication	Presentation is clear, engaging, and well-organized. Writing samples are concise and informative, explaining design choices and findings.	Presentation is informative, but may lack some clarity or organization. Writing samples are generally clear, but may contain minor errors.	Presentation unclear or disorganized. Writing samples contain inaccuracies or lack necessary details.	Presentation confusing or poorly delivered. Writing samples unclear or inaccurate.

Extension

- Research different materials and technologies used in real-world animal prosthetics, exploring bioprinting or advanced robotics.
- Contact local animal shelters or veterinary clinics to learn about their experiences with animal prosthetics and the needs of animals with disabilities.
- Create awareness campaigns about animal prosthetics and advocate for animal welfare initiatives.