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BASIS Lesson Plan

Lesson Name: Catapult Challenge

Grade Level Connection(s)

NGSS Standards: 3-5 Engineering

**Note to teachers: Detailed standards connections can be found at the end of this lesson plan.*

Teaser/Overview

In this fun, hands-on lesson, students will work collaboratively to solve an exciting engineering challenge. Students will be introduced to the engineering process, which they will use to create a catapult that can accurately and consistently launch a projectile (ping pong ball) into a target, or one that launches the projectile as far as possible.

Lesson Objectives

- Students will be able to describe and employ the engineering design process
- Students will design and build catapults using simple, everyday materials
- Students will work independently and collaboratively to solve a specified problem by creating technology
- Students will understand the concepts of projectile motion, accuracy, and precision

Vocabulary Words

Note to volunteers: you shouldn't need to introduce all of the following vocabulary words. For younger grades, consider skipping "accuracy," "precision," and the geometric terms; for older grades, you may not need to define "model," "projectile," or "triangle."

- **Engineering**: Process of using math and science to create solutions to problems
- **Technology**: A device that solves a problem; the outcome of the engineering process
- **Catapult**: A device that launches a projectile
- **Projectile**: An object that is launched or thrown, usually in the air, by a force
- **Accuracy**: The degree of closeness to a true or desired quantity/location. In this activity, accuracy is the ability to hit the target with the ping pong ball.

- **Precision**: The degree to which further tests show the same results. In this activity, precision is the ability to hit the same location multiple times with the ping pong ball.
- **Geometry**: A branch of mathematics that studies shapes and relationship between objects in different places
- **Triangle**: A shape made out of three straight lines
- **Quadrilateral**: A shape made out of four straight lines
- **Model**: A simplified representation of something

Materials

In a gallon-sized zip-lock bag or paper bag (1 per group, identical materials in each)

- Popsicle sticks
- Masking tape
- Straws
- Rubber bands (different sizes)
- Plastic spoons (different thickness of plastic if possible)
- Cardboard base (one per team)
- Ping pong ball
- Rubber ball

For the entire class

- A bucket or other container to serve as a target. Multiple containers for larger groups
- Measuring tape to calculate distance the projectile travels
- Some background images of catapults for students to examine

Classroom Set-Up

Please have students separated into groups of 3-4. Students should begin at their desks facing the front and will later be in their groups of 3-4. Volunteers will need space in one part of the classroom for students to test their catapults. It would be helpful for volunteers if students are wearing name tags.

Classroom Visit

1. Introduction (10 minutes)

Role Model Introduction:
Being a role model is an important part of being a BASIS volunteer! Begin your lesson by explaining who you are and what you do as an engineer. Feel free to tell your "story" as if giving an elevator pitch to kids: Why did you become an engineer? What problems are you trying to solve? What do you do in your job? Why should students relate to you? Feel free to bring in photos, specimens, and other props. Let your personality shine through!

Topic Introduction:

1. Introduce engineering
    - Write **engineering** on the board
    - Activate students' prior knowledge with a group discussion: What do you know about engineering? What do engineers do? What kinds of projects do they work on? What kinds of things do they build? (This also helps you to adjust the lesson according to the class's background).
    - Engineering is a way of finding solutions to problems using science and math.
    - Problems may be big (how to we get cars across the SF Bay?) or small (how can we keep the sun out of our eyes?)
2. Introduce technology
    - Engineers address these challenges by creating **technology** (write on board), which is the outcome of the engineering process. What kinds of things do we already know about technology?
    - Technology can be electronic, but it definitely doesn't have to be!
    - It also can be complicated (a bridge) or simple (paper and pencil)
    - What kinds of technology can students see in this classroom? What problem do they solve? (eg shoes help us walk without hurting our feet; a computer helps us record and learn things, communicate, and play games; the walls help us display things and keep sounds from going from one room to another; etc.)
    - Have students done any engineering projects of their own, in or outside of school? What problem were they trying to solve? What technology did they create?
3. Introduce engineering challenge
    - Introduce the problem: What problem does your team want students to solve? Can you tie it into the local community or current events? For example, maybe the problem is how to get a package to the volunteers at Cal from the school you're visiting; how to get a basketball into a hoop using technology instead of arms; or (for a real-world example); how to create a colorful abstract painting on a skyscraper; or how to get an airplane in the air if the runway is only as long as the

schoolyard (think aircraft carriers). Or maybe it's a new Olympic sport like a mechanized shot put? Get creative!

- Invite students to brainstorm ideas about what technology they could build to solve the problem at hand.
    - Give everyone a few moments to think
    - Invite students to share their ideas with the person next to them
    - Guide an all-class brainstorming session
    - Hopefully the idea of building a catapult has come up – if not, suggest it!
- Give students a brief background on catapults to make sure everyone is starting on the same page, and no one is advantaged with prior experience.
    - Who has heard of catapults? What are catapults used for? (Listen to student ideas and experiences).
    - Share some images and discuss the history of catapults and their uses today: Originally catapults were designed for use during battles or wars. Today, catapults are used for a variety of reasons, from toys to launching planes and jets from aircraft carriers that have limited runway space.
- Guide a discussion of how a catapult works (more or less complex description depending on the grade)
    - If we are trying to hit targets with catapults, we need to understand **force**. How do you think force will affect the speed/distance of the ping pong ball?
    - We should also understand something about the **direction of force** (write on board, define). When you test your devices, think about direction of force, ie how far back the catapult is pulled before it's released.
    - What shapes do you see in the examples? What function do you think they serve? Consider introducing the terms **geometry**, **triangle**, **quadrilateral**, etc. as they come up.
    - Emphasize the value of triangles, if the class does not come up with this on their own: A triangle is the strongest geometric shape. Its sides cannot move unless the length of the sides changes, which means that in this challenge the sides would have to break in order for the shape to change. On the other hand, a square or rectangle can become a diamond or other quadrilateral without any sides breaking, which can stress joints.

Teaching Tip: Guide Group Discussion

- Write new vocabulary words and brainstorm lists on the board
- Refer back to the board to engage visual learners and English Language Learners
- Give students 3 seconds to think before calling on anyone
- Be aware of examples you use that may not be accessible to all students: for example, some students may not have ridden a roller coaster, been on an airplane, played with a smartphone, or even been outside of their hometown!
- Guide students to figure things out together by turning statements into questions
    - Instead of saying: "A baseball cap is a kind of technology, because it solves the problem of how to keep the sun out of our eyes."
    - Try: "Can you think of an example of technology from this classroom? What about that baseball cap hanging up by the door? What problem does it solve? How does it solve that problem?" etc.

2. Learning Experience (30-40 minutes)

- Now that we've learned some things about catapults from science, math, and even history, let's put them to use as engineers!
- Students will work in teams to create a catapult that launches a ping pong ball either into a target or as far as possible across the classroom, using only the materials provided. (Which criteria you give can depend on the set-up of the classroom, the age/background experience of the class, and your own preference).
- Begin by introducing students to the **engineering process:**
    - Define: specify criteria and constraints that a possible solution to a simple problem must meet.
    - Develop solutions: research and explore multiple solutions to the problem.
    - Optimize: improve a solution based on results of simple tests, including failure points
        - Emphasize that engineers often have to test and re-design many times before they find a solution that works! Give examples: are we still driving cars like the ones our grandparents drove? No, every year engineers improve upon car designs. Will we be driving the same cars in the future? No, engineers will continue building on each other's solutions.

Step 1: Define the problem

- Reiterate the problem that students are trying to solve – check for comprehension.
- We're going to create a **model** (write on board, define) of a type of technology that will solve the problem.
- Introduce the word **criteria** (write on board, define):
    - The device must launch the ping pong ball [into the target or as far as possible]

    - If students will be launching the ping pong ball into a target (for older / more experienced classes), introduce the terms **precision** and **accuracy**, and help students understand the difference.
        - Show visuals of marks on a target to illustrate the difference. Which are they aiming for here? One? Both?
        - If your catapult launches the ping pong balls so that they all land in the same place but do not hit the target, is that an example of accuracy or precision?
        - What if all your ping pong balls hit the target but they hit it at different points on the target (if target is large enough for this to happen)?
    - (Criteria can be modified to change the difficulty of the challenge)
- Introduce the word **constraints** (write on board, define):
    - The students can only use the materials provided
    - No part of any student's body can cross over the launch line
    - Students will have [X] minutes.
    - (Constraints can be modified to change the difficulty of the challenge)
- Challenge students to ask questions that will clarify the criteria and constraints (can we use materials from our desks, does the ping pong ball have to stay in the cup, do bounces count for distance, does it matter how high it goes, how big can the catapult be, etc.)
    - Check to be sure everyone understands the criteria and constraints.
- Let the students see the materials as a class by holding them up in front of the class.
- Reiterate to students that there is no failure in this challenge, and everything can be improved. You may wish to present the acronym FAIL: Future Advantage In Learning.

Step 2: Develop solutions

- Separate students into groups of 3 or 4 and give each group a bag of supplies.
- Have them start by individually brainstorming and drawing designs. After individual brainstorming, groups should get together to share and evaluate ideas. Remind them to use productive and supportive language as they evaluate the ideas they and other members of their group came up with. Also encourage them to see if multiple designs might be created into one final solution they're going to try to create.
- After they've agreed on a design as a group, allow them to start building their creations.
- As groups finish their designs, have them test their catapults in an area of the classroom where they aren't risking hitting other students or anything else that shouldn't be hit.

Step 3: Optimize

- Once groups do an initial test, have them evaluate how well their design solves the challenge.
- Guide groups to consider: What did each part of the catapult contribute? How well did each part work? What weaknesses does their catapult have? Which parts should be changed to address that weakness?
- Continue with the process of testing and redesign until each group has had the opportunity to come up with several iterations of their design (or more if time and interest level allow).

Teaching Tip: Differentiate for grades 3, 4, and 5

- Ask the teacher about students' background in engineering, and adjust constraints and criteria accordingly.
- Adjust vocabulary and complexity of concepts you introduced based on age – especially when it comes to mathematics.
- Read the room. If the challenge is too easy or hard, feel free to adjust!

Possible extensions:

- This is a great opportunity to have students use science journals throughout the entire activity. They can draw and write their brainstorming ideas at the beginning and record results, observations and ideas throughout the remainder of the project.
- You can increase the difficulty of this activity for older or more advanced groups by making the target more challenging to hit, either by making it smaller or by placing it farther from the launch area (changing the criteria). You may also wish to bring in a variety of targets at varying distances, and even make them worth different amounts of "points" for groups to collect.
- You can also increase the difficulty of the challenge by limiting the amount of supplies groups can use – or placing a cost on all the materials and giving each group a budget they can spend on supplies (changing the constraints). This can be really fun if students are old enough!
- For younger groups just challenge them to design something that can launch the projectile as far as possible.
- This is a great opportunity for students to get some experience measuring distance and calculating the average length of multiple launches.

3. Wrap Up: Review and Discuss the Learning Experience (5-10 minutes)

- Have groups present their solution to the rest of the class, explaining what challenges they encountered and the solutions they designed. Ideally each group will have the opportunity to demonstrate the function of their catapult.
- Prompts may include: Why have they included the various components of their design? What did they learn the first time that helped them to be successful the second time? Why did they try their first design? What worked? What problems did they have? What did they change the second time? Did that solve the problem?
- Encourage students to respond to one another's solutions, and identify patterns. Did more than one group try something similar? Did different groups experience similar challenges?

4. Connections & Close (5 minutes)

Connections to the real world around students:

Engineering is everywhere! What other problems would students like to solve in the future? What else would they like to create? Do they have any questions?

Close:
Wrap up by leaving a few minutes for students to ask questions about engineering, about being an engineer, and about becoming an engineer. Then, thanks and goodbye!

Follow Up: After the Presentation

Teachers who wish to extend the impact of this lesson may find the following CRS web pages useful:

- http://www.crscience.org/educators/helpfulreports
- http://www.crscience.org/educators/treasuretrove

Standards Connections

NGSS:

- Connections by topic
  - 3-5 Engineering Design
- Connections by disciplinary core ideas:
  - 3-5-ETS1 Engineering Design
- Connections by scientific & engineering practices
  - 1. Asking questions and defining problems
  - 2. Developing and using models
  - 6. Constructing explanations and designing solutions
- Connections by crosscutting concepts
  - 2. Cause and effect: mechanism and explanation
  - 6. Structure and function
- Connections by performance expectation:
  - 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.