READY FOR PRIMARY TIME: ADAPTING ENGINEERING CURRICULUM FOR THE K-2 CLASSROOM

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FINDING GREAT ENGINEERING IDEAS

- ASEE’s eGI searchable database of lessons and activities by grade level

- Try Engineering has searchable lesson database and online games

- TeachEngineering publishes classroom tested lessons created by university faculty, graduate students, and teachers

- Engineering is Elementary curriculum written by team of developers at Boston’s Museum of Science
BRIDGE BUILDING INSPIRATION FROM EGI

- **Activity: Build a Human Suspension Bridge**
- In this activity for grades 4 through 6, students become acquainted with the engineering principles and forces that help support bridges. Then 16 students form a human suspension bridge.
BRIDGE BUILDING INSPIRATION
FROM TRY ENGINEERING

Popsicle Bridge Lesson: Using 200 sticks students design bridge to support 5 pounds; extra points for using the least sticks. For age 8-18.
Designing Bridges Lesson for 8th Grade includes this idea for directly experiencing the forces. Students build a human bridge spanning the room strong enough for a cat to cross and directly experience tension and compression forces.
LEVEL: Grades 1-2

Students explore why bridges are shaped differently. Students distinguish between beam, arch, and suspension bridges and learn how bridge designs counteract and redirect forces and motion. In the culminating design challenge, students design, construct, and test their own bridges.
HOW MUCH TIME SHOULD I PLAN?

- Whole group introduction – 5-10 minutes
- Hands-on activity – 20-30 minutes
- Whole group wrap-up discussion – 5-10 minutes
- Depending on activity no more than 45 minutes including clean-up.
WHAT CHALLENGES WILL APPEAR?

- Children’s literature
- Everyday situations that arise in classrooms
- Contests
HOW DO I SET UP THE CLASSROOM FOR ENGINEERING LESSONS?

- Kindergarten: 3 areas:
  - rug for whole group
  - one table for small group lesson with adult
  - additional areas around the room for self-directed activities as students wait for turn at table

- 1\textsuperscript{st}/2\textsuperscript{nd} grades: 2 areas:
  - rug area for directions, discussion
  - tables for hands-on activities

- 3\textsuperscript{rd}-5\textsuperscript{th} grades: 1 area:
  - entire lesson can be done with students at their tables; have a counter or additional table for Materials Store
WHAT GROUP STRUCTURES WORK BEST FOR STUDENT GROUPS?

- Kindergarten: In a small group of no more than 6 students around a single table with an adult. Each student gets his/her own materials.
- 1st and 2nd grade: Partners sharing materials
- 3rd-5th grade: Small Groups, 3 or 4 students with defined roles:
  - Getter
  - Recorder
  - Starter
  - Reader-reporter
WHAT IS FREE EXPLORATION AND WHY IS IT IMPORTANT?

- Get it out of their systems so they can focus on using the materials as directed in the lessons

- Opportunity to establish and enforce rules about how students can use particular materials

- Open-ended exploration leads to discoveries

- It’s what real engineers do
WHAT IS THE BEST WAY TO “RATION” SUPPLIES?

- Kindergarten and 1st grade: Determine exactly how much each student/group gets – make sure everyone gets exactly the same

- 2nd and 3rd grade: Budget based on the total number of items OR use prices on items and give everyone same amount to spend

- 4th-5th grade: Scoring guides that reward using less materials while still solving problem
HOW CAN CLEAN-UP TIME BE EASIER FOR YOU AND YOUR STUDENTS?

- Have a cleanup plan before beginning the lesson

- Materials Store – students pick up and return unused supplies to counter

- Plan for waste – tubs for dirty water etc.

- Assign clean-up chores
  - Colored dots within each group
  - Table groups assigned task
MATERIALS STORE
WHAT ARE SOME EFFECTIVE WAYS TO HAVE STUDENTS SHARE THEIR WORK?

- Walk around show
- Use document camera for student presentations
- Buddy classes
- Parents
- Bulletin board or showcase display
EXTRA BONUS: ENGINEERING AS A LIFE LESSON

- Solving practical problems
- Criteria for success
- Constraints
- Trade-off between success and constraints
BUILDING BRIDGES WITH THE BILLY GOATS GRUFF

An engineering curriculum unit for primary students
LAUNCH THE DESIGN CHALLENGE
THE THREE BILLY GOATS HAVE A PROBLEM

- Besides the troll, what other problem do the billy goats have? (need a bridge to cross the stream)

- How can you help? (build them a bridge)

- Can you build a bridge strong enough for the little billy-goat to cross safely and avoid the troll lurking below? Strong enough for the middle-sized billy-goat or the big billy-goat? For the whole family to cross together?
TIME FOR FREE EXPLORATION

- Show students the materials they will be using to tackle the bridge challenge:
  - Abutments
  - “River” and “Boat”
  - 5"x8" index cards for bridge building
  - Gram weights to represent billy-goats:

- Organize students into engineering teams
- Provide hands-on free exploration time
- Wrap-up making a class list of student discoveries during free exploration time
WARM-UP WITH BEAM BRIDGES

Find out the least number of cards needed to support:
- one little billy goat (5 gram)
- one medium billy goat (10 gram)
- one big billy goat (20 gram)
- the family (5 + 10 + 20)
- class generated challenges

Did everyone get the same results?

What is the relationship between the number of cards and the weight supported?

Why might engineers try to build things with the least amount of materials?
WHAT HAVE OTHERS DONE?

- What have others done? Research primary style
- Students sketch what their bridge might look like or draw a bridge they’ve seen
- Explore local bridges with photos (easily available online) and/or by using children's books

- The kid-friendly PBS Building BIG website is an excellent resource for bridge photos and background information: http://www.pbs.org/wgbh/buildingbig/bridge/index.html
BEAM BRIDGE
ARCH BRIDGE
ARCH BRIDGE
CORVALLIS BRIDGE
EXPLORE ARCH AND DOUBLE BEAM BRIDGES

Find out the maximum weight each of the following bridges can hold; students can use any combination of billy goats but will need to find a total weight.

- arch bridge using TWO cards (only one way to construct this one)
- arch bridge using THREE cards (could use two cards for arch OR beam)
- Deep beam bridge using THREE cards
- Deep beam bridge using FOUR cards

How can we record results?
DEEP BEAM BRIDGE
HOW WILL YOU KNOW IF YOU ARE SUCCESSFUL IN SOLVING THE PROBLEM?

A successful bridge design will (criteria for success):

- Span the river. Show paper river.

- Be high enough for boats to pass under. Demonstrate cup boats going under.

- Must support the billy-goats.
  - Discuss with students what "support" means: If the bridge sags, but doesn't fall is that support?
  - Does the bridge need to be level?
  - The class can agree on a definition for success.
WHAT ARE THE CONSTRAINTS? TRADE-OFFS?

The constraints or RULES are:

- You may only use the materials provided to build the bridges.

- You may use a maximum of FIVE index cards.

- Scoring will be based on the number of cards you used AND the weight supported.

Talk with students about why using less cards might be a better solution; relate to the cost of buying materials to build a real bridge.
IMAGINE POSSIBLE SOLUTIONS AND DESIGN

- Brainstorm ideas as a class

- Individual Think Time: Each design should include a labeled drawing and a list of materials needed.

- Find a partner or form an engineering team. Students with similar design ideas can work together.

- Turn in the plan, pick up building supplies
ENGINEERS PLANNING THEIR DESIGN
SAMPLE DESIGN

Draw a diagram of your design.

Make a list of materials you’ll need.
  • Abutments and river
  • Index cards
  • Weights and “boat” to test bridge

Follow your plan and create it.
DID YOUR BRIDGE PASS THE TEST?

- Try out your design.
- Collect data on how your invention meets or doesn’t meet the criteria.
- Display the data visually (graph or table) and/or write a summary
- Did you solve the problem?

Students test their ideas for a bridge that supports the little billy-goats Gruff. For each type of bridge find the maximum capacity before failure.
TESTING
# HOW MANY CARDS TO SUPPORT THE LITTLE BILLY GOATS?

<table>
<thead>
<tr>
<th>Type of Bridge and Number of Cards</th>
<th>Number of Goats on Bridge</th>
<th>Total Weight Supported (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 card – beam</td>
<td>3 small goats</td>
<td>$5 + 5 + 5 = 15$</td>
</tr>
<tr>
<td>3 cards – beam</td>
<td>2 small + 3 med</td>
<td>$5 + 5 + 10 + 10 + 10 = 40$</td>
</tr>
<tr>
<td>2 cards - arch</td>
<td>4 large + 1 med</td>
<td>$20 + 20 + 20 + 20 + 10 = 90$</td>
</tr>
</tbody>
</table>
TRADEOFFS AND ANALYSIS, REDESIGN

- Talk with students about the trade-offs between number of cards used and number of goats supported.

- How can you decide which is the best overall design for the small goats?

What could you change to make it better?
- Improve your design
- Test it out.
COMMUNICATE

- Share your results with others
- Plan an event so that students can show off their bridges. Invite buddy class or parents.
- Display bridges in school display case or make a bulletin board with photos and captions
MATH CHALLENGES

Change the challenge for some primary math:

- Practice skip counting (5's, 10's, and 20's)
- Multiplication as repeated addition
- Commutative property of addition
- Adding with more than two addends
- Using an ordered list
CASCADING MATH CHALLENGES

Choose ONE bridge design: a beam bridge with a certain number of cards (5 is enough) OR an arch bridge using two cards.

- Only small billy goats can cross, what is the maximum your bridge will hold?
- Only medium-sized goats, how many?
- Only large goats, how many?
- Only small AND medium goats, list all the ways this works.
- Only small AND large goats, list all the ways.
- Only medium AND large goats, list all the ways.
- All sizes of goats can cross, list all the ways.
EXTENSIONS– TAKING IT FURTHER

- Change the constraints: Add new materials: tape, paper clips, popsicle sticks, straws, etc.
- Change the criteria for success: Pose new challenges (perhaps student generated) – Can you build a bridge to span a lake?

More research:
- Human bridges – experience the forces
- Interactive websites
  - How Stuff Works
  - Building Big
LONG BRIDGE TO SPAN A LAKE
BILLY GOATS REDUX

"And after that, they went up to the hillside. There the billy-goats got so fat they could hardly walk home again. And if the fat hasn't fallen off them, why, they're still fat. And so snip, snap, snout, this tale's told out."

OR is it? Fatter billy-goats need stronger bridges to return to the other side of the river. The engineering design challenge and math opportunities continue!
PARACHUTING WITH HOT AIR HENRY

An engineering curriculum for primary students
WHAT IS THE PROBLEM? WHAT HAVE OTHERS DONE?

- Hot Air Henry needs to get safely to the ground from his runaway balloon. How can you help?

- Parachutes are used to drop safely to the ground.
HOW WILL WE KNOW IF OUR DESIGN IS SUCCESSFUL? WHICH PARACHUTE IS BEST?

- The best design will fall the slowest.
  - How will we determine which parachute is the slowest?

- A successful design will stay upright and minimize side-to-side movement so Henry doesn’t fall out.

- Have a target with points?

- Agree on testing location and rules for dropping, measuring results, etc.
WHAT ARE THE CONSTRAINTS (RULES)?

- All parachutes will have four strings attached to the four corners (all same size).
- All parachutes will have one large paper clip as the “load”

Decide on a variable to explore:
- What material works best? tissue paper, napkin, plastic wrap, or fabric (all same size and shape)
- What size works best? Choose one material and try out large, medium, and small sizes.
- What combination of material and size works best?
IMAGINE, PLAN, BUILD, TEST, REDESIGN, COMMUNICATE
OOBLECK, SLIME, AND PLAYDOUGH

Materials Engineering for the Elementary Classroom
WHAT’S THE PROBLEM?

- Oobleck Design Challenge: Use properties of oobleck to make a moat that you can cross if you know the secret. Write a story.

- Slime Design Challenge: Design a slime recipe that would make a fun toy. Write an ad to sell the slime toy.

- Playdough Design Challenge: Design quality control tests for playdough.
HOW WILL WE KNOW IF OUR DESIGN IS SUCCESSFUL?

- Oobleck: Enemies can’t cross. Friends know the secret for crossing. Story that incorporates what we know about oobleck.

- Slime: Fun toys that does what we say it does in our ad and others want to play with it.

- Playdough: Scoring guide that helps us decide what is good playdough and what is not.
IMAGINE, PLAN, BUILD, TEST, REDESIGN, COMMUNICATE