Lesson: Gumdrop Bridge (Application Exp.)

1. NJ standards addressed in the lesson:

5.1.12.C.1: Reflect on and revise understandings as new evidence emerges.

In building their gummy bridges, students will be asked to use force diagrams to predict the weak points in their design and to predict if, if the bridge fails, where it will do so.

5.1.12.C.2: Use data representations and new models to revise predictions and explanations.

Students will need to revise their explanations for the weak points in their bridge if the bridge does not fail where they expected it to. In addition, students will have to reconstruct and add to bridge design to account for weak points and redistribute forces.

5.1.12.D.1: Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences.
AND
8.1.12.C.1: Develop an innovative solution to a complex, local or global problem or issue in collaboration with peers and experts, and present ideas for feedback in an online community.

Students will work in groups to design, construct, analyze, and redesign their bridges.

5.1.12.D.2: Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams.

Students will follow protocol similar to real engineering in which they must first submit designs and calculations (force diagrams) before "purchasing" materials to construct their product.

2. What students should know before they start the lesson:

- Force diagrams
- Newton's third law
- Basics of engineering design process

3. Goals of the lesson

Content:

Goals	Standards Addressed
Use force diagrams as a real life indicator of expected forces.	5.2.12.D.1
Kinds of engineers involved in making bridges (Name 2 aside from civil!)	8.1.12.C.1

Procedural:

Goals	Standards Addressed
Understand parts of the Engineering Design Process	8.1.12.C.1, 5.1.12.D.1
Conduct an application experiment	5.1.12.C.1, 5.1.12.C.3
Use force diagrams as a basis for design analysis	5.1.12.C.2, 5.1.12.D.2

Epistemological:

Goals	Standards Addressed
Understand why a given solution does not work and come up with solutions.	5.1.12.C.1,
Analyze what assumptions were made and how they affect results	5.1.12.C.1, 5.1.12.C.2
Learn to appreciate and use others' abilities and cooperate to achieve a common goal	5.1.12.D.1, 8.1.12.C.1
How do different engineers join to achieve common goal?	5.1.12.D.1, 8.1.12.C.1

Metacognitive:

Goals	Standards Addressed
How can I contribute my strengths to the discussion and help solve the problem?	5.1.12.D.1, 8.1.12.C.1
How do I know that my design is the strongest?	5.1.12.C.1, 5.1.12.C.3

4. Most important ideas

- Engineering content:
    - Aspects of the engineering process: Identify the problem, research the problem (find what works), develop possible solution, construct prototype, test and evaluate, Redesign/communicate solution.
    - Involvement of many different kinds of engineers in the bridge building process
    - Analysis and results don't always match.
- Using a visual aspect as an analysis tool (force diagrams represent real forces).

5. Student potential difficulties:

- **Direction of exerted forces**
    - ✓ Students may have to be reminded that because the whole bridge acts together, there are forces that may be exerted on one point from somewhere else on the bridge. Similarly, students may need to be reminded that not all forces are being exerted towards nodes (gumdrops). Some may be pulling away from the node (difference between compression and tension forces).

- **Narrow design view**
  - ✓ Student, during the design process, may only concentrate on their bridge's ability to support itself or just the force being exerted on it. As a result design flaws may occur in the bridge's ability to support its own weight (insufficient strength on either end) or the ability to support a single force being exerted at one point. Students may need to be reminded of this and make sure they make a bridge that is supported all around.

- **The actual construction and design process.**

  Students need to be reminded of the type of difficulties actual engineers have with construction. Sometimes designs need to be reevaluated if the initial design does not work out as planned and sacrifices may have to be made in design or construction or money in order to achieve something similar to the original design.

  ex:

  "What is standing in the way of you succeeding with your original design?"

- **How to systematically overcome difficulties**
  - ✓ Once students have been made aware of design problems, it is typical for students to try to address the entire problem as a whole, rather than analyzing one small issue at a time that resulted in the whole issue.

6. Equipment needed:

Student Use	Teacher use
• Toothpicks • Gumdrops • Rulers • Engineering design handout	• Styrofoam cup • Paper clips • Pennies or bolts or bb's

7. Lesson description:

<u>Toothpick Bridge Design (Application experiment)</u>

<u>Lab Goals:</u>

- Conduct an application experiment.
- Understand engineering and design process
- Apply Force Diagrams to real situations

<u>The Story:</u>

Welcome to Candyland! You and your team of gumdrop engineers have been hired to build the bridge over the fudge river. Due to the booming health movement sweeping the nation, the Candyland sweeconomy is not doing so well, so it is important that your bridge minimize cost while maximizing load strength (there are some pretty heavy people in Candyland, as you could imagine).

<u>Design Criteria</u>

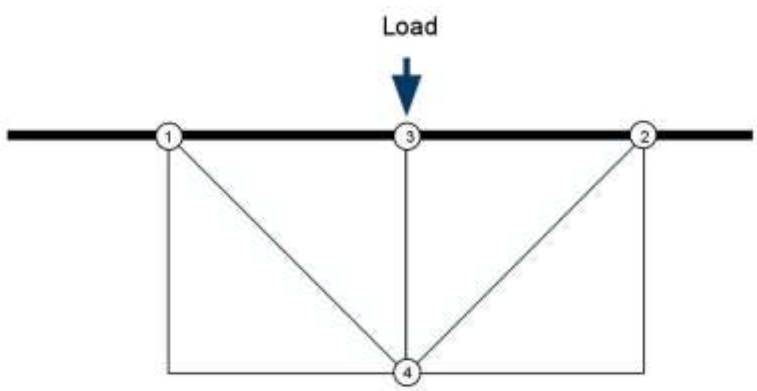
1) Your bridge must be 20 in long.

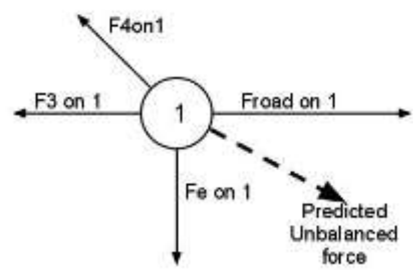
2) The unsupported part of the bridge will be 12 in. which leaves 4 in. of support on each side:
3) Design must minimize cost. The cost of items is as follows:
   Gumdrops – 1 CC (Candy coin, currency in Candyland)
   Toothpicks - 2CC

Design will be tested by hanging a cup from bridge and slowly adding pennies until bridge fails. **As soon as anything fails, the bridge is considered broken and no more pennies will be added.**

Procedure:

a. Last night I had you look up bridge designs. Now that you have your assignment, based off of what you saw, think about which designs you think would best suit your problem.
b. For each design, look at the central section of the bridge. Analyze the structural integrity of the design by drawing force diagrams for each joint in the bridge that you think will be a problem.
   Ex:





c. Once you have decided on a main design, sketch out the whole design.
d. Based on your force diagrams, where do you think the bridge is most likely to fail?(Use your force diagrams for this reasoning.)
e. Build your bridge. Use the table below to keep track of your cost:

Item	Price per item	Total
Gumdrops	1 cc × __________	________cc
Toothbicks	2 cc × __________	________ cc
	Total Cost:	**___________cc**

Design Process Handout

Step	Notes
1) **Problem:** Draw a sketch of the scenario (measurements) .	
2) **Research/Possible Soln's:** Based on your research from last night, Look at some of your favorite designs, analyze with force diagrams	
3) Best Possible Soln: Sketch Final design features.	
4) **Soln. design features and calculations** Use force diagrams to express why you chose this design and where you predict your design will fail.	

5) **Construct, test, and evaluate**: Begin construction of bridge. Note any changes you make. What assumptions are not holding? **If drastic changes were made to design, redraw bridge here**.	

Bridge Testing:

Maximum Load (in pennies)________________ Total Cost ______________CC

$$\frac{\_\_\_\_\_\_\_\_\_\_\_\_(\boldsymbol{Load})}{\_\_\_\_\_\_\_\_\_\_\boldsymbol{cc}\ \ (\boldsymbol{Cost})} = \_\_\_\_\_\_\_\_\_$$ **Final Score**

6) **Communicate Solution**: Where did your design fail? Did it match your prediction? Why or why not (what assumptions did you make) Draw force diagram for failed joint and specify where unbalanced force was.	
7) **Redesign**: What would you do next time to make sure the same structural failure does not happen.	

Teacher Notes:

In this activity students will be required to build a bridge to support maximum load while minimizing cost. The materials are less than ideal, so a lot of creative thought will have to go into designing the bridges. It may be helpful to assign the students to research various bridge designs so that they have an idea of where to start before they come to class. They need not know the assignment, but they can be told that it will benefit them to do the reaserach.

When analyzing designs and drawing force diagrams, students may have difficulty figuring out which direction forces are in. Students will need to be reminded that the JOINT is the object of interest and the forces are being exerted on the Join of interest by the other joints through the toothpicks. As shown in the example, the direction of the force exerted by 4 on 1, therefore is up and to the left, not down and to the right, as this would be the force exerted by 1 on 4. Finally, in order to analyze the failing point, students will, to the best of their ability, draw force diagrams that are indicative of the amount of force being exerted by using lengths to represent magnitude of force.

Either before or after the project, students can discuss the kinds of engineers that would be involved in building a bridge aside from civil engineers. Some may include:

- *Electrical engineers for lighting*
- *Chemical or material engineers for building materials*
- *Mechanical engineers if the bridge can move, for boat passage, etc.*
- *Traffic engineers*
- *Software engineers if there is any computerized sensors or detection of traffit, etc.*
- *Environmental engineers to make sure the exhaust of vehicles will not affect surrounding areas or the river flowing underneath.*

Finally, it is important for students to realize that the score of their bridge is not indicatory of their grade on the assignment. Their grade will depend on the rubrics for an application experiment (which they will have access to from the teacher website). So it is their work and accurate analysis of assumptions and correct construction of force diagrams and proper reasoning of agreement or disagreement between predictions and outcomes that will affect their grade for the assignment.

8. Time Table(2 Day lab or 1 day extended period)

Clock reading during the lesson	**"Title of the activity"**	**Students Doing**	**Teacher Doing**
0 - 5 min	Homework quiz, receive feedback	Writing	Checking up equipment for the first activity
5-10 min	Introduction, statement of rules and materials	Listening taking notes, Getting into groups.	Addressing class, showing material
10-40 min	Initial designs and calculations	Working in groups. Discussing designs, drawing force diagrams drawing initial design.	Assisting students when necessary. Helping students get past design trouble by asking probing questions (see ***possible student difficulties*** section)

Clock reading during the lesson	"Title of the activity"	Students Doing	Teacher Doing
40-70 min (0-30 min if continuing on another day)	Build and test bridges	Constructing working bridge, testing, either with rest of class or individually	Helping students get past hurdles and difficulties in design. Probing assumptions.
70 – 85 min (30-45 min next day)	Redesign and engineering involvement discussion	Discussing with whole class where their bridge failed, why it failed, how they would fix it.	Discussing how design failed, if predictions matched outcome, what assumptions did not hold, how they would fix design.

9. Formative Assessments:

Content Goals:

- Students can correctly represent structural integrity using force diagrams
- Students can recognize engineer involvement with bridge building aside from civil.

Process Goals:

- Proper presentation of information in Design Process Handout.
- Answering homework question about engineering design process.
- Ability for students to initially analyze force diagrams and understand whether their force diagram correctly predicted structural failure. Students can discuss why design did/did not work.
- Correct procedure for application experiment (scientific ability rubrics)

Epistemological Goals:

- Students' ability to accurately and effectively analyze assumptions and explain how they affected the final result.
- Ability of students to effectively solve problems and hurdles in the design process.
- Students are able to effectively work in groups and no one individual is doing bulk of work.
- In Homework: Students can describe a good bridge with more aspects than just structural integrity (aesthetics, concern for environment, lighting, etc)

Metacognitive Goals:

- Ability to answer homework question on contribution to the team and design process.
- Ability to state why their design failed with force diagrams, and to design a better bridge which effectively removes structural flaw from force diagram.

10. Modification for different learners:

By nature of the course, different learners will automatically be accounted for. Students will be working in groups, so the activity is already a cooperative learning activity. The activity could utilize technology in the form of graphing or mathematical programs for learners who prefer the organization of a computerized write-up. Bilingual or ELL students should have no difficulty as they not only have peer instruction, but all concepts used in the lab have been previously addressed and students are constructing new knowledge together. Since the teacher is not introducing new terms or ideas, there is no risk of misunderstanding.

11. Homework:

1) Based on how your bridge failed, draw a force diagram for the faulty joint, as well as the whole bridge. Then, using the same materials, describe how you would fix the problem. Show your reasoning with force diagrams and examples of where the load would be and how it will be transferred throughout the bridge.

2) What difficulties did you have in the engineering and design process ? (List at least one) How did you overcome these difficulties?

3) What was your contribution to the design process?

4) List 3 engineers (aside from civil engineers) that you think would be involved in the bridge building process. For each one, list specifically what their job would be and why it is important.
5) Pretend your Bridge was chosen. What would you have to add to the bridge to make it the perfect addition to Candyland. Think of bridges you've seen and been on. (think aesthetics, accessibility, etc). Also include one idea for your bridge that is going to be unique for your bridge (Be creative, but try to be realistic. i.e. No teleporters or hover-things. Choose something that is within the scope of today's technology and is still useful.)