Phase I – Research and Planning – Due Date: Midterm

1. Identify the "Big" concept to be covered by the engineering design challenge.
2. Research appropriate learning standards associated with the topic.
3. Identify and discuss the different types of problem solving and declarative/procedure knowledge needed.
4. Explore objectives and ancillary concepts/content covered by the project.
5. Identify possible activities.
6. Select the best activity for your classroom.

Phase I - Research and Planning

1. Applications of Triangle Congruence (High School Geometry)
2. Standards:
   G-SRT.B.5 - Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.
   G-CO.D.12 - Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.)
3. Knowledge needed by students includes:
   a. Students should have learned how to draw (freehand, with a ruler and protractor, and with technology) geometric shapes with given conditions. Also, students focused on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.
   b. Students should be comfortable with using informal arguments to establish facts about the angle sum and exterior angle of triangles.
   c. Students should be able to identify/classify types of angles, triangles and other polygons, angle pair relationships as well as perform calculations with these given perpendicular and parallel lines, such as determining the measure of unknown angles and side lengths.
   d. Students should be able to identify and recall postulates and theorems with respect to congruent parts of two-dimensional geometric figures.
4. Objectives could include:

- How do constructed forms help you to understand the principles of geometry?
- Where and how are relationships within triangles used in real-world situations?

I like the idea of constructing bridges and having a design challenge centered around that. The idea of congruent triangles is quite important in constructing bridges and it lends itself well with the design process.

Possible Activities:

Triangle Toothpick Bridges
https://www.cpalms.org/Public/PreviewResourceLesson/Preview/151277

Popsicle Bridges
http://www.scholastic.com/browse/lessonplan.jsp?id=1509

Trusses with different Shapes
https://www.teachengineering.org/lessons/view/cub_trusses_lesson01

6. I chose the Triangle Toothpick Bridges.

Phase II – Implementation

1. Engineering Design Process used: CPALMS Design Process
   (Ask, Imagine, Plan, Create, Test, Improve, and Share)

2. Timeline:
10/21 - I will finish my Congruent Triangle Unit
10/22 - Introduce and do an activity on the Stanford Design Process
10/23 - Take the full block day (about an hour and forty minutes) to complete our design challenge

Engineering Design Notebook: Progress in each step
At the end of this Journal is the student guide worksheet packet that I had students work through for each of the first six steps in this design process. The final step was done in front of the class as a group. I tried to follow the plan as close as possible on cpalms.org website.

Ask:

I introduced the topic through a youtube video on the Tacoma Narrows Bridge collapse in 1940 in order to engage the students. (5 min) https://www.youtube.com/watch?v=3mclp9QmCGs

I then lead a class discussion based around the questions in their BRIDGE BONANZA packet (below) with the following questions (5 min):

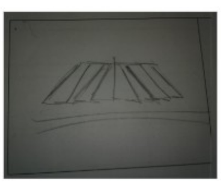
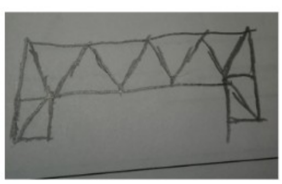
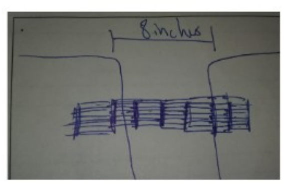
- What is a bridge?
- Where do you see bridges?
- Does the design of a bridge influence its purpose, or does the purpose influence its design?
- How would you adapt triangle congruence theorems to create a stable bridge support system?
- What properties do you predict are most important for constructing a stable bridge?

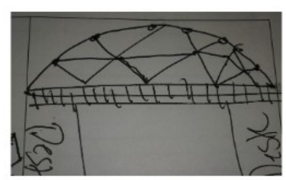
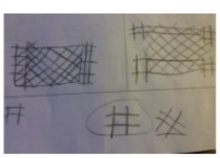
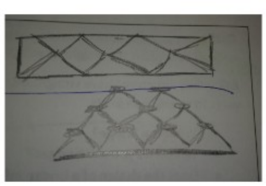
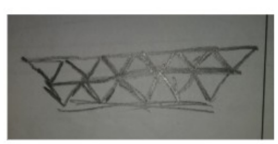
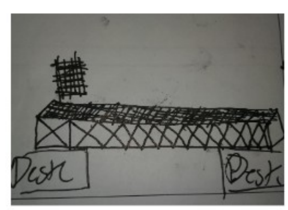
Imagine:

I reviewed the goal, then directed students to brainstorm at least two bridge ideas that could meet the requirements (2 min), asking the following guiding questions:

- What will your design look like?
- How will you use the materials to create your design?

During this time, I circulated the classroom and visited each table. After 2 minutes, I regrouped the students to go to the next step.

Plan:

I gave student groups 3 minutes to put their ideas together and develop their team's design.

During this time, I circulated the room to make sure all students were being involved in the process. Some questions I kept in mind and asked:

- Has everyone had the opportunity to share their ideas?
- What materials will you choose to use in your design?
- If a student is not talking, look at them and say, "What ideas do you have about the design?"

After 3 minutes, we regrouped as a class to go to the next step. I acted as “overseer” and had students present their design to me before actual construction. I also took this time to specify the procedure for construction:

Describe the procedure students will follow once their design is approved:

- One student from each group (Runner) will obtain a "shipment: of supplies (100 toothpicks and 40 gumdrops)
- One student (Recorder) will record the team's build process in the space provided on the Student Activity Sheet
- Teams may choose to use no more than 100 toothpicks
- Teams may choose to use no more than 40 gumdrops
- The bridge *must* be able to support the weight of at least one geometry textbook for 15 seconds
- Time allowed for bridge construction: 30 minutes
- The bridge must be at least 8 inches long.

Create:

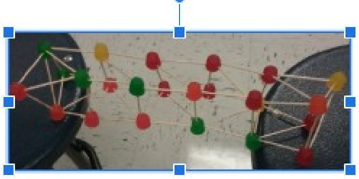
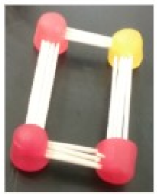
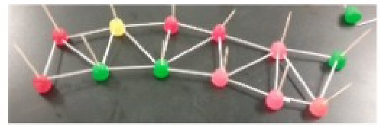
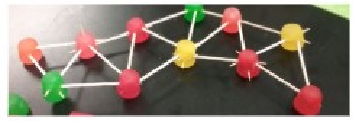
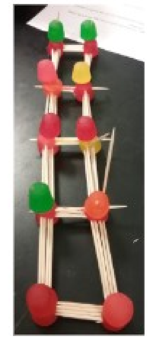
Students had only 30 minutes to build their team's design according to their plan.

During this time, I again circulated the classroom to visit each group. Some questions I kept in mind: "How did you come up with this design?" "Have you ever done anything like this before?" "What have you contributed to this design?" "Can you help this student with this part?"

I had to remind students to test small parts of the bridge before building the entire structure.

Teams tracked the build process on the Create section of the Student Guide

After 30 minutes, tell students to stop building and that it is time to test.

Test:

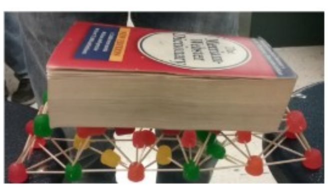
First, I again reviewed the goal with the students: *Use theorems about triangles, angles, and lines to construct a bridge that will be stable enough to support the weight of your textbook(s).*

The bridge must be stable enough to support the weight of your textbook(s) for at least 15 seconds.

Bridge success will be determined via the attached scoring rubric.

After this, we tested, and I lead a discussion in which the students compare the different designs groups came up with and had these points in mind:

- Ask students to describe any similar ideas multiple groups used.
- Ask students to describe any different ideas groups came up with.
- Ask students why they think some designs came closer to meeting the goal.

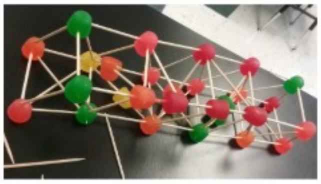


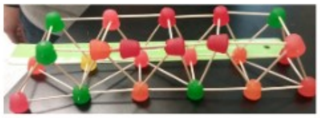

Improve:

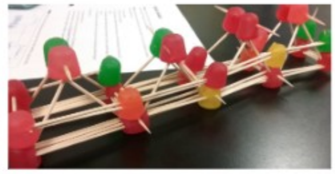
After the first test, students answered the questions on their worksheet and then decided what improvements needed to be made to their design.

During this time, I circulated the classroom and visited each table. I asked questions such as: "How are you going to improve your design?" or "What changes are you making to your design and why are you making them?"

After 10 minutes, tell students to stop building and that it is time to test again.







Final Test and Sharing the Solution:

Review the goal with the students: *Use theorems about triangles, angles, and lines to construct a bridge that will be stable enough to support the weight of your textbook(s).*

The bridge must be stable enough to support the weight of your textbook(s) for at least 15 seconds.

Bridge success will be determined via the attached scoring rubric.

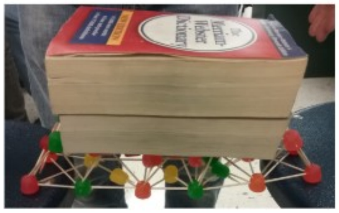
After testing, we again had a class discussion using the following questions:

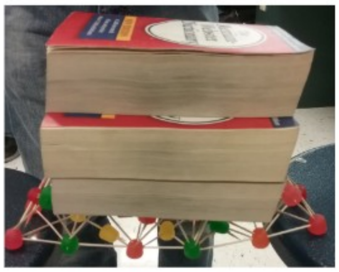
- Describe any similar ideas multiple groups used.
- Describe any different ideas groups came up with.
- Why do you think some designs came closer to meeting the goal?
- Did your design meet the requirements of the challenge?
- Have you tried multiple designs?
- If yes, did you record what you learned from each design?
- Can your bridge be stronger or more visually appealing?
- Can your bridge be built using a more efficient design?
- How are you using scientific inquiry to steer design decisions?

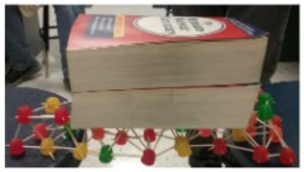
Discussion (5 minutes):

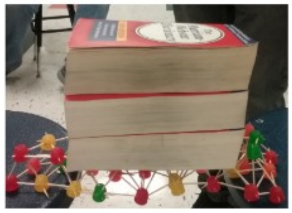
- Did your team's design meet the goal? Why or why not?
- Did your design improve? How do you know?
- Are there any changes you would still like to make to your design?

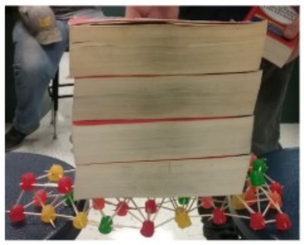
Their homework was the standards worksheet at the end of the Student Guide as an assessment piece.











Reflections

What went well with the engineering design challenge?

Prior to doing this challenge, I had introduced my students to the design process one class period and we discussed and did different exercises for each of the steps. I think this set up the challenge really well and allowed for more success. Students were really engaged from the beginning. Having went through the process and then introducing the idea with a disaster from engineering history, the students seemed really hooked. Students knew they were on a bit of a time constraint and this allowed them to really push through and get some good work done in a short amount of time. I was pleased to see the use of the geometry we had discussed in our lessons being put into action. Many of the conversations were centered around which types of congruency to use for the challenge.

What did not go well with the design challenge?

Two out of the four groups had designs that failed to hold the required weight. The biggest factor seemed to be the time constraint. In the future it may, in fact, be better to give the students the full block day to test and redesign and then do the final weight test the next class period. I think if I had allowed just even another 10 minutes, both the groups that failed would've been able to do a better job. This did allow for really good class discussion though.

What concepts were covered?

Triangle congruence, trusses, support, angles, parallel, perpendicular, mass, mass ratio, construction purpose, design, and function

How did the ED process help teach the science and mathematics concepts?

The ED process brought the geometry to life really well with bridge construction. I had one student say that it was nice to see that "math isn't done in a vacuum." I asked her about that statement and she said that the bridge challenge gave her a real idea how math can help solve actual problems. Going through the ED process gave students a chance to work and rework different ideas. I really challenged students to consider the geometry after their first building and testing phase. It was great to see how student thinking and design progressed in just a short lesson with the design process. I also found that a couple of my students that are typically unengaged, really diving into this challenge.

Did I choose an appropriate engineering design process? Should I simplify or make more complex?

I think the design process that I used (Ask, Imagine, Plan, Create, Test, Improve, and Share) really worked well. I really wanted to use the Stanford design process which is a little more simplified version (Empathize, Define, Ideate, Prototype, Test) because of the empathize idea. I really like the idea of beginning with putting yourself in someone else's shoes and having that initial step drive the rest of the engineering and design. I found that the process I used worked a little better for my challenge however.

How can I improve this activity to use with future students?

The time constraint seemed to be the biggest issue I faced with my students. In the future, I would like to either keep the constraints the same, but allow for more time or change the materials around a bit to allow for shorter time constraints. I am leaning towards incorporating more time and pushing the actual final testing of their bridges a class period. Students would be able to reiterate their designs much easier and allow better access to the design process that way. It is also worth noting that I tested this project in my remedial math class. It is a class with 16 low performing students and they did an excellent job. They were able to really connect the math to the activity.

References

Colorado Standards - Academic Standards. (2015, May 19). Retrieved September 18, 2019, from https://www.cde.state.co.us/standardsandinstruction/coloradostandards-academicstandards.

CPALMS. (2019). Retrieved September 18, 2019, from https://www.cpalms.org/Public/.

Engineering a Bridge. (2019). Retrieved September 18, 2019, from http://www.scholastic.com/browse/lessonplan.jsp?id=1509.

Lespérance, S. (2006, September 23). Tacoma Bridge. Retrieved September 22, 2019, from https://www.youtube.com/watch?v=3mclp9QmCGs.

Raz, A. (2017, February 21). Get Started with Design Thinking. Retrieved September 22, 2019, from https://dschool.stanford.edu/resources/getting-started-with-design-thinking.

Triangles & Trusses - Lesson. (2019, July 2). Retrieved September 18, 2019, from https://www.teachengineering.org/lessons/view/cub_trusses_lesson01.

BRIDGE BONAZA

Goal: Use theorems about triangles, angles, and lines to construct a bridge that will be strong enough to support the weight of your textbook(s).

Ask: Many structures have straight beams that meet at joints. You can use models to explore ways to strengthen joints.

- What is a bridge?
- Where do you see bridges?
- Does the design of a bridge influence its purpose, or does the purpose influence the design?
- How would you adapt triangle congruence theorems to create a stable bridge support system?
- What properties do you predict are most important for constructing a stable bridge?

Your bridge must…

1. Be at least 8 inches long
2. Be constructed with no more than 30 craft sticks or 100 toothpicks
3. Be constructed with no more than 40 gum drops or marshmallows
4. Be sturdy enough to support the weight of a geometry textbook for at least 15 seconds

Imagine: Brainstorm at least two bridge construction ideas that could meet the requirements.

.	

Plan: Combine ideas with your team members and develop a bridge design. Use the space below to draw a diagram of your team's bridge.

Create: Follow the plan your team developed and build your bridge.

Bridge dimensions	**Materials used** (number of toothpicks/sticks)	**Weight the bridge can support**
.		

Build process:

1.____

2.____

3.____

4.____

5.____

____

____

____

Test:

Trial one	Trial two
.	

Improve:

Did your design meet the requirements of the challenge?

____

____

____

Have you tried multiple designs?

____

____

____

If yes, did you record what you learned from each design?

____

____

____

Can your bridge be stronger or more visually appealing?

____

____

____

____

Can your bridge be built using a more efficient design?

Consider the following two standards:

MAFS.912.G-CO.3.9

Prove theorems about lines and angles; use theorems about lines and angles to solve problems. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.

MAFS.912.G-CO.3.10

Prove theorems about triangles; use theorems about triangles to solve problems. Theorems include: measures of interior angles of a triangle sum to 180°; triangle inequality theorem; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.

Explain how understanding these concepts helped you to build a successful bridge:

Scoring Rubric

4	• The bridge meets all required specifications. • The diagrams and explanations are complete and easy to follow. • Geometric language is used correctly. • A complete explanation of the testing of the original design is included, as well as any improvements suggested or made to the finished model.
3	• The bridge meets all required specifications. • The diagrams and explanations are complete and easy to follow but may contain a few minor errors. • Geometric language is used correctly. • Evidence is shown of the testing of the original design prior to the finished model.
2	• The bridge does not meet required specifications. • Diagrams and explanations are not complete or they are hard to understand. • Geometric language is missing, used incorrectly or used sparingly throughout the project. • There is little effort shown and no proof of testing original design.
1	• Major elements of the assignment are incomplete.
0	• Assignment is not handed in or shows no effort.