Grade Level/Course:
Grades 3-5/Introduction to Engineering Design Model

Lesson/Unit Plan Name: Designing a Building with STEM

Rationale/Lesson Abstract: Students will be faced with a design challenge. They have to construct the tallest, strongest building with their assigned construction materials. Their design model is limited by cost and by materials available for building. It is also limited by time. Their client wants a product as soon as possible.

Students will first be introduced to an engineering design process for elementary school students. They will follow this process throughout the construction of their buildings. Students will begin with brainstorming and end with their finished building. Each construction material will be assessed for cost and students will be expected to spend the least amount of money on the construction of their building.

Timeframe: 1-2 class periods.

Common Core Standard(s):
Grade 3 Mathematics CCSS:

3.OA.3 Use multiplication and division within 100 to solve word problems in situations involving equal groups, arrays, and measurement quantities.

3.NBT.2 Fluently add and subtract within 1000 using strategies and algorithms based on place value, properties of operations, and/or the relationship between addition and subtraction.

Grade 4 Mathematics CCSS:

4.OA.2 Multiply or divide to solve word problems involving multiplicative comparison.

4NBT.4 Fluently add and subtract multi-digit numbers using the standard algorithm.

4NBT.5 Multiply a whole number of up to four digits by a one-digit whole number.

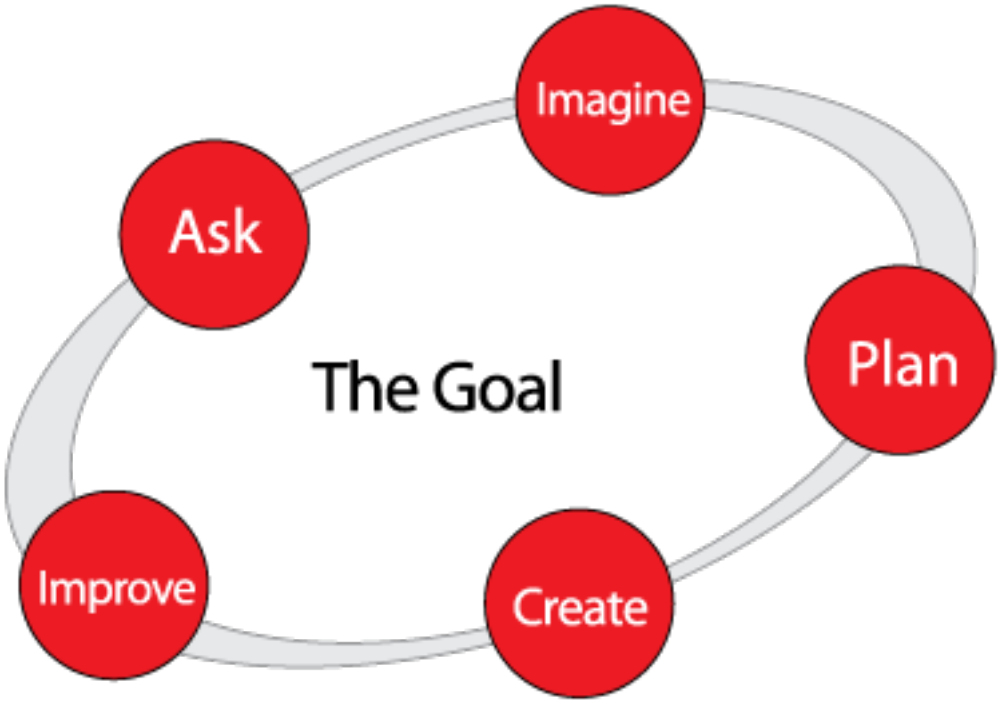
Grade 5 Mathematics CCSS:
5NBT.5 Fluently multiply multi-digit numbers using the standard algorithm.

Next Generation Science Standards:

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.



ASK: What is the problem? How have others approached it? What are your constraints?

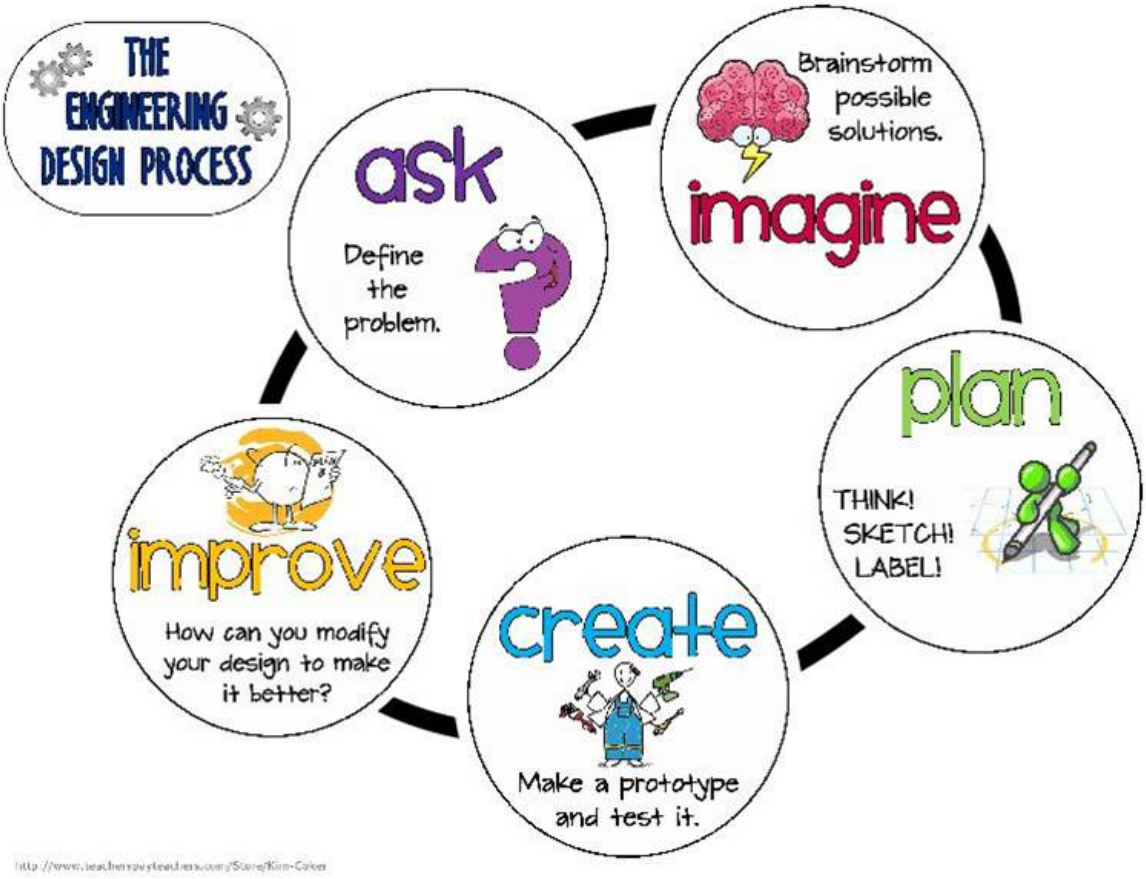
IMAGINE: What are some solutions? Brainstorm ideas. Choose the best one.

PLAN: Draw a diagram. Make lists of materials you will need.

CREATE: Follow your plan and create something. Test it out!

IMPROVE: What works? What doesn't? What could work better? Modify your designs to make it better. Test it out!

Engineering is Elementary http://www.eie.org/overview/engineering-design-process



Another example of the elementary engineering design process.

Instructional Resources/Materials:

For a class of 33 students:

Three 10 oz. bags of mini-marshmallows
Three 1 lb. boxes of regular spaghetti
graph paper, pencils, rulers
plates and bowls to hold constructions materials for each group of students
a few paperback books to test building strength
science notebooks to record engineering and design model and take notes

Activity/Lesson:
The purpose of this lesson is to introduce elementary school students to the engineering design model, to engage the students in building the strongest, tallest tower they can build with uncooked spaghetti and mini-marshmallows and to make students aware that they are constrained in this project by materials, time and their building budget.

Students will be presented with a design challenge. They have been hired to build a structure with certain materials. They can only use the materials that they have. They must finish their building within a short time period. They must tally up and pay for every piece of building material that they use. If they break anything, they still have to pay for it.

Students should be in groups of 2 or 3 students to participate in this challenge. Students will first be introduced to the 5 step design model from the Engineering is Elementary website or from the image in the lesson plan (depending upon access to technology). Students will look

at this model together, read about the design model and step-by-step begin the process of planning to build their buildings. The problem they are faced with is how to build the strongest, tallest structure with the construction materials they have. This problem should be written out on the whiteboard or chart paper so that students are aware of the problem they are responding to.

Brainstorm Session
Before beginning the actual building (and before the materials are distributed to students) teacher will engage students in a brainstorming session (full class or in groups) to come up with ideas of how to build their structures. How can it be strengthened? How can it stay together? Students should be directed to draw a model of what they would like to build. If students have not thought about braces or geometric structures for their buildings, you may want to suggest this (or you can let them explore on their own.)

Each small group will be given 40 pieces of uncooked spaghetti (20 ½ size and 20 regular size) and about 50 marshmallows. Their construction costs assessed will be $5 per building rod (piece of spaghetti) and $2 per connector (marshmallows) that they use. Each group of students will each have a tally chart so that they can record how many building materials they are using, including tallying any breakage or waste (like eating a marshmallow). They cannot trade their materials, borrow any from another group or give any away. They are "constrained" by the amount of their materials. They can modify the length of their spaghetti as they see fit. At the beginning of the activity, students must stay in their groups while construction is going on.

After students have completed their drawings, they will have 20 minutes to complete their structures. The teacher should filter through the groups, helping where necessary and facilitating where needed.

Gallery Walk
At the end of 20 minutes, the teacher will request that everyone stop their construction and students will be given an opportunity to walk around to look at other models as a group. When the class has returned to their construction groups, students should be directed to talk to each other about what they saw, note any ideas that they got from their gallery walk and work on any improvements that they think can be made in their building design.

Finally, the buildings will be tested for strength and durability. A paperback book or a small group of index cards should be laid across the top of the building to see if it can hold up.

Students should be given an opportunity to go back and fix their buildings again to make them stronger.

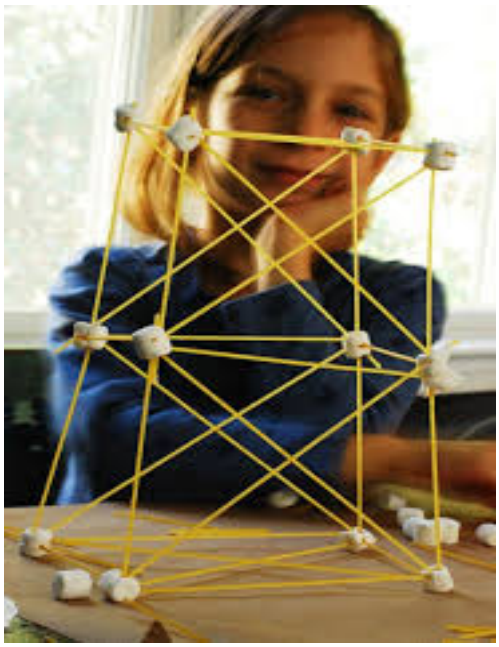
Calculating Costs of Construction
Once either the time is up or the design completed, students should tally up all of the materials that they used in the construction of their building and then calculate the cost of the building. Any discarded materials that cannot be reused must be tallied into the final cost. They must also account for any wasted or broken materials in the cost of their building.

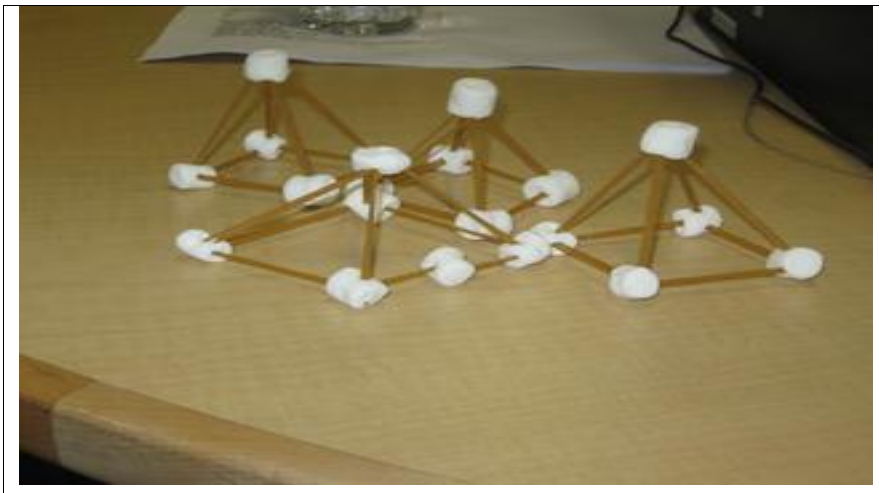
Students should calculate their costs and show their work on their building materials page. Students should be directed to solve for the cost of the building using at least two multiple methods. Suggestions could include generic rectangles, partial products, bar models, etc.

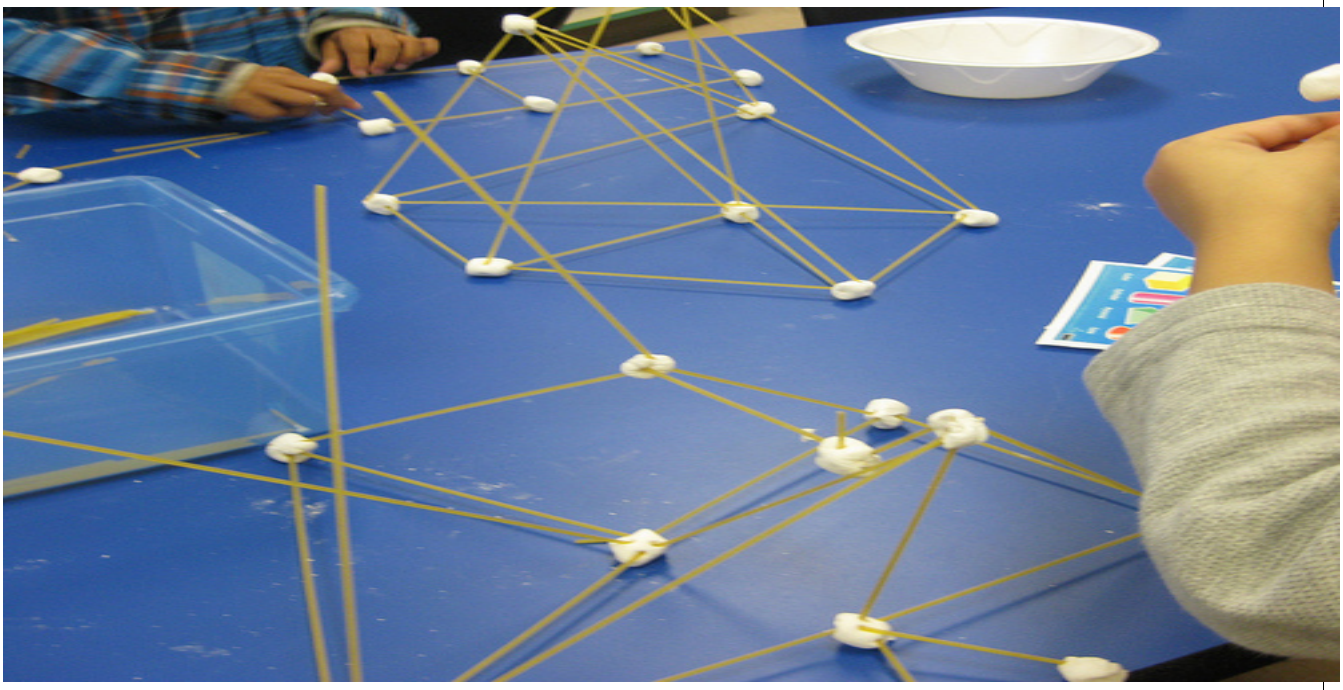
Group Presentations
Following the mathematical calculations, students will make 2-3 minute presentations about their structures explaining why they constructed their buildings the way they did and how much the finished building cost.

Before students disassemble their buildings (and eat their marshmallows), students should take a final gallery walk to look at the buildings.

Some images of spaghetti and marshmallow buildings are included on the next pages.







Names: _____ Date: _____

Construction Worksheet

Building Materials	Cost per piece	Number of pieces used	Number of pieces wasted	Final Cost of Construction
Spaghetti Rods	$5 each			
Marsh-mallows	$2 each			

Make sure to tally your construction materials. Add in any broken or wasted materials. Multiply your costs using multiple methods. Show your work below.

Assessment:
Final assessments will include Construction Worksheets and group presentations.

Extensions:
At the end of the activity, brainstorm with students other problems class could solve using the engineering design model. Make a list on chart paper and hold for future activities.