The Book-Support Challenge

4th Grade
Unit 4 – Revolutionaries from the Past
Text Connection: *Now and Ben: The Modern Inventions of Benjamin Franklin* by Gene Barretta

Design Challenge Summary
Standards: What standards are addressed?
<u>Science:</u> **NS.1.4.9** Identify variables that affect investigations **NS.1.4.13** Use simple equipment, age appropriate tools, technology, and mathematics in scientific investigations (e.g., balances, hand lenses, microscopes, rulers, thermometers, calculators, computers) **NS.1.4.5** Communicate the designs, procedures, and results of scientific investigations (e.g., age-appropriate graphs, charts, and writings) **<u>Math:</u>** **4.MD.1** Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two column table. *For example, know that 1 ft is 12 times as long as 1 in. Express the length of a 4 ft snake as 48 in. Generate a conversion table for feet and inches listing the number pairs (1, 12), (2, 24), (3, 36), ...* **<u>Other:</u>** **SL.4.3** Identify the reasons and evidence a speaker provides to support particular points
Challenge: What will the students be required to do?
Students are required to build a structure to hold an open science textbook at least 7.5 cm above the desk. You must be able to read and turn the pages while the book stays on the support. Your group will have ten minutes to complete a structure.
Result: What will students know, value, and be able to do as a result of the lesson? What's the big idea?
Students will know the design loop. Students will value collaboration and discussion. Students will be able to use the design loop and their understanding of measurement to build a structure to hold an open science textbook at least 7.5 cm above the desk. The big idea of this challenge is to follow directions and collaborate to design a functional book-support structure in 15 minutes.
Assessment: What evidence will be used to determine student learning?
Did groups work collaboratively together? Did students read and follow directions? Did this structure successfully meet criteria? Were you able to express your ideas and listen to others ideas in a respectful manner?
Prior Knowledge/Experiences: What prior content knowledge and skills will the students need?
Students will need to know how to measure using a metric ruler. Students will need to know how to work together collaboratively. Students will need to have critical reading skills.

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Summary/Connections: How will this design challenge connect with new/future learning, other content areas, real world experiences, etc.?
This design challenge will have students use the following skills: inquiry, higher-order thinking, investigations, and innovations.
Materials/Equipment/Preparation: What materials and equipment will students need to successfully complete this design challenge?
Index cards, Paper clips, Rubber bands, Science textbook, Ruler, Recording form

***Extension:** Add money values to supplies being used in design challenge. The goal is to spend as little as possible and have a structure that meets the criteria. (4.NBT.4, 4.MD.2)
Example:
Index cards $1.00
Paper clips $1.58
Rubber bands $5.00
Science textbook
Ruler

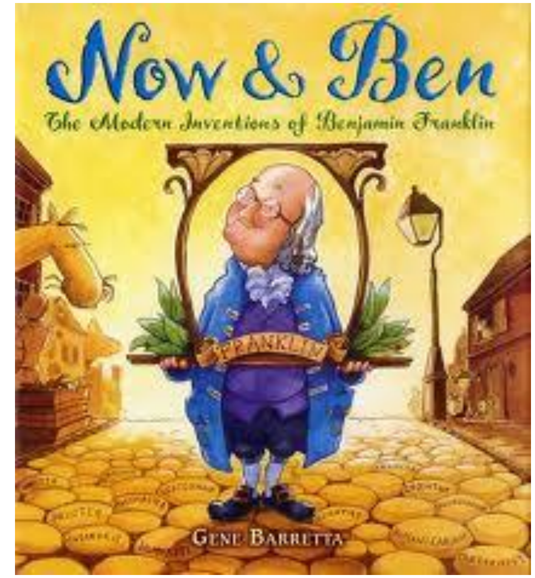
*Some additional information on the concepts within this challenge and some reflection questions are attached to this summary. This information is an excerpt from a Project-Based Inquiry Science Unit found at: http://its-about-time.com/pbis/pdf/ls/div_ls1.pdf

The Book-Support Challenge

Student Recording Form

Design #	Note cards used	Paper clips used	Rubber bands used	Draw your design	What happened?
1					
2					

The Book Support Challenge



Ben Franklin invented bifocals so he could see better but he lost them. You need to help him invent a support to hold up a book at least 7.5cm off the desk so he can read and turn the pages without the book falling.

Supplies:
Index cards, cm ruler, rubber bands, paper clips
Happy inventing!

1.3 Read

The Science of Structures

You just finished your first two tries at building a book support. You also talked about the design ideas of other groups. You learned about some ideas that worked well and others that did not. Soon you will work on a revised challenge. Before you do, you probably want to know about the science of structures.

Matter

All objects are made of **matter**. Objects of any form (solid, liquid, or gas) are made of matter. All matter has mass and takes up space. The amount of space that something takes up is its **volume**. The book you are trying to support is made of matter. The matter we are most familiar with is made of extremely small particles called **atoms**. These atoms combine with other atoms to form very small particles called **molecules**. Molecules attach to each other to form the objects that you see, touch, hear, and even taste and smell.

matter: **anything that has mass and takes up space.**

volume: **the amount of space that something takes up.**

atom: **a small particle of matter.**

molecule: **the combination of two or more atoms.**

gravity: **a pull between two objects.**

Gravity

You have probably heard of **gravity**. You definitely have seen the effects of gravity. Gravity is a pull between objects. All objects experience this pull towards other objects. The pull between most objects is very small. You usually do not see the objects affected in any way.

However, when one (or both) of the objects is *very* massive (has a lot of matter) you can see the effects. Earth is very massive. There is a pull between Earth and a book. The job of the book support is to resist Earth's pull on the book. It must keep the book from falling toward Earth's surface. Your job is to use the materials you've been provided to construct something strong and stable enough to resist the pull of gravity on the book.

Strong Structures

Structures that are **strong** resist **folding** and **compression**. Think about these two characteristics separately.

Imagine a sponge on its end. You can push down on top of the sponge to see if it is strong enough to resist the push of the hand. If the push is hard enough, the sponge will fold over in half and collapse. In the picture you can see a sponge that is unable to resist the push of a hand. The sponge's material folds near the center. Suppose you put a heavy book on the sponge. You probably would see the sponge fold in a similar way.

Now imagine the same sponge sitting flat on a surface. If you were to push the sponge with your hand, it would squeeze into a smaller space. This is called compression. Imagine that the hand were a large book. The sponge would compress a lot.

A sponge is not very strong. It will fold or compress a lot when you put a large weight on it. A **strong structure** will not bend or compress much when a push or pull acts on it.

strong: **able to withstand force.**

folding: **reducing length by bending over.**

compression: **reducing size by squeezing.**

strong structures: **structures that resist folding and compressing.**

stable: **able to resist tipping over.**

Stable Structures

Structures are **stable** if they resist tipping over. Again, think about the sponge. Suppose it is sitting on top of a table. In the picture you see that the table supports the sponge well and prevents the sponge from tipping. The sponge is stable. Even though the sponge is partly hanging over the edge, the sponge is still well supported and will not tip and fall to the floor.

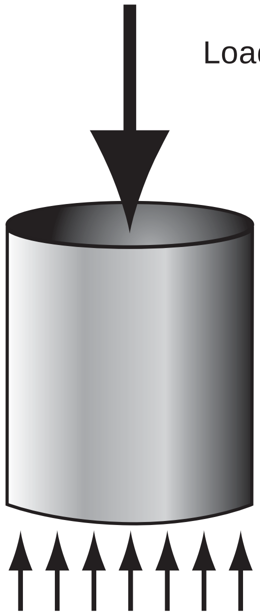
center of mass: **an imaginary point on or near an object around which the object's matter is equally distributed.**

load: **the amount of push or pull a structure has to resist.**

What if you keep moving the sponge toward the edge of the table? What will happen? It will eventually fall off. The dot on the sponge represents its **center of mass**. The center of mass is an imaginary point. It is located at a place on or near an object where all of the matter of the object is equally distributed around it. The center of mass of the sponge is in the middle of the sponge, along an imaginary line going through the dot drawn on the sponge.

What happens when you move the sponge far enough over the edge of the table so that there is no support to one side or under its center of mass? There is not enough stable support to carry the load. The sponge will tip and fall towards the floor. If the other side of the sponge were supported by a second table, then there would be a stable support.

In the series of pictures you can see what happens when the center of mass moves past the support structure and no additional support is provided. The object will be unstable and will tip over or collapse.



Structures with Columns

Some of you might have found that columns work very well. Columns are very strong structures. They distribute their **load** throughout the column. Load comes from what is on top of something. It is the downward push from objects on top. Distributing the load keeps any one part or area of the column from having to support the entire load.

You can think about this in the following way: If you hold an index card flat, with its surface parallel to the floor or tabletop, you can bend the card rather easily.

However, if you hold the card vertically, perpendicular to the floor or tabletop, it is very difficult to fold the ends down toward the floor.

When you roll or fold the index card into a column, it will not compress or fold because it is vertical. Also, it is very difficult for any part of the column to fold in the same direction.

Columns are also very good structures because you can attach them together to make bundles of columns. This achieves two goals:

- The structure is very wide. This means the center of mass of the book has more places to be located over the support structure.
- Many columns, rather than just a few, distribute the load, so each column supports less of the book. This is very similar to lifting something heavy. If you and several friends lift a couch, each person lifts a small part of the load. The more people you have helping, the less of the load each has to lift.

Reflect

Think about the book supports you designed and built so far. Try to think about the science concepts you have read about and discussed as a class. Answer the following questions. Be prepared to discuss your answers with the class.

1. Was your structure strong? If not, did it collapse because of folding, compression, or both?

2. How could you make the structure stronger to resist folding or compression?

3. Was your book support stable? That is, did it provide support so that the book did not tip over? Did it provide this support well? Draw a picture of your book support showing the center of mass of the book and the places in your book support that resist the load of your book.

4. How could you make your book support more stable?

5. How successful were the book supports that used columns in their design?

6. How could you make your book support work more effectively by including columns into the design?

7. Explain how the pull on the book could better be resisted by the use of columns in your design. Be sure to discuss both the strength and the stability of the columns in your design. You might find it easier to draw a sketch and label it to explain how the columns do this.

8. Think about some of the structures that supported the book well. What designs and building decisions were used?

You are going to get another chance to design a book support. You will use the same materials. Think about how your group could design your next book support to better meet the challenge. Consider what you now know about the science that explains how structures support objects.

1.4 Design

Another Book-Support Challenge

Just when you thought you had it all figured out, the challenge has changed! You've realized how useful a book support might be for keyboarding, especially for someone who has forgotten their glasses. Imagine making money selling book supports. What would it take to make your first book support more appealing to buyers, but not be too expensive to produce?

Cost is one of the most important factors that product designers must keep in mind. The cost of your book support is directly related to how much material you use. Assume that each index card, rubber band, and paper clip costs 10 cents. You need to design a low-cost book support that can hold a book in an open position and still allow you to turn pages easily. Once again, keep track of the supplies you use in this final design.

Update Your Criteria and Constraints

Now that the challenge has changed, review your criteria and constraints. Update these lists. Then, consider these changes as you design and build your new book support.