

Designing and Building Bookshelves

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Grade Levels

Grades 4 - 6

Lesson Overview

Students will make and assess measurements of a space in their classroom and conduct an empathy interview. They will take these measurements and insights and develop a scale model bookshelf of appropriate size to fit the space. Students will explore and determine effective structural and strength elements of the shelf through building and testing models with various weights. They will work collaboratively to create scale blueprints and models of a shelf that they can then present to the class. The models will be voted on by the class and a final model will be chosen to be built. Each student will be able to play a small part in the construction of the shelf with teacher assistance, i.e. driving screws, sawing boards, gluing parts, or measuring.

Learning Objectives

- Students will be learning about measurement and equivalence using tape measures and creating scale models using graph paper.
- Students will also learn about angle measurement and identification through cutting shear support in both 90-degree and other angles.
- Students will have to collaborate, cooperate, compromise and work towards a common goal.
- Students learn basic construction skills: clamping, cutting with a hand saw, using a tape measure, using a drill and screw gun.

Standards

CCSS.MATH.CONTENT.4.G.A.1: Draw and identify lines and angles, and classify shapes by properties of their lines and angles. Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.

CCSS.MATH.CONTENT.4.G.A.2: Classify two-dimensional figures based on the presence or absence of parallel or perpendicular lines, or the presence or absence of angles of a specified size. Recognize right triangles as a category, and identify right triangles.

CCSS.MATH.CONTENT.4.MD.A.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), ...*

NGSS Constructing Explanations and Designing Solutions (Elementary School 3 - 5)

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Apply scientific ideas to solve design problems.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

NGSS Constructing Explanations and Designing Solutions (Middle School 6 - 8)

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Preparation

- Create balanced teams of four students who will collaborate together throughout the design challenge.
- For Activity 1, have thin cardboard and tape available for building and one heavy book (like a large dictionary) for testing.
- For Activity 3, have the options for shelf locations in the room labeled; students will need one tape measure per group for measuring spaces, and paper and pencils for their individual prototype drawings.
- For Activity 4, have grid paper ready for students to draw their plans on.
- For Activity 5, have grid paper ready for students to draw their parts on. Corrugated cardboard should be pre-cut into 2-inch strips to represent lumber. To make it easier for students to cut out their parts, triangles can be cut from thin cardboard.
- For Activity 6, prepare any materials needed for the shelf selection process.
- For construction day, pre-cut parts of shelves. Have screws, nails, screw gun and hammers available.

Materials and Resources

- thin cardboard (from cereal boxes) for initial construction experience
- corrugated cardboard for final prototypes
- masking tape or blue tape
- plain paper
- assortment of books the designed shelf is intended to hold
- 11 x 17 ¼" grid paper

- Empathy graphic organizer for Activity 2
- pencils
- scissors
- one tape measure for each group
- 1" x 8" pine lumber for sides and shelves
- 1" x 1" pine lumber for cleats
- sheet of masonite or thin plywood to cut triangles from for shear strength
- 1 1/2" construction screws
- 3/4" finishing nails for attaching triangles
- screw gun, child-friendly hammers

Activity 1: Mighty Strong Shapes (50 minutes)

- Students will be broken into groups of four (however teacher deems fit).
- The teacher will explain that each group is to use the provided cardboard and tape to construct a structure that will hold the weight of a dictionary without collapsing, paying close attention to what kinds of shapes seem strongest. (You may need to set parameters around size and how much material can be used.)
- After students have attempted construction, bring the large book around and test the groups' structures.
- Debrief with whole group. "What did you notice about the structures that were successful and what qualities were not successful? What kinds of shapes seemed to withstand weight?"
- Tell students that we are going to be doing a design challenge of building a bookshelf for the classroom and to think about what they have learned while they design their shelves in the coming weeks.

Activity 2: Books and Readers (30 minutes)

- Present students with a pile of books their classroom will be using in their work this year. They might be a variety of books: some large reference books, smaller and larger paperbacks, possibly some small sets of books in bins.
- Present an Empathy graphic organizer, explaining that we'll be working with it to help us understand the needs of students, teachers, and books. We suggest 3 sections for the graphic organizer:
 - space for students to draw pictures showing different ways they can imagine themselves and their classmates using the books in the pile over the course of the year
 - a set of questions (and space to record answers) for students to use to interview their teacher about the use of books (for example: What are some important things you've learned from books in your life? Could you choose two books from the pile and tell us what you hope we as students might get from those books? What are the most important elements needed in a structure we'd use to store these books, in your opinion?)
 - space for students to write about what they imagine would be the most difficult parts of being a book (for example: being handled roughly, being

thought of as boring), and the most rewarding parts of being a book (being read with interest and excitement, being handled as a valued object, etc.)

- Have students work on these organizers while sitting together in their teams of four, sharing their thinking.
- Have the groups take turns coming to interview you as a group
- Call the whole group together, eliciting a few of the insights groups gained through their Empathy work, which might inspire them as they begin their prototyping work.

Activity 3: Prototype a Shelf (50 minutes)

- Present a short slideshow with images of a variety of shelf designs, using a discussion protocol to scaffold careful noticing and thinking about how the designs are functioning (to keep books off the floor, to make it easy to find different books, to keep them from being damaged, to organize/categorize them).
- Show the potential locations for the new shelf in the room and the group of books the shelf is meant to hold and organize.
- Demonstrate use of measuring tape (they'll use it for measuring the space for the shelf and the books).
- Work time: Groups make measurements of space and books and take notes on this information.
- Individuals draw initial shelf prototypes with measurements and share them in their group.
- Students will decide as a group on the basis for a single design.
- Collect all prototype drawings, keeping them in groups.

Activity 4: Graphic Representation (30 minutes)

- Teacher will introduce $\frac{1}{4}$ " grid graph paper, explaining that on the paper one square represents one inch. Demonstrate how one foot is 12 inches and would be represented by 12 linear squares on the graph paper.
- Demonstrate how blueprints of a structure can be made by drawing both elevation and ground views of an object
- Ask students to create blueprints of their proposed shelves, including all measurements.

Activity 5: Transfer to 3D (50 minutes)

- Introduce how to create a parts drawing on graph paper, using plan drawing done during Activity 4, and how to cut out parts and transfer to corrugated cardboard by tracing.
- Students work in their groups to make their parts drawings. Note: When a group's parts drawing is complete, teachers may want to make a copy of it, giving the copy to the group to cut up and preserving the original.
- Students work in groups to cut pieces out of their parts drawings and trace onto corrugated cardboard (pre-cut into 2" wide strips - representing lumber).

- Students work in groups to assemble their prototypes using corrugated cardboard, tape, and thin cardboard triangles for shear strength.

Activity 6: Share Out (50 Minutes)

- Teacher goes over protocols for the group presentation and selection processes.
- Each group presents their prototype, explaining their thinking about how their design will function to hold and organize the books and how it reflects what they learned during the Empathy phase of the project.
- Students vote, using some selection process, for the prototype design they think is most successful.

Activity 7: Construction (50-100 minutes)

- While the class is busy with a different activity, using either parent volunteers or an assistant teacher, one adult will assemble actual shelves using the students' designs. The adult must have a clear conception of the assembly of each shelf.
- The adult can call out pairs of students to assist in the assembly of the shelf, either measuring, cutting, or screwing. The students should be asked to help each other as much as possible.

Assessment

To provide some structure for students, the teacher may create a checklist for each group to use to keep itself on track, making the criteria for each step very clear. At certain stages the teacher may want to use posters on which to write discoveries or questions that come up in discussion.