Cut to Fit

Content Focus: Math

- Geometric Shapes and Relationships
- Measurement: Objects And Units
- Modeling: Spatial Reasoning

Content Focus: Technology

- Manufacturing Technologies

Content Focus: Built Environment

- Architectural Drawing / 2D
- Ergonomics
- Measuring/Estimating

Performance Outcome(s)

- Create shop drawings for a piece of furniture.

Standards/Interdisciplinary Connections

					
S	**S**	**L**	**A**	**M**	**T**
Science	**Social Studies**	**Language Arts**	**Art - Visual**	**Math**	**Technology**

How To Read The Symbols: The symbols in **bold** indicate the subject standards that this lesson satisfies.

Lesson Outline (2 - 5 lessons)

1. Motivation
2. The Challenge
3. Measure The Chair
4. Draw Each Piece
5. Estimate Material Costs
6. Reflection
7. Extensions And Variations
8. Middle School Standards

Salvadori Prerequisites

- FOUNDATION - BASIC SKILLS: Architectural Drawing / 2D (Activity #1); Measuring/Estimating (Activity #3)
- LESSON(S): This lesson can serve as an extension to the "School / Science / Sit Right / Go Beyond" project by having students analyze their cardboard chairs instead of a wooden chair. It is also a good complement to "School / Language Arts / Design Writes / Go Beyond."

CONCEPTS

- When preparing an item for mass-production, designers and engineers use detailed shop drawings identifying the dimensions and connection instructions for each piece.
- Optimization of material limits waste, conserves resources, and can be critical in maintaining an economical and efficient production process.
- The challenge of depicting three-dimensional shapes as two-dimensional forms develops important visualization and geometric modeling skills.

RESOURCES

On-Line

- http://www.pencilpages.com/articles/make.htm: A good illustration and description of how pencils are manufactured.
- http://www.quiltindex.com/ATQF/q_and_a_single.asp?QAID=7 - An example of calculating fabric use.
- http://www.denverfabrics.com/pages/static/curtains/curtain-panel.htm - Another example of calculating fabric use.
- http://www.woodandthings.com/Greenleaf/create-a-chair/index.html - A site that offers custom chair designs.

MATERIALS

Facilitator

- : Q&A
- : Teacher Tip

Students

- ⭘: Student guide: Shop Drawings, Fact-sheet: Standard Lumber Sizes
- 1 wooden chair made of relatively straight, flat pieces of wood, graph paper, straight-edge rulers, compasses, protractors, triangles, pencils

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MOTIVATION

Take out a pen or pencil and a piece of paper. Today, you will be doing something unusual with your pen or pencil. You will be observing it.

- *Look carefully at your writing utensil. How many different parts does it have? How many separate pieces went into making the functioning whole?*
- How many pieces does a regular pencil have? ⭘: Q&A

With a regular pencil, you can see most of the separate pieces clearly. Some pens are transparent and you can see the pieces inside. Some pens are easy to take apart and put back together. Some mechanical pencils and other pens are much harder to figure out. If you can't see the inside, try to imagine the separate pieces that make up the tool. Even if you're not sure how it works, come up with a theory and determine the number and the general shapes of the pieces inside.

On your paper, make a rough sketch of each of the separate pieces.

Write a short description of how your pen or pencil was assembled. You do not have to know how it was actually put together, just imagine and describe a series of steps for putting it together (for pens that are easy to disassemble, you can simply describe how you put them back together).

Share your work with the rest of the class.

How do you think industrial designers (people who design the objects we use everyday at home, at school, and at play) communicate their design ideas to the factories that make the products?

THE CHALLENGE

You are going to create shop drawings for a chair and from those drawings calculate how much it would cost to make this chair from wood.

MEASURE THE CHAIR

The chairs the students are going to use for this lesson are the ones they are sitting in, or, if for some reason that will not work, a chair from somewhere in the room.

If a friend came to you and asked you to build another chair that is exactly the same as the one you're sitting in, how would you go about doing it? What if you wanted to build one for every member of your family? What would you do if a company that makes chairs wanted you to figure out how to build one-thousand chairs of this design? How would you make sure they built them correctly, making sure that every piece is the right size and fits perfectly when assembled?
: Q&A

*For every chair that is manufactured, drawings are made that illustrate the exact dimensions of each piece and how they connect. These drawings are called **shop drawings**, because the shop that cuts the materials uses these drawings to ensure that each piece is the right shape and size.*

When a piece of furniture or any other engineered item is mass-produced, its pieces are cut out of the smallest possible larger pieces of material, to reduce the amount of extra material that is thrown out. The waste produced from making one chair may not seem like that much, but if you multiply that by one-thousand, it would really start to add up! Companies that make such items would go out of business if they weren't careful about how much of the material they buy is wasted.

Your challenge is to make shop drawings for your chair that you have been presented with. Once you have completed your shop drawings, you will make a list of all of the pieces and their dimensions. This will help you to figure out the dimensions of the wood the pieces would be cut from and the minimum amount of wood you would need to make these pieces. This process is called optimization of material. By calculating the dimensions of the lumber used to make the chair you will be able to approximate the material costs of making one chair.

1. Distribute the student guide. : Student Guide: Shop Drawings
2. Students carefully examine their chairs with the following questions in mind:
    a. How many pieces of wood might be used to build the chair?
    b. How will they be connected?
    c. Are there multiple pieces with similar dimensions that could be cut from a longer plank of wood?

3. In groups, students make an inventory of every chair piece. This is called a **parts schedule**.

DRAW EACH PIECE

1. Students label and measure each piece. As they do so, have them think about how to label multiple pieces of the same dimension and encourage them to be creative as they measure difficult shapes. ⭘: Teacher Tip
2. Groups draw templates of all the parts separately on pieces of graph paper (centimeter paper is recommended), making sure they are properly labeled and communicate all relevant dimensions (they should mark the dimensions on the inside of the shapes since they will be cutting them out.) They may have to tape two or more pieces of paper together for long pieces of the chair.
3. Students cut out the templates.

ESTIMATE MATERIAL COSTS

- *What are some of the major costs of manufacturing a chair?* ⭘: Q&A
- *What are some ways of minimizing the material costs?* ⭘: Q&A

1. Hand out the fact sheet and introduce to students the concept of standardization, explaining that wood is processed into lumber of standard sizes. ⭘: Fact sheet: Standard Lumber Sizes
2. Using their knowledge of the dimensions of each piece of wood used to make the chair, students add up the lengths of pieces of the same or similar dimensions to determine the types and amount of lumber needed to construct the chair. For example, if the seat of the chair is made up of twelve ¾" x 4" slats with a total length of 18 feet, a company would have to order three 8 foot pieces of 1" x 4" lumber to make the seat (by looking at the fact sheet, students will be able to determine that 1' x 4" lumber comes only in 8 foot pieces).
3. Using this process for all of the pieces of the chair, each group develops an inventory of the lumber needed to make the chair.
4. With the help of the activity sheet, students estimate the total cost of the lumber needed to construct the chair. Results may vary from group to group depending on how students decide to organize production.

REFLECTION

- *Did the cost estimates vary from group to group?*
- *Which groups calculated the lowest cost for the materials for production? What are some means of cutting the cost of production even further?*
- *What are some other types of information that you would have to include if you were actually going to have a factory make the chair?*
- *How well did you meet your challenge? What would you do differently next time?*

EXTENSIONS AND VARIATIONS

- Each group exchanges shop drawings with another group and tries to create a model of the item of furniture using only the information on the drawings.
- Students create a hardware schedule for the chair, listing the dimensions and location of all of the hardware used to connect the pieces of wood. Include drawings of the different types of hardware and note how they work.
- Take a field trip to a real manufacturing shop in your area to see the optimization process firsthand.

MIDDLE SCHOOL STANDARDS

Science

- Science and Technology

Language Arts

- Speaking, Listening, and Viewing (E3a, b, c)

Art - Visual

- Media, Techniques, and Processes

Math

- Number and Operations Standard
- Algebra
- Measurement
- Problem Solving
- Connections

Technology

- The Nature of Technology (1, 2, 3)
- Design (8, 9, 10)
- Abilities for a Technological World (11, 13)
- The Designed World (17, 19, 20)

MOTIVATION

- *How many pieces does a regular pencil have?*

  Most regular pencils are made up of 5 pieces: the graphite core which does the writing, the two wooden half-dowels (made from slats) surrounding the core, an eraser, and a metal attachment called a “ferrule” to hold the eraser to the shaft.

MEASURE THE CHAIR

- *If a friend came to you and asked you to build another chair that is exactly the same, how would you go about doing it? What if you wanted to build one for every member of your family? What would you do if a company that makes chairs wanted you to figure out how to build one-thousand chairs of this design? How would you make sure they built them correctly, making sure that every piece is the right size and fits perfectly when assembled?*

  One way would be to make diagrams or **templates** that indicate the exact dimensions of each part. The pieces of the chair are cut from one or more larger pieces of wood, just like clothes are cut out and sewn from larger pieces of fabric. A pattern may have been used as a template to make sure that the pieces were cut correctly each time.

ESTIMATE MATERIAL COSTS

- *What are some of the major costs of manufacturing a chair?*

  While there are many costs associated with manufacturing an item the major costs usually come in the form of materials and labor. Other costs might include manufacturing machinery and upkeep, energy costs, transportation of materials and the finished product, design and testing costs, etc.

- *What are some ways of minimizing the material costs?*

  Besides the obvious way of reducing material costs, which is to design a product which uses less or cheaper material, one of the most effective ways of reducing material costs is to limit material waste. This can be done by limiting the number of separate parts or by using pieces that can be easily cut from standard sizes of lumber or other materials without excess waste.

name(s) date

Cut To Fit

Shop Drawings

Student Guide

You will be making a **shop drawing** for your wooden chair. Remember that if it were to be mass-produced, workers in a shop would cut each piece according to your drawings, so be sure to they include all the important information.

A **shop drawing** is an illustration of each piece of the chair. Your drawing should clearly indicate all of the dimensions for of each piece as well as how the pieces will be connected.

1. Look carefully at all of the pieces of you chair.
2. Devise a labeling system for the pieces using numbers or letters (or both). How will you label different pieces with the same dimensions? Make small freehand drawings of all of your pieces, marking their measurements as you proceed, as in Fig. 2.
3. Draw each piece to scale on graph paper, marking the measurements as in Fig. 3.

Fig. 1

Fig. 2

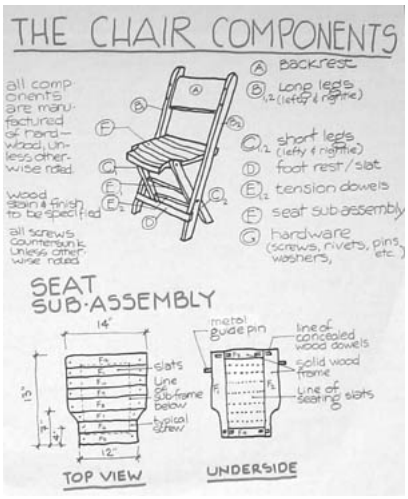
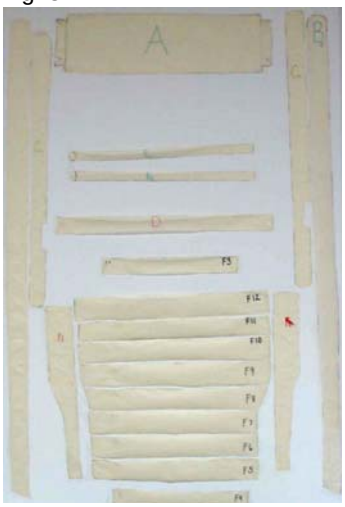


Fig. 3



4. Once you have completed the layout for all the pieces, look at them to see if some pieces have similar dimensions. Do you think all were cut from a longer piece of lumber? Look at the “Standard Lumber Sizes” facts-sheet to see common standard lumber dimensions and how much each costs. Notice the relationship between size and cost.
5. Try to figure out the smallest standard sizes and lengths of lumber that would be needed to make all of the pieces of your chair. For example, if the seat of the chair is made up of twelve ¾” x 4” slats with a total length of 18 feet, a company would have to order three 8 foot pieces of 1” x 4” lumber to make the seat. Make a list of all of the pieces of lumber you would need to make the chair.
6. Look at the fact-sheet to see how much each piece of lumber costs. Add up the cost of the pieces of lumber you need to estimate the total cost of the material for the chair.

name(s) date

Cut To Fit
Standard Lumber

Fact Sheet

Lumber 101

You may have heard of a 2 by 4, but what does that mean? When people say "2 by 4" (written 2x4), they are referring to a piece of wood that is 2 inches thick by 4 inches wide. It could be any length. But a 2x4 is *not really* 2 inches thick or 4 inches wide! The thickness and width of wood planks are *listed* in whole numbers (called **nominal** sizes), but the *actual* dimensions are smaller. See the table below:

Nominal (inches)	1	2	3	4	5	6
Actual (inches)	11/16	1 ½	2 1/2	3 3/8	4 ½	5 3/8

So a 2x4 is really 1 ½ x 3 3/8, but calling it that would be a lot more complicated.

It is most economical to buy lumber in the standard available sizes. Custom cuts cost more. The table below lists the standard sizes and associated prices from a particular lumberyard.

Size	6'	8'	10'	12'	14'	16'
1x4		0.67*				
1x6	0.90	1.20	1.75			
1x8		1.86	2.33	2.80		
1x10		2.99	3.75	4.50	5.83	6.67
1x12		3.60	4.50	5.40	7.00	8.00
2x4		2.25	2.84	3.40	3.97	4.80
2x6		3.00	4.00	4.80	5.60	7.20
2x8		4.27	5.33	6.40	7.47	9.59
2x10		5.67	7.08	8.50	10.50	12.26
2x12		6.80	8.50	10.20	12.60	14.40
4x4		4.00	5.00	6.00	8.40	9.60
4x6		6.40	8.00	9.60	11.20	12.80
5x6		8.00	10.00	12.00	14.00	16.00
6x6		9.60	12.00	14.40	16.80	19.20
6x8		12.80	16.00	19.20	22.40	25.60
3x10		10.00	12.50	15.00	17.50	20.00
3x12		12.00	15.00	18.00	21.00	24.00

*The prices are indicated per foot of the board's listed length. So, the 8 foot long piece of 1x4 would actually cost: $0.67 x 8 = $5.36.