



Sit Right

Content Focus: Science

- Human Body
- Matter: Properties

Content Focus: Technology

- Construction Technologies
- Engineering Design







Content Focus: Built Environment

- Architectural Drawing / 2D
- Beams
- Compression/Tension
- Ergonomics
- Scale/Proportion
- Stress

Performance Outcome(s)

- Design and build a strong, lightweight ergonomic cardboard chair proportioned for your comfort.

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 (multiple-lesson project)

1. Motivation
2. Explore Properties of Cardboard
3. Design the Chair
4. Construct the Chair



Lessons from the Salvadori Classrooms
LESSON TITLE: Sit Right
PREPARED BY: Janny Gédéon and Kubi Ackerman (revised by Michael Bettencourt)
TOPIC: School
SSLAM: School / Science / Go Beyond
Copyright © 2006 Salvadori Center

5. Present
6. Reflect
7. Extensions And Variations
8. Middle-School Standards

Salvadori Prerequisites

- FOUNDATION - BASIC SKILLS: Working with Scale (Activity #3); Architectural Drawing / 2D (Activity #1)
- FOUNDATION - STRUCTURES 101: Push and Pull, Stress Test, Beam Team
- LESSON(S): "Form and Furniture" (School / Math / Pull Apart)

CONCEPTS

- The strength of any material can be increased or decreased by changing its form. Seemingly weak materials can be strengthened through folding, creasing or other form modifications.
- Ergonomic design is the practice of designing objects that conform to the dimensions and movement patterns of the human body to maximize comfort and usability.
- While designing and constructing an object, whether it be a skyscraper or a cardboard chair, it is important to apply an understanding of load distribution to identify and reinforce areas of potential weakness.

RESOURCES

On-Line

Many websites have information on cardboard chair design. Some examples are:

- <http://mrpollak.tripod.com/chair/> - The Chair Project
- http://www.moma.org/collection/browse_results.php?object_id=2529 - Frank O. Gehry, *Bubbles Chaise Longue*
- <http://www.watermanswebworld.com/code/everythingcorrugated.html> - Everything Corrugated

Book(s)

- Levy, Matthys and Mario Salvadori. *Why Buildings Fall Down*. W.W. Norton and Company. New York, NY. 1992.



MATERIALS

Facilitator

- ●: Q&A
- ●: Teacher Tip

Students

- ●: Student Guide: Designing Your Chair
- ●: Fact Sheets: (from “School / Math / Form and Furniture”) Chairs of All Shapes and Sizes, Corrugated Cardboard
- Cardboard, Elmer’s glue or glue guns and glue sticks, box knives or utility knives, spare blades, metal-edged yardsticks, cutting mats, binder or bulldog clips, cardstock, rulers, pencils, paper

MOTIVATION

Distribute two (2) pieces of legal size plain paper to every student.

- *Without cutting, tearing, or taping, can you make a “pedestal” to support a notebook (or small book) on your desk using just 1 piece of paper?* ●: Q&A
- *Can you use the other piece of paper to make a “bridge” to support a notebook (or small book) between two desks?*

Students take a few minutes to work on these challenges.

- *Were you able to find a way to support a notebook? What strategies did you use?*
- *How did changing the form of the paper change its structural properties?*
- *Can you come up with an explanation of why folded paper can carry more weight than flat paper?* ●: Q&A
- *Did the amount of folding make a difference in how much the paper could carry?*
- *What are the forces acting on the paper that was made into a “pedestal”? Can you think of a structural term for objects that support loads in that way?* ●: Q&A
- *What are the forces acting on the paper that was made into a “bridge”? Can you think of a structural term for objects that support loads in that way?* ●: Q&A
- *Can you think of other examples from your experience in which materials are made stronger by changing their form?* ●: Q&A



THE CHALLENGE

Your challenge is to design and construct a functional *ergonomic* chair out of cardboard. While that may sound like a difficult challenge, cardboard can be a very strong material if used correctly. In fact, there are many architects and designers who have built cardboard chairs.

EXPLORE PROPERTIES OF CARDBOARD

Before you begin your design process, it is important to explore the properties of cardboard. ●: Teacher Tip

Hand out 1 foot by 2 inch strips of corrugated cardboard, some cut so that the corrugation runs along the length of the strip, and some cut so that the corrugation runs along its width.

- *Take a minute to examine these pieces of corrugated cardboard.*
- *What do you notice about the structure of cardboard?* ●: Q&A
- *What is the relationship between the paper exercise we did and the structure of cardboard?*
- *How do you think cardboard supports loads?*
- *What is the difference between the two strips of cardboard?*
- *How might that affect the structural properties of each?*
- *Which strip would support more weight as a column (positioned straight up and down)? Why?* ●: Q&A
- *Which strip would support more weight as a horizontal beam (positioned flat)? Why?* ●: Q&A
- *Can you think of any position in which the other strip is stronger?* ●: Q&A
- *How could the two strips be attached to make an even stronger structural element?* ●: Q&A

Distribute the corrugated cardboard Fact Sheet. ●: Fact Sheet: Corrugated Cardboard



DESIGN THE CHAIR

- *If the chair you are sitting on right now were made of cardboard, would it be able to support your weight? Why or why not?*
 - *What types of modifications would you have to make to your chair if it were made of cardboard in order for it to support your weight?*
 - *Can you think of how starting with a different form (than the form of your chair) would make the cardboard chair more practical, comfortable, and stronger?*
 - *What advantages might a cardboard chair have over the chair you are sitting in now? How might you design your chair to make use of those advantages? ●: Q&A*
 - *What would be your main design strategy to make sure the chair would support your weight? ●: Q&A*
1. Students make quick sketches of one idea for a support system for their chair. In groups, students share their ideas for a support system.
 2. Groups share their ideas for how they might construct a chair to support the weight of a student. Each group chooses one strategy.
 3. Groups begin brainstorming designs for the chair. It may be helpful to distribute the fact sheet showing the variety of chair designs throughout different cultures if they are not already familiar with it. Students discuss and address the questions on the student guide. ●: Fact Sheet: Chairs of all Shapes and Sizes, ●: Student Guide: Designing Your Chair
 4. Each group produces several rough sketches for possible designs that incorporate the weight-bearing method they chose before selecting one that all members agree upon.
 5. If your class has completed the Form and Furniture lesson, students revisit the measurements they derived from the activity. If they have not, groups take basic physical measurements of each other to determine the optimum dimensions for an ergonomic chair. The activity sheet from Form and Furniture may be helpful in this exercise.
 6. Groups create detailed drawings of their chair design. These should include:
 - a. 1 plan
 - b. 1 side elevation
 - c. 1 front elevation
 - d. 1 back elevation
 - e. details of any intricate attachments or pieces
 - f. notes on the direction of the corrugation in structural pieces



Recommend that students use a scale of at least 1" = 1'. 1½" or 2" scales may be easier to work with.

CONSTRUCT THE CHAIR

1. Groups build scale models of their chair using regular paper or cardstock. As they do so, encourage them to think about minimizing the number of separate pieces they use to make the chair by folding or combining pieces.
2. Groups make a list of all the pieces they will need, noting their dimensions.
3. Using the drawings as a guide, students cut out pieces and assemble them using glue. Remind students that they will probably have to make adjustments to their design along the way as they are presented with unanticipated challenges. ●: Teacher Tip
4. Groups test their chairs for strength. Students sit on the chairs and other group members examine carefully for any signs of weakness such as bending or shifting of parts. Any perceivable weaknesses are reinforced.
5. If desired, groups decorate their chairs.

PRESENT

1. Groups present their chairs and explain the design process to the rest of the class. Other class members test each other's chairs for comfort.
2. If possible, present the chairs to the rest of the school. Possibilities include organizing a display or placing chairs in the library or other areas for public use.

REFLECT

Students respond to the project. Questions for reflection include:

- *What were some of the difficulties you faced in making your cardboard chair?*
- *When you were designing your chair, did you focus mainly on its function (i.e. how it would support your weight and its comfort) or its aesthetics (i.e. how it looks)? Are you satisfied with both aspects of the chair?*
- *Evaluate the strength of your chair. Is it strong enough? What could you do to make your chair stronger?*
- *Evaluate the comfort of your chair. Is it comfortable? What could you do to make your chair more comfortable?*



- *Evaluate the looks of your chair. Is it attractive? What could you do to make your chair look better?*
- *Do you think it is possible to make a functional chair out of notebook paper? Why or why not?*
- *How well did you meet your challenge? What would you do differently next time?*

EXTENSIONS AND VARIATIONS

- Groups weigh their chairs and compare results. What are the advantages of having a lighter chair?
- Groups test how ergonomic the chairs are by sitting in them for a week and noting long-term comfort or physical effects.
- Students conduct experiments to test the strength of cardboard and come up with a maximum amount of pounds per square inch (p.s.i.) that cardboard can hold in various forms. Compare results to information available for other materials.
- Students make an ergonomic cardboard desk to go with their chair.

MIDDLE SCHOOL STANDARDS

Science

- Science and Technology (E)

Language Arts

- Speaking, Listening, Viewing (E3b, c, e)

Math

- Geometry
- Measurement

Technology

- Nature of Technology (1, 2)
- Design (8, 9, 10)

MOTIVATION

- Without cutting, tearing, or taping, can you make a “pedestal” to support a notebook (or small book) on your desk using just 1 piece of paper?*

A piece of paper will be able to hold up a notebook or small book if it is folded. There are many possible approaches; a common strategy is to fold the paper in a zig-zag pattern.
- Can you come up with an explanation of why folded paper can carry more weight than flat paper?*

Folded paper can carry suspended weight because of its rigidity. The more folds the paper has, the more the weight gets distributed among the creases, which are resistant to bending (though if the paper is creased too tightly it may be difficult to balance the book on the paper).
- What are the forces acting on the paper that was made into a “pedestal”? Can you think of a structural term for objects that support loads in that way?*

The piece of paper that is supporting the book on the desk is under compression; as such, it is acting as a column.
- What are the forces acting on the paper that was made into a “bridge”? Can you think of a structural term for objects that support loads in that way?*

The piece of paper that is supporting the book between the desks is under both tension and compression. As the paper bends, the creases must resist the compression on the top of the paper as well as the tension on the bottom (though, in general, paper is much more resistant to tension than it is to compression – the bridge is much more likely to crumple than to tear). In that sense it is acting as a beam.
- Can you think of other examples from your experience in which materials are made stronger by changing their form?*

There should be many examples you can use in the classroom – almost all objects are designed so that their form adds strength to their material. One example is the soda can: thin aluminum is relatively easy to bend when it is in a flat sheet, but when it is rolled into the shape of a cylinder it gains strength. Also notice the top of the can, where the aluminum is folded around the edges, adding strength, and the bottom, where it is domed to resist outward pressure.

EXPLORE PROPERTIES OF CARDBOARD

- *What do you notice about the structure of cardboard?*
The cardboard used for boxes is called “corrugated” cardboard because of the folded middle layer which gives it its strength. The folding increases the material’s resistance to compression, adding a great deal of strength with a minimal amount of extra weight (corrugated cardboard is much lighter than, and not much weaker than solid cardboard of the same thickness.) The flat outer layers provide rigidity and resistance to compression in the opposite direction than the corrugation, as well as creating a smooth surface.
- *Which strip would support more weight as a column (positioned straight up and down)? Why?*
The strip with the corrugation positioned the long way (top to bottom) would support more weight because the folds resist bending in the perpendicular direction.
- *Which strip would support more weight as a horizontal beam (positioned flat)? Why?*
The same strip (corrugation positioned the long way) would be strongest as a beam for the same reason.
- *Can you think of any position in which the other strip is stronger?*
The other strip would be stronger as a short column laid on its long edge.
- *How could the two strips be attached to make an even stronger structural element?*
The two strips glued flat together would provide extra strength to resist forces in all directions.

DESIGN THE CHAIR

- *What advantages might a cardboard chair have over the chair you are sitting in now? How might you design your chair to make use of those advantages?*
Some of the advantages cardboard has over other materials are that it is cheap, light, and easy to cut and glue. This allows for a lot of flexibility as far as the form of the chair is concerned - because it is cheaper and lighter than steel, for example, large solid forms can be incorporated. Encourage students to be innovative and creative in coming up with their designs.
- *What would be your main design strategy to make sure the chair would support your weight?*
There are many possible approaches to structural integrity. All of these incorporate the concept of redundancy - the support system should look like it can support much more weight than it actually has to, to compensate for potential construction flaws and for

material fatigue (a term that describes how any material gradually weakens from repeated strain). Some approaches include:

- Layering of multiple sheets of the same shape to produce thick, solid supports
- Multiple columns
- Sheets of folded cardboard placed vertically
- Stacked cardboard (though remind students that the corrugation is more likely to crush when the load is placed directly on flat sheets).

EXPLORE PROPERTIES OF CARDBOARD

Before you begin your design process, it is important to explore the properties of cardboard.

It will be necessary to begin collecting cardboard several weeks before students begin step III: Constructing the Chair. There are many possible sources for used cardboard boxes, including recycling centers, grocery store dumpsters, bicycle shops (which often have large boxes), etc. If possible, include students and parents in the collection process.

CONSTRUCT THE CHAIR

- Using the drawings as a guide, students cut out pieces and assemble them using glue. Remind students that they will probably have to make adjustments to their design along the way as they are presented with unanticipated challenges.

Review basic safety tips for working with knives and blades. Collectively, set up a “safe area” for cutting where other activities are restricted. Review cutting techniques, including the use of metal rulers or yardsticks for straight edges, the importance of scoring, and how to change blades. Blades should be changed often as cardboard will dull them quickly.

Also discuss optimum glue technique, as students are often prone to extreme overuse of glue. Remind them that too much Elmer’s glue will actually weaken the bond and take much more time to dry. It is recommended that you use glue guns, as hot glue dries much faster, though it is important to remind students of the danger of burns. Binder or bulldog clips can be used to hold glued pieces together until they dry.

Sit Right

Designing The Chair

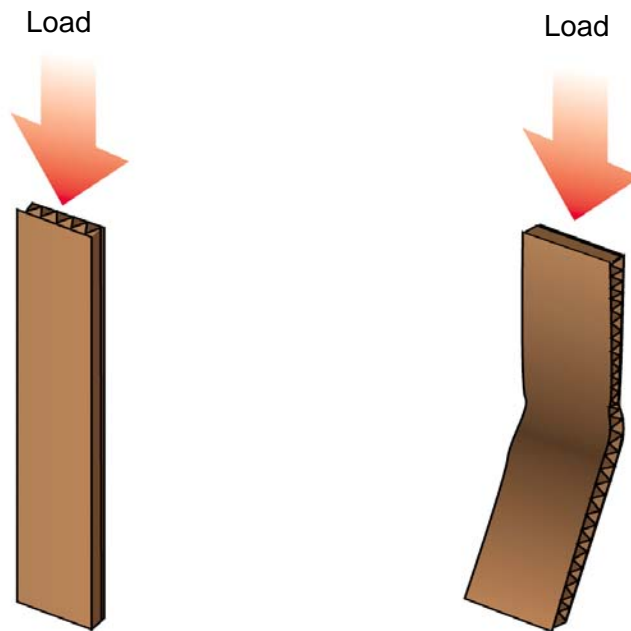
Discuss what you would like your chair to look like and the features you would like it to have.

- What is the ideal position you would like to be in as you sit in a classroom chair?
- What will your chair have to look like in order to accommodate that position?
- How will most of your weight be supported?
- What parts of the chair will be supporting your weight?
- How strong will the back of the chair need to be given your position in it?
- How much weight should your chair be able to support? (Remember to factor in a considerable **margin of safety** - a chair that is just strong enough to hold one student will fail quickly with repeated use!)
- Will your chair have legs or will be supported by a solid base?
- Will your chair have arm-rests?
- Will it have a head-rest?
- How will you construct strong connections between the different pieces of cardboard?
- What are some different types of connection possibilities?

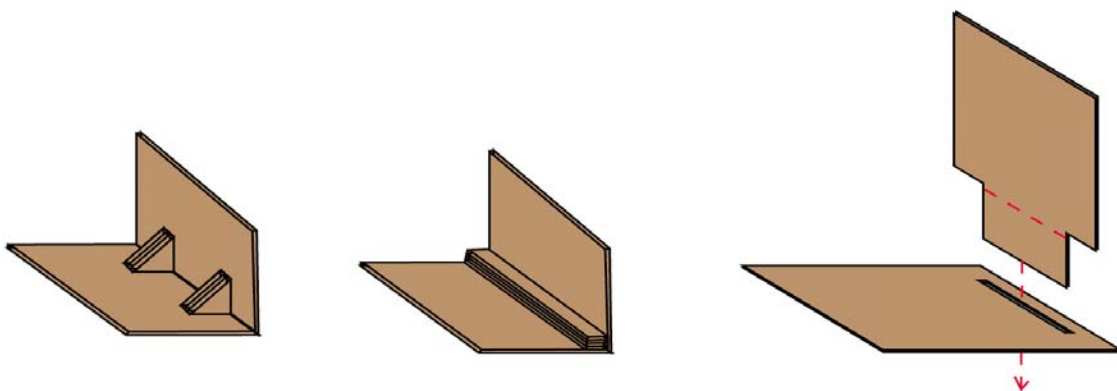
Sit Right

Working With Cardboard

Below: Cardboard cut so that the corrugation runs up - down (left) supports a load. Cardboard cut with side-to-side corrugation (right) supports less load, and will buckle under strain.



Below: A few methods for attaching pieces of cardboard together (with glue).



Above: After the flap is inserted into the groove, it can be folded back (along the dotted line) and glued to the underside of the bottom piece.

Forms and Furniture

Chairs of the World



This chair was made as a throne for Queen Hetepheres of Ancient Egypt, who ruled during the 4th dynasty (about 2500 B.C.E.)



These oak thrones were made in France in 1860.

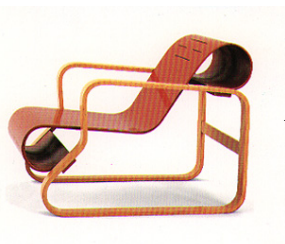
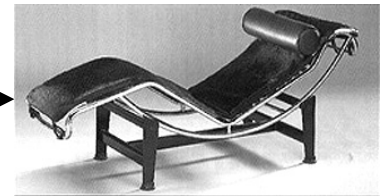


This chair is from the late Qing dynasty in China (about 1900 C.E.)



This stool is used by royalty in the Ashanti tribe from the West African nation of Ghana.

This ergonomic chair was designed by the Swiss architect Le Corbusier in 1928.



This chair is made of laminated pieces of wood and was designed in 1931 by the Finnish architect Alvar Aalto.

American designer Charles Eames designed this chair in 1948 to look like a piece of abstract art.



This chair was built by designer Arne Jacobsen in 1960.



This chair, designed by Olivier Mourgue in 1964, was used in the science fiction movie *2001: A Space Odyssey*.



This chair, designed in 1967 by the Vitra Company, was the first mass-produced chair to be made out of one piece of material, meaning that it requires no assembly.