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The Paper Bridge

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Type:	Icebreaker; Design Project
Length:	20 minutes plus testing and discussion time
Location:	In-Class

Summary

Students are required to plan, design, and construct a means for supporting a load between two classroom table tops. Student teams have twenty minutes, a newspaper, and a roll of tape to complete the task. This is a quick (20 minute) exercise for introducing students to the design process. The team activity can be a good first-session icebreaker in any class.

ABET Descriptors

Engrg. Sci. Content:	First Year to graduate level
Type:	System
Elements:	Establish plan, objectives, critical thinking, synthesis, analysis construction, testing and evaluation
Features:	Ice-breaking activity, development of student creativity, open-ended, consideration of alternatives, production processes, communication
Constraints:	Time, materials, safety, aesthetics
Effort:	Team

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There is a need to support the textbook for this class between two tables in this room. Your team has 20 minutes to plan, design, and construct the longest, aesthetically-pleasing span between the two tables that will support the textbook at the center of the span. Each team has been supplied with the same newspaper and roll of masking tape. You may not support the span from the floor. You may not support the span from the ceiling. You may not attach the span to the tables.

Two maximum length measurements will be taken in the test phase:

1. The maximum length of the unloaded structure which produces a two inch center deflection.
2. The maximum length of the loaded structure at failure.

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Engineering Notes

This project has been given to teams of students in middle school, first year engineering students, senior engineering classes, and to engineering design faculty. I give this project in the first week of every class I teach, both as an icebreaker and to demonstrate what is engineering design. Observing teams working on this project will provide you with many questions and topics on design and team work which you can use in your class discussion throughout the remainder of the school term. Unfortunately there are many more than can be discussed here. However, I will present some which I have used in the past.

Objectives/Comments:

This is a very good ice-breaking activity for all ages and all field of engineering, requiring no analysis because of the time limit.

The main objective of this project is to introduce students to design on the first day of class, in any class. This project demonstrates that engineers must plan, design, and construct the design in answer to a need. Students must organize the team. They must determine "what is the problem?", decide on the goal of the project, identify constraints, and gather more information before beginning the "technical design." Teams must then test and evaluate their designs in competition with other design teams. All this can be done in a 20 minute session plus a test time of 20 minutes for 4-5 design teams per class. I normally use design teams of 4-5 students.

Discussion:

The most likely construction will be to roll the paper into tubes and tape the tubes. Tubes can then be placed end-to-end, with one tube inside the next, to form a long tube span. This tube span can consist of a single long tube, or several long tubes taped side-by-side. A smaller number of constructions will focus on trusses and suspension bridges. Below is a series of questions that the teams can be asked to discuss relative to the designs posed above.

Design. How was the "designing" accomplished? Did the team use sketches to communicate? Did the team arrive at the design by consensus? Or by another means? Did

the team plan the design? Or did the design just happen as time went on? For more "engineering-experienced" teams, did you use a "textbook" engineering design process, or did you revert to a "gut" approach because of the time limit?

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Resources. Students were given four resources; the paper, the tape, time and person power to construct the longest span. The first three will be discussed here, and the fourth later. How were the resources used? If resources were left over, then the team could have used these to make a longer span.

Did the team use all the paper?	*Usually NO*
Did the team use all the tape?	*Usually NO*
Did the team use all the time?	*Usually YES*

Discuss with the team that the goal was to construct the longest span with the resources available.

Construction (manufacture). How did the team set up the construction process? Were team members assigned roles, or did everyone just "do their thing"? Was paper separated by size, texture, color, etc.? Was the tasks of rolling the paper and tearing the tape assigned to team members, or did team members do both? How were the resources doled out and controlled.

Gathering Information. Did the team search for additional information? Did the team pick up the book (weight) to see how heavy the load was? Did the team test a section of the span as they went along to determine its strength and/or stiffness?

Team Dynamics. How did the team determine the leader of the group; was it by consensus or was it by default? Who took the leadership role?

Load Application. If using a book for the load, students may consider two ways of loading the span; laying the closed book flat, or opening the book in the center and placing the book straddling the span. This should raise questions about understanding the conditions of the problem and gathering more information.

Testing. Have the student teams perform the testing and measuring on their span so that there is no quarreling among groups. Do not allow other groups to aid in the testing of the team's span. However, make note whether other teams are observant in keeping the measuring "accurate."

Test #1. Begin the testing on the unloaded bridge (deflection measurement). Begin with the tables close together and take measurements as the tables are pulled apart until the 2" deflection is reached. Note with an * on the measurement if the maximum length of constructed span is reached. After all tests are completed, talk about conservativism in design.

Test #2. When test #1 is complete, move the tables together again. Have students move the tables apart to take an initial "loaded reading." Put the book in center of the span,

measure the span length. Continue the test by moving tables apart, put book in center of span, and measure the span length. Continue the procedure until the span fails. Total

collapse of the span, or dumping the load (failure to hold the book) is considered failure. For structures which become compliant as the span increases, a 20-second limit is imposed on movement of the structure. Failure to stop moving within 20 seconds after load application is deemed "failure." Again, note with an * those spans which "max out" on construction. *(Do not imposed the deflection constraint on this test; this test is to determine failure only.)*

Follow-on Activity.

The project can be done a second time with the same teams. This provides teams the opportunity to improve on their first results. Almost all teams will try to modify their earlier designs to "make them better." It is advisable to give the class some additional information that will encourage them to 'think differently" the second time around. One or both of the following will help in this respect:

1. Tell them that a team of middle school students have constructed a span under the same circumstances which was 10-12 ft long.

   Design teams will not believe that this is possible! The rolled paper tubes are not sturdy enough. Tell them to think about it and come to class next time to do it again. *Ah ha, perhaps a different concept is needed. Perhaps they will be motivated to think differently.*

2. You may wish to show them the first part (Part I only) of the Ken Burns video documentary on Roebling and the Brooklyn Bridge. This film on bridge-building should give the students additional ideas to pursue. (*The Brooklyn Bridge*, Ken Burns)

Both of these provide additional information which the students should use in developing a "better concept." I suggest that this information be given to the student without any elaboration.

Design Process. Discussion of the design process later in class may cover the following topics:

Read and reread the problem carefully.
Understand the given constraints.
Have each student repeat what was understood of the problem.
Discuss whether this is a puzzle problem.
See in how many ways the given constraints can be mis-interpreted.

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Think if the given constraints can be "twisted", or look for any 'loop holes" in the given constraints.
Dig the "hidden clues" to solve the apparently "impossible" problem in different ways.
Brainstorm different new ideas and designs based on the "twisted" constraints.
Hold the "obvious first thoughts" on the design solution.
Think whether a better solution exists if the roles of some of the design parameters are reversed.

Materials Required:

Two tables of the same height
Per team:
1 Large Sunday Newspaper
1 Roll of masking tape
A weight to load the bridge; can use a book
A long (15-25 ft) tape measure