4-H Project Connections:

- Junk Drawer Robotics
- Woodworking
- Cake Decorating

4-H Science Abilities:

- Plan
- Design solutions
- Build/construct
- Troubleshoot
- Redesign
- Collaborate

4-H Life Skills:

- Cooperation
- Contributions to group effort
- Planning and Organizing
- Problem solving

Colorado Standards:
Content Area: Mathematics
Fifth Grade and Eighth Grade
Standard: 4. Shape, Dimension, and Geometric Relationships
Content Area: Science
Eighth Grade
Standard 1. Physical Science
Observe, explain, and predict natural phenomenon governed by Newton's Laws
Invention: Designing investigations and engineering new products involves a large degree of invention. Scientists and engineers often have to think "outside the box" as they push the limits of our current knowledge. They must learn from their failures to take the next steps in understanding. (CO Science Standards adopted 12/10/09 p. 24).

National Science Education Standards

Standard A, Science as Inquiry: all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry.

Standard E, Science & Technology: all students should develop abilities of technological design and understandings about science and technology.

Standard F, Science in Personal and Social Perspectives: all students should develop understanding of personal health, populations, resources and environments, natural hazards, risks and benefits and science and technology in society.

STEM Connections

Colorado State University Extension

Connecting Science, Technology, Engineering, and Math concepts to our everyday lives.

Super Structures

Shape is an important characteristic of all structures. Can using the right shape help you build a structure that supports something heavy?

You might wonder what engineers do and what that has to do with your everyday life. Engineers apply the principles of science and mathematics to develop useful, cost effective, even elegant, solutions to technical problems. Their work is the link between scientific discoveries and the products and processes applications that meet the everyday needs of society. In short, engineers make the "stuff" we see around and use everyday. The toothbrush we use to brush our teeth, the computer or iphone, the cars we ride in and our schools, stores and bridges all are designed by engineers.

Structural engineers are a special kind of engineer who design the skeletons of buildings and bridges so that they will carry loads and withstand **forces** like wind and earthquakes. Structural engineering is a subset of civil engineering which is the oldest and largest branch of engineering.

In these activities you will be working with some of the same forces that structural engineers address. What is the most important consideration when you are building a structure? You don't want it to fall down. As you know, the force that pulls things down is **gravity**. A building is made of heavy materials (dead force) and is also full of heavy materials like furniture and people (live force). All of this weight pushes down. The ground underneath pushes back up. Spreading out the foundation of the skeleton of a structure helps provide more upward force. Forces which pull up and down are called **vertical forces**. Structures also have to be built to withstand **lateral forces** which move from side to side. The lateral forces that effect buildings are wind and **seismic** activity or earthquakes. The goal of structural engineering is to create structures which are **stable**, in other words they can carry the live and dead forces of the structure and withstand external forces without collapsing or changing shape.

So, you may be wondering, this is all very nice and I am glad that someone is making sure the buildings I'm in are safe, but why do I need to know about this? When you start looking closely, you will see that many of the things you use and make use these same principles. Understanding forces and shapes can help you build better bookshelves and bird houses, sturdier and more efficient robots, and even better multi-layer cakes. You can choose stronger furniture and select better tools by knowing what kinds of shapes to look for in their construction.

You may also have noticed above that engineers come up with cost effective solutions to problems. Engineers have to apply the concepts of criteria and constraints in their work. **Criteria** are rules which lay out the expectations and specifications of a project, how big, how strong, what safety and environmental standards are expected, and so on. **Constraints** are the limitations or restrictions. The most important one is often cost, a project can only cost so much. There can also be constraints on the size and appearance, the time available, and environmental impact. The engineer's job is to come up with the best design possible for the amount of money available. Criteria and constraints are also part of your life. Your school work is judged by criteria set by your teacher. You have constraints on how much money you can spend or how much time you have for video games.

Engineers carry out their work using the "Engineering Design Process". This is similar to the scientific method, the set of steps that scientists use when they are carrying out experiments. The Engineering Design Process is a set of steps that engineers use to solve problems and carry out project. There are lots of variations, but generally the steps are: Identify a problem, criteria and constraints, brainstorm possible solutions, choose an idea to develop, build a model or prototype, test, redesign, identify problems with the model, and around and around until the problem is solved. Engineers do lots of testing and retesting and when you do this kind of project, so will you!

Ages: 8-16

Time: 45 minutes

Materials:

Activity 1(per team)

10 File cards

5 inches of masking tape

100 gram weights made of sand and snack size sandwich bags. (Or use paperback books)

Activity 2 (per team)

15 coffee stirrers

20 1/2 coffee stirrers

10 file cards

10 inches of masking tape

5 pipe cleaners

1 can of soda

Paper for drawing designs

Power Words:

Constraints: The limitations or restrictions on a project

Criteria: The rules or expectations for a project

Force: Pushes or pulls which change or maintain the position of a structure

Gravity: The force between all objects. On earth, gravity pulls objects down

Lateral force: Forces directed at the sides of a structure

Seismic: Related to earthquakes

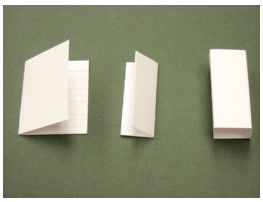
Stable: A structure that is able to carry a realistic load without collapsing or deforming significantly

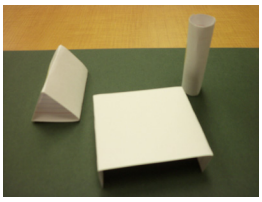
Vertical force: a force which pulls up or down on a structure

Experience / "What to Do"

Activity 1: Exploring Shapes

With your team members, get 10 file cards, 5 inches of tape, and two 100 gram weights or paperback books.





You are going to test the strength of different shapes, a table, a square, a triangle and a round column. Make the table by folding about 3/4" in on each side and standing up the card. Make the square by folding the card in half and then in half again. Open and tape securely into a square, For the triangle fold the card into 3 equal parts. Open and tape securely. To make the column, roll the card into a circle and tape securely. In order to balance the card and weight, you will need 2 triangles. Can you do a fair test of the shapes if you only use one of the other shapes? No, so use two squares, two columns and two tables as well.

Lay a file card across the top of each pair of structures. Then test the strength of each shape by placing your 100 g weight on it. What happens? Will any of the shapes hold 2 weights? Which shapes are strongest? Does it matter where you put the tape? Where is the force from the weight concentrated in each shape?

Discuss with your team members which shapes would be best for building a strong stable structure. After you reach some conclusions, look at the Science/Engineering Notes below.

Activity 2: Being Supportive (in a Competitive Way)

Your criteria for this activity is to design and build a structure that will hold a can of soda at least 4" above your work surface for at least 1 minute.

Your constraints are that you may use only the materials in your kit and that you have 7 minutes for project design and 15 minutes for project building and testing. You also need to contain the cost of your project.

At the end of the contest, your team will receive 1 point for each item in the kit that you do not use. You will also receive 1 point for each inch above 4" that your structure stands.

Your kit contains the following: 15 coffee stirrers, 20 1/2 size coffee stirrers, 10 file cards, and 5 pipe cleaners.

From the supply table, you may get a pair of scissors (you may not use the scissors as part of your design, only to modify the materials), and your leader will give you 10 inches of masking tape and a can of soda. You also need some paper and pencils for drawing your preliminary designs.

Step 1—Project Design—7 minutes

Lay out your materials so everyone in your team can see them. Define the problem, criteria and constraints. Brainstorm some possible solutions. (Remember the things you learned about shapes and forces in the first activity.) Pick the design that the team likes best and draw a plan or blueprint showing what you are going to build including what materials you plan to use and where you will use them. Remember that you are limited to the materials you have and that you get credit for anything you do not use. At the end of the time, show your plan to your leader who will release you to start building.

Step 2—Project Build—15 minutes

Using the plan you developed, start building. Make sure every team member is involved. As you go along, discuss modification that you may need to make. Remember that you get extra points for extra height and for having materials left over.

Step 3—Competition

Whose structure wins?

Science/Engineering Notes Both the triangle and the circle are strong, stable shapes and resist pushing and pressure. A square or rectangular shape is naturally unstable. Weight placed on a square is distributed on the vertical sides and it tends to collapse or slide to the side. To prevent this engineers include trusses in their designs. A truss is a straight piece that is connected between two opposite corners, forming triangles. Pressure on a truss pushes down to the wide bottom of the square instead of placing pressure on the side pieces. Notice that you used the same materials in each example with very different results. When you build, you want to use a strong and efficient design.

Share/Reflect/Generalize/Apply :

Think about some of the large structures you have seen like bridges, power plants and tall buildings. What shapes do you see in used in the construction?
If you plan to build a bookcase, what structural considerations should you have in mind? What engineering concepts do wedding cake bakers apply?

Career Connections: There are a lot of great websites to help you learn more about engineering careers and the kinds of things engineers do. Our country and our world for that matter are going to need lots and lots of engineers in the future so it is a really good area to **consider.** Check out these for starters….

www.engineeryourlife.org
www.engineergirl.org
www.egfi-k12.org
www.discoverengineering.org

References:

http://constructionmanagementdegree.org/blog/2010/100-awesome-engineering-projects-for-kids/
http://www1.cyfernet.org/act-CYFAR/mom/02-08-Bridges/Feeling_TenseAbout2SnapWithFish.pdf
http://www.ces.ncsu.edu/depts/fourh/old/greenlight/afterschool/StrawTowers.pdf

This STEM Connection was developed by: Christy Fitzpatrick. To find out more about 4-H STEM activities, contact your local county Extension office. http://www.ext.colostate.edu/cedirectory/countylist.cfm More activity sheets can be found at http://www.colorado4h.org/k12/activity_sheets/activity.php

Teacher Tips

- Preparing for Activity 1: Lay out enough file cards for each team to have 10, give each team 2 sand or other weights and some masking tape—about 5 inches is probably plenty. They can have more if they need it, but they probably won't.
- Preparing for Activity 2: Make a kit with the listed materials for each team. You will need to cut 10 coffee stirrers in half. Measure carefully so they will all be the same length or, if you would prefer, just give the teams 25 coffee stirrers and ask them to cut 10 into equal halves. Set up a supply table with scissors, masking tape, rulers, and a can of soda for each team. Also provide some paper and pencils for the design part of the activity. You will also need a way to time the final contest—a stop watch or clock with a second hand.
- At the beginning of the activity, put youth into groups of 2-4 members. Two or three gives more opportunity to participate.
- Have them read the introduction on the front page. Ask them if they know any engineers and what kind of work they do. Ask them why someone might want to be an engineer. Tell them that there are some websites on the bottom of page two that they can look at to learn more about engineering and why it is a great career.
- For activity one, the teams are told that they need to make two triangles in order to balance the weight and then reminds them that they will also need to use two of each of the other structures to do a fair test. This is a good chance to remind them that good experimental design means testing only one variable at a time, in this case the shape of the structure. Doing that with different numbers of cards introduces another variable.
- Starting Activity 2: making a written plan is usually the activity that kids like least, but thinking through their design will help them use their time and their materials most efficiently. If there is grumbling, have them give ideas about why you are "making" them do this part. Be clear that you will not release them to start building until you see a plan that is actually something they can follow. Review the criteria and constraints and the contest (one point for each piece of material left over and one point for each inch greater than 4" that will successfully hold up the can) before they start their plans. You can decide if you would like to let them get their material kits before they start to design, but they may not begin building until the plan is approved. You could also just lay out one set of materials and they could all come up and look at it.
- Before they start to build, tell the teams that they can use the soda can as they are constructing to test their structures but then will have to take it off. During the contest, they will pick someone, it could be you, to place the can onto the structure.
- Chances are very good that when they actually start to build, they will end up with something pretty different than their original idea. That is fine, the idea is to give them a place to start. If they are having trouble, suggest that they go "back to the drawing board".
- The coffee stirrers in this kit are 7" long which is a bit longer than ideal (around 5" is best). The teams can cut more of the stirrers if they need to. The shorter lengths seem to work better and are easier to work with. You might be able to find shorter stirrers (these came from Walmart).
- The youth have 15 minutes for the build part of the activity. They may not be finished by then. Take the opportunity to stop everyone, bring them together away from their creations and hold a short discussion about their work. How are things going? What problems have they run into? What would they like to ask the group? What is something they have discovered that works well? Remind them that engineers work in teams and that team meetings to share ideas are an important part of an engineering project.
- Ask if groups are ready to test or if they need more time? Give them 5-10 minutes more and then get everyone together for the "contest". It's best to rotate around to each work area so the structures don't get damaged by moving them. Each group chooses someone to place the can on their structure and then they will be timed for 1 minute. Also measure how high off the table the soda can is. All successful teams will go into the "Final Round" where teams swill how you their leftover materials. They earn one point for each unused item. Add one point for each whole inch the structure is above 4 inches. The team with the most points (in other words the team that used the fewest materials and still met the criteria and who successfully went "above and beyond") "wins". You can decide how competitive you want to make this. Usually kids in informal settings respond well to low stakes competition.

Activity Extensions:

Woodworking, animal science: Have youth sketch out plans for birdhouses, animal pens, chicken coops, fencing or other structures related to their projects.

Robotics: Attaching something to the robot is always a challenge and one where a knowledge of shapes can make life easier. Try converting an NXT robot into an artbot by attaching a marker and then programming the robot to draw shapes by repeating short move sequences. Robots need to turn on a caster wheel for this to work. Or build a junk drawer robotic arm. The same principles of shape and strength will apply.

If your group enjoys building, check these websites for additional structure building projects, check out this website. There is a whole section of structure building activities as well as a plethora of other topics!
http://constructionmanagementdegree.org/blog/2010/100-awesome-engineering-projects-for-kids/

If you have trouble finding these materials or want to try something different, you can use marshmallows and regular spaghetti or gumdrops and toothpicks as other types of building materials.