NATIONAL SCIENCE & ENGINEERING WEEK

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Vertically challenged

Part of the British Science Association's National Science & Engineering Week activity pack series. **www.nsew.org.uk**

BIS Department for Business Innovation & Skills

BRITISH SCIENCE ASSOCIATION

About this Pack

Background

This activity pack is concerned with buildings and the forces that are required to put them together. The activities included in this pack will show how buildings are constructed using scientific ideas. Whether it is a tower made out of spaghetti, a bridge made out of paper or glue made out of milk; you will be able to investigate what it takes to make a real life engineer or architect!

The first section contains details on how to carry out the activities. The second section has background notes on the science behind the activities.

Science safety

Some of these activities involve using potentially dangerous objects. Please read each activity carefully, and take appropriate measures to ensure the safety and enjoyment of all participants.

Educational Links

All activities in this pack contribute towards Key Stage 1 Investigation and Skills in science, Skills in designing and making and Skills in social subjects in the 5-14 Guidelines. We recommend that you consult the National Curriculum on the website (www.nc.uk.net/), and the 5-14 Guidelines (www.ltscotland.org.uk/5to14).

Acknowledgements

The activities in this pack were compiled and adapted from a number of sources. Many thanks go to all to who helped in the making of this pack, in particular, Elizabeth Robertson who donated Activity 13 from her book "The Instant Egg Race File - a collection of tried and tested practical problem-solving activities". To obtain a copy of this publication send £7.50 (which includes postage and packing) to Science Designs, 6G Salmon Lane, Stonehaven AB39 2NZ.

For more information on projects, resources and events which engage young people in their built environment and the space around them, check out the CABE Education website at www.cabe-education.org.uk/

Activities

Activity 1:
A question of balance

You will need: A long stick e.g. a walking stick or a ruler, a piece of clay or a weight, sticky tape

First, place your fingers at each end of the stick and move them inwards until the stick is balanced. This is the centre of gravity. Next attach a piece of clay, or weight, onto the stick with tape. Try balancing the stick on your fingers now. Has the centre of gravity changed? Repeat the experiment by changing the position and size of the weight. Where do you think the centre of gravity would be in different objects, for example, a doughnut, your body, your house, the Earth?

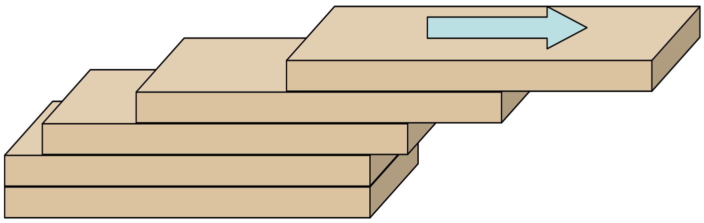
Activity 2:
What's long and sticky?

You will need: A long thin stick (about 1 metre), a piece of clay or Plasticine

Attach a piece of clay, about the size of your fist, about 20 cm from the end of your stick. Try to balance the stick vertically on the end of your finger; first balancing with the clay at the bottom of the stick and then with it at the top. Which is easiest? How long can you balance the stick for?

Activity 3:
Lift up a grown up

You will need: An adult, a child, a long plank of wood, a block of some sort (wood or a brick)



First, make your lever by placing the plank of wood on top of your block. Your lever will work best if the block is closer to one end so that the lever is unbalanced.

Next, get your adult volunteer to stand on the short end of the lever whilst the child stands on the long end. Can the child lift the adult? How is this possible?

Activity 4:
Flying cornflakes!

You will need: An ice lolly stick, a pencil, cereal, a metre ruler, a small container

Put the ice lolly stick, at right angles, across the pencil. Put a piece of cereal on one end of the stick, hit the other end of the stick with your hand and watch out for flying cornflakes!

If you mark where the pencil is and record the distance that the cereal flew, you should now be able to place a small container at this distance and try again to see if can catch your cereal.

Activity 5:
Stack Attack

You will need: 15 – 20 rectangular, flat blocks of the same size and shape (for example, you could use textbooks, playing cards, wooden blocks, or flat rulers)

Stack the blocks, one on top of another, to make a column. Start by moving the top block as far to the right as possible without it falling off the stack. Next, move the top two blocks together so that they both extend over the third block as far as possible without falling off. Now move the top three blocks, and then the top four blocks and so on down the stack. How many blocks do you have to move before the top block is completely beyond the base of the stack?

Activity 6:
Do less work!

You will need: Strong string (about a metre), scissors, a book, a rolling pin

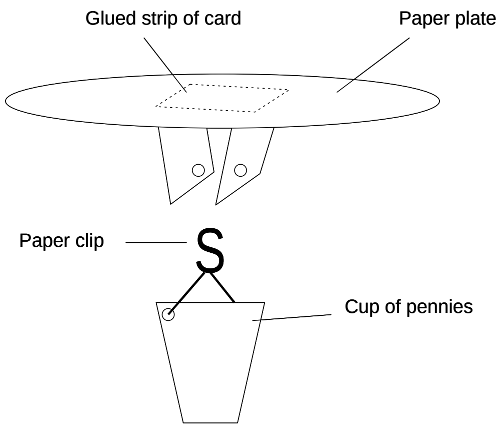
Tie a long piece of string securely around your book making sure there is enough left to run over your rolling pin. Place the book on the floor and lift it by pulling on the string. Think about how much force is required to pick it up. Now get someone to hold the rolling pin loosely by the handles. Run the string over the top of the rolling pin and pull down on it to lift the book. How much force was required this time? Is it easier or harder?

The rolling pin is acting as a 'pulley'. What do you think would happen if more pulleys were used?

Activity 7:
Sticky situations

You will need: 1/2 cup of skimmed milk, 2 tbsp vinegar, 3 large cups or beakers, 1 coffee filter a plastic spoon, paper towels, 1 tsp baking powder, water

Put the milk and vinegar into a cup together and stir for about a minute. The lumps that form are called 'curds' and the remaining liquid is called 'whey'. Separate the curds and whey by straining the mixture through a coffee filter/paper towel into a cup. Scoop the curds out from the filter and dry them out by gently squeezing them with a paper towel until they feel firm. Put the curds into another clean cup, stir in 2 tsps of water and then add the baking powder. Now add very small amounts of water until it looks like glue.



You can test the stickiness of your glue in the next activity.

Activity 8:
How sticky?

You will need: Different types of glue, including your homemade glue and some peanut butter/honey, paper plates, a hole punch, paper cups, string, large paper clips, lots of pennies/small weights

To make your glue testing equipment first cut a strip of card, about 5cms wide, all the way across a paper plate. Punch a hole at each end of the strip and fold it into thirds.

Spread some of the glue you want to test on the middle third of your strip and glue it to the bottom of a paper plate. Do this on a separate plate for each type of glue you want to test making sure you use equal amounts of glue each time. For the best results, let the glue dry for about 30 minutes.

Punch two holes on either side of a paper cup and tie each end of a piece of string to each of the holes in the cup. The string should make a handle for the cup. Twist a paper clip into an 'S' shape and attach one end to the string handle on your cup and the other end to the two holes in the strip of card (once the glue has dried).

Hold your paper plate off the ground so that the cup doesn't rest on a surface. Now count the number of pennies/weights you can put into the cup before the strip pulls away from the paper plate.

How many pennies can each glue hold? Which glue is the stickiest?

Activity 9:
Home shapes

You will need: pencil, crayons or paint, paper

Take a look at your house. What sort of shapes is it made up of? Rectangles, triangles, squares? Try drawing your house by drawing the largest shape first and then filling in all the other smaller shapes and details.

Next, draw a picture of how your dream house would look. Think about what sort of style you would like your house to be, for example, a medieval castle, a skyscraper or a country cottage. What would you like to put in your house? Would it have a swimming pool or tennis courts? What would it be made of?

Activity 10:
How does a building feel?

Act out the different parts of a building and feel the forces that architects and engineers must contend with!

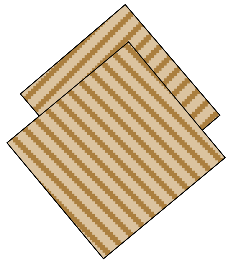
- Be a column by balancing a pile of books on your head.
- Be a cantilever (a structure, such as a diving board or a balcony, that is only supported at one end) by holding out a pile of books at arm's length.
- Be an arch, with two people, by leaning against each other's hands.

Think about what forces you are feeling. Are you in tension (being stretched) or compression (being squashed)?

Think about what other structures you could make for example; a tunnel, a dome or a suspension bridge. Can you make a whole building?

Activity 11:
Tough balloons

You will need: Balloons filled with air, balloons filled with water, sticky tape, 4 30cm x 30cm pieces of thick cardboard from a cardboard box



NB: Make sure you have someone with you when testing this experiment to make sure you do not fall. Also, make sure you test your water filled balloons outside or somewhere that you can get wet!

Make two strong platforms by gluing two pieces of cardboard together so that the corrugated lines in the cardboard are going in opposite directions. This should make it extra strong.

Start by standing on one of your platforms supported by the balloons filled with air. The balloons stay in place better if you tape them onto the bottom platform and then put the second platform on top. Have a friend pop one balloon at a time. How few balloons still support your weight?

Do balloons filled with water hold your weight better or worse than balloons filled with air? Why do you think one works better than the other?

Activity 12:
Strong shapes

You will need: Toothpicks, jelly sweets (midget gems work well!)

Make a variety of shapes, such as a square or a triangle, from the sweets and toothpicks by placing one sweet in each of the corners. Press the sides and corners of each of the shapes. Which shape is the strongest?

Which shape do you think would be best to use to construct a building?

Activity 13:
Spaghetti Towers

For each group you will need: 50g of dried spaghetti (approx 50-60 strands), supply of mini-marshmallows

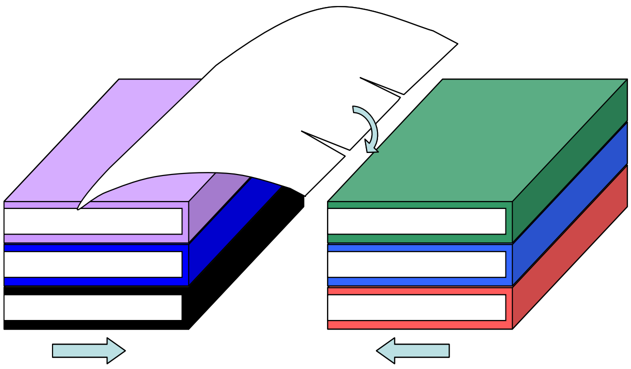
This activity works best as a competition between groups of 2 – 5 people. Each group must construct an unsupported spaghetti tower. The spaghetti is used as the struts and walls and the marshmallows are used to connect the joints. The highest tower wins!

Top tips: Think about the results of activity 12. Which was the strongest shape? Can you use this shape to help build your tower? Could you combine shapes to make a tower that is both tall and strong?

Activity 14:
Foam homes

For each group you will need: 1 plate, 1 or 2 bowls, 1 hand mixer and/or electric mixer, 1 ruler, washing up liquid, water. Optional: spoons or lolly sticks

This activity works best in groups of 2-3 people. The challenge is to build a tower of foam at least 30cm high and no more than 25cm across its base. You may not use any supports other than the foam itself. You can alter the consistency of the foam by either adding more washing up liquid or by whisking your foam faster or for longer. Which team can make the highest tower?



What type of foam makes the best structure: light and fluffy; dense and strong; or maybe a combination of both?

Activity 15:
Bridging the gap

You will need: 4 or 6 books (to make two stacks of equal height), card, scissors, lots of pennies or small weights

Make two stacks of books of the same height and make sure they are about 10cm apart. Lay one piece of card across the books and measure how many pennies it can hold before it collapses.

Try this experiment again and try different techniques to strengthen your bridge. You can try folding your card in half, pleating your card, or you could even make an arch. You can do this by cutting two slits into the edges of your card, pushing the flaps under the edge of your book covers and pushing the books together slightly.

How many pennies can the strongest bridge hold?

Activity 16:
Build like a beaver

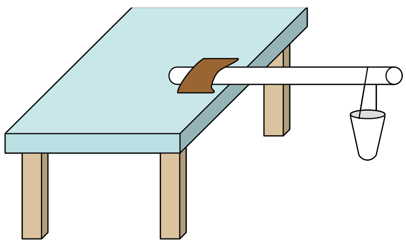
You will need: A long, clear container, sand, gravel, plasticine or clay, ice lolly sticks and a bucket of water

Fill your container with sand and dig the course of a river through it. Choose a good place for your dam and construct it using the ice lolly sticks, clay and gravel. Your dam should still let a little bit of water through but not too much. How could you make your dam structure stronger? What shape do you think it should be?

Test you dam by emptying a bucket of water down your river. Did your dam hold back the water?

Activity 17:
Cantilever fever

You will need: Newspaper, masking tape, string, a plastic cup or yoghurt pot, pennies or small weights



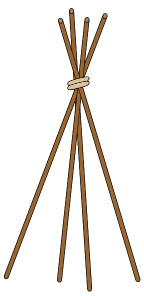
A cantilever is a structure that is only supported at one end, such as a diving board, a book shelf bracket, or a tree branch. They are also often used in bridge construction.

How far out from a wall, or tabletop, can you build a cantilever structure with the materials provided?

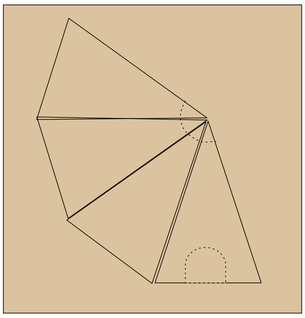
Next, try to make a cantilever that reaches 50cm out from the wall or tabletop. How can you strengthen this structure? You can test the strength of your cantilever by attaching a piece of string to your cup and hanging it from the end of your construction. How many pennies can your structure hold?

Activity 18:
Invent a tent

You will need: 4 straight twigs (about 30cm long), string or a rubber band, paper (preferably brown paper), scissors, a pencil, sticky tape, decorations



Tie your twigs together, quite loosely, about 7 or 8cms from the top. Arrange the twigs so that they form a conical shaped frame.



Using a piece of scrap paper and a pencil, trace the outline of one of the triangular sides of your tepee frame and cut this out for your template.

Next, stretch out a large piece of paper and trace around your template four times so that the long edges of the triangles are touching. Cut this shape out and make a small hole in the bottom of one of the short sides for a door. Decorate the piece of paper however you wish.

Fold the paper along the long pencil lines and tape the edges up to make your cover for your tepee. Next, cut the tip of the cover off for the twigs to fit through. Once this is on, you can tape the twigs into place on the inside corners of the cover.

Activity 20:
Creature comforts

Do some research on how different animals build their houses and present your findings on a poster. You could think about one of the following ideas or you could use your own:

A bee hive
A bird's nest
A termite mound
A caddis fly larvae case
A badger set

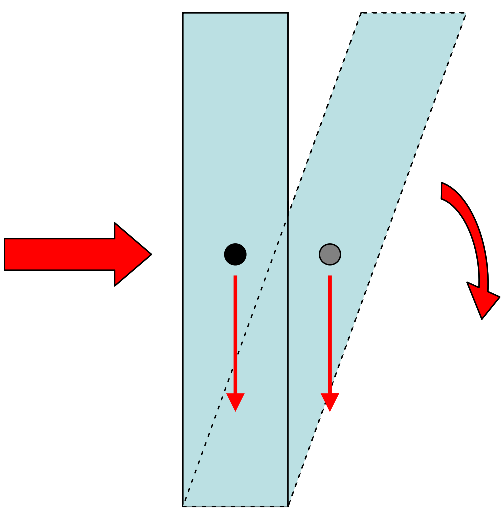
What sorts of materials are used to build the home? How are they constructed? Are they made by one animal or are they made as a group? What size and shape structures do they build?

Organiser's notes

Activity 1: A question of balance

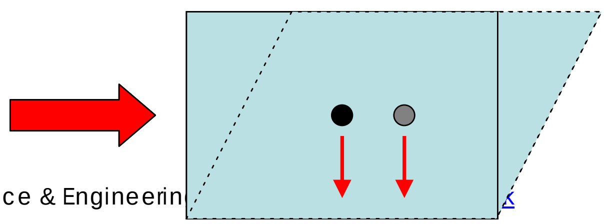
Gravity acts on all objects on Earth. The average location of an object's weight, and the point at which the effect of gravity seems to be concentrated, is called the centre of gravity. An object can be balanced if it is supported directly below this centre of gravity.

High centre of gravity



If an object has a low centre of gravity it tends to be stable and will not fall over easily. When the centre of gravity of an object is high it becomes more unstable and is more likely to topple. If the centre of gravity moves outside the boundaries of the base; the object will fall over. For example, it would be easier for a double-decker bus (high centre of gravity) to be pushed over on a windy road than a car (low centre of gravity). This is because it takes less effort to move the high centre of gravity outside the boundaries of the base of the vehicle.

Low centre of gravity



Activity 2: What's long and sticky?
When you balance the stick on your hand it will rotate around its centre of gravity. The further away the weight is located from the axis of rotation (such as your hand), the slower the stick turns. When the weight is at the top of the stick this rotation is slow enough to correct the movement quickly and the balance is easily maintained. When the weight is at the bottom of the stick the rotation is much quicker and it is much harder to balance.

Activity 3: Lift up a grown up
A lever is made up of three important parts that are necessary for it to work; a fulcrum (a point around which the lever turns or pivots), a load (the things you are trying to lift or move) and the force applied to the lever. In this case; the plank is the lever, the block is the fulcrum, the adult is the load and you are the force trying to move the load.

Levers are used to help you move a large load with a small force. The further away the force (child) is from the fulcrum the easier it is to move the load (adult). If the force created by a child, at a large distance from the fulcrum, is bigger than the force of an adult, at a short distance from the fulcrum, then the child will be able to lift the adult.

Activity 4: Flying cornflakes
In this experiment; the lolly stick is the lever, the pencil is the fulcrum, the cereal is the load and you are the force. If you place the cereal at one end of the lolly stick and place the pencil close the opposite end; when you hit the lever the cereal should move the greatest distance. If you want to try and get the cereal into your container you must try to hit your lever with exactly the same force each time.

Activity 5: Stack Attack
When you balance the top block of the stack, the centre of gravity of this block rests on the edge of the second block below. When you balance the top two blocks; the centre of gravity of those two blocks combined was balanced on the third block. Every time you move a new set of blocks, the centre of gravity of the growing group of blocks was positioned on the edge of the block below.

Activity 6: Do less work!
A pulley is a simple machine made out of rope, or string, and a wheel (or in this case a rolling pin). Pulleys change the direction of the force applied in order to lift an object. This means we pull down instead of up therefore making it easier to lift as you can use your body as a counterweight. With each additional pulley added to the system, the weight is easier to lift. If you have two pulleys you can lift twice as much weight as if there was no pulley at all. If you have three pulleys then you can lift three times as much and so on.

Activity 7: Sticky situations
Milk is made of solids and water. About 3.5% of the solids are proteins. There are two different types of proteins: casein and whey. When you mix the milk and vinegar together, the acid in the vinegar makes the casein in the milk stick together to form the small white lumps (curds).

Simple milk curds can also be combined with chemicals and then hardened into plastics. Casein is used to make combs, jewellery, even some house paints. Casein glue in paint is what makes it stick to your walls and ceilings.

Activity 8: How sticky?
When your glue is applied to the paper plate, the proteins in your glue either connect to molecules of the card or flow into the card's pores and spaces. As the liquid in the glue evaporates the proteins become hardened. This makes the pieces of card stick together. If you had tested your glue on a material, such as polished metal or glass, instead of your paper

plate, then the glue would not have stuck as efficiently. This is because these types of materials do not have as many pores or spaces for the glue to attach itself to.

Activity 9: Home Shapes

Architects work very hard in designing the perfect building for their client. To do this they must think of what the building will be used for, how many people it is meant for, the conditions of the building site and which building materials will be the most appropriate.

Architects also need to consider how the building will look. What types of colour will they use? What shapes and forms will be used? Should the building blend in or stand out? Will it be plain or will it be fancy?

Think about the different styles of buildings in different countries. How would a house in a hot, desert country differ from a house in a cold, icy country? What differences would you expect in structures built on swampy ground or on mountain terrain?

Activity 10: How does a building feel?

Structures such as columns are under constant compression and need to be made out of materials that can tolerate these conditions such as brick, steel or reinforced concrete.

Cantilevers need to be very strong so that they can resist bending and breaking. When a structure is being bent it is being compressed on one side and in tension on the other. This means cantilevers need to be made out of a material that is strong in both tension and compression such as steel or aluminium.

An arch uses compression to balance its own weight and the weight piled on top of it (for more information see notes for activity 15). Materials such as concrete or cast iron are often used to make arch bridges.

Activity 11: Tough balloons

A gas is made up of atoms surrounded by large amounts of space. This means that a gas can be compressed into a smaller area or volume. In a liquid the atoms are much closer together and the volume of a liquid cannot be reduced.

When you stand on the balloons filled with air you squash the balloons and the gas inside squashes along with it. When you stand on the balloons filled with water the volume inside cannot be reduced and the balloon has to stretch outwards causing it to pop.

The more balloons there are under the platform; the easier it becomes to support your weight. As the balloons are squashed downwards the surface area of the balloon touching the platform increases. This means that you are spreading your weight over a much larger surface area and reducing the pressure on each individual balloon.

Activity 12: Strong shapes

You should find that the triangle is the strongest shape as it does not tend to bend or buckle. The square is quite weak as it often breaks at the joints but can be strengthened with the addition of a diagonal support (therefore creating two triangles). A lot of buildings use triangles in their structures, such as the roof and walls, because they are so strong.

Activity 13: Spaghetti Towers

From activity 12) you can tell that triangles are the strongest shape. It is possible to build a tower out of only squares but this structure will not be very strong and would be quite wiggly. Structures built from only triangles would be a lot stronger but will use up all of your materials before your tower gets very tall. The best way to build a tall tower would be to use a combination of triangles and squares.

Even though the tower is standing still, the individual parts are always pushing and pulling against each other; they are either in tension or under compression. Imagine taking the place of one of the pieces of your tower; would you feel squashed or stretched? The vertical pieces of spaghetti in your tower will be in compression, and this force will be greatest at the base of the tower. The horizontal and diagonal pieces of the tower may be in tension.

Activity 14: Foam homes

Think about building a real tower. Where would you need the tower to be the strongest? At the top or the bottom? Tall buildings require strong, flat foundations that will shoulder the weight of the building. By making the bottom of your tower out of thick dense foam you are recreating the foundations of a real building. This strong base should be the best structure to hold the rest of your tower made out of light fluffy foam.

Activity 15: Bridging the gap

In this experiment the weakest type of bridge should have been the simple piece of card across the gap. This is the equivalent of a beam bridge, such a log across a stream. This type of bridge relies on the strength or stiffness of the material laid across the gap. If the card, or log, starts to bend then it makes a very bad bridge. If you fold the card in half, or into a square beam, then the bridge should hold more weight, as the card will be stronger, but the bridge will still be generally weak.

Arches were made by Romans hundreds of years ago and have great natural strength. Arches use a curved structure which provides a high resistance to bending forces. When a weight is placed on top of an arch the force is transferred to the sides which begin to push outwards. Supports at the side of the bridge, called ‘buttresses’ or ‘abutments’, or in this case the books, push back on the sides to make the structure stronger and prevent the bridge from buckling.

If you try pleating your piece of card, i.e. folding it so that it looks like a flat fan; then the bridge should become very strong. A pleated card acts like a row of triangles and these triangles effectively increase the thickness of the card. This structure is extremely resistant to buckling and bending. You can make this pleated card even stronger by securing the ends of the V-shaped channels so that it does not flatten out when a weight is placed on it.

Activity 16: Build like a beaver

There are many ways to improve the strength of your dam. One common type of dam is called an arch dam. This is a structure which has a curved surface which faces the water. When the water presses on the dam the arch strengthens the structure.

Some dams rely on their sheer weight to hold the water back. These are called ‘gravity dams’. Other dams are propped by giant supports called buttresses, so called ‘buttress dams’. To strengthen your own dam you could employ all of these techniques, e.g., an arched structure; a heavy structure, which would be difficult to move; or by using supports to prevent your dam from moving.

Activity 17: Cantilever fever

For this experiment you should find that the further away from the edge of the table you hang your weights the easier your structure will break. This is due to a force called ‘torque’, a rotational force that increases with distance from the fulcrum (in this case the edge of the table). For example, if you were hanging from a tree branch you would be a lot safer hanging close to the trunk than right at the end. The further away from the trunk you are hanging, the greater the torque and the more likely you are to break the branch and fall.

One way to strengthen your cantilever might be to make the base of the structure thicker. This would mean that the centre of gravity, and most of the weight of your structure, would be closer to the fulcrum and there would be less torque acting on the cantilever. So, to continue with the tree example, if the branch you were hanging from had a thick and heavy base, you would be a lot safer than if the branch was the same thickness the whole way along.

Another way to increase the strength of your structure would be to use a vertical support at the base of your cantilever and tie a string, or wire, between the top of the support and the end of the structure. This would reduce the tension on the top of the structure and the compression on the bottom. If you tied a piece of rope between the end of your branch and the tree trunk then the branch would be a lot more secure.

Activity 18: Invent a tent

Tepees are just one example of the type of home that an American Indian may have built. In this type of society, the houses that were built were not only constructed because they coped well with the climate and suited their needs, but also because of social reasons. The sizes of houses were often determined by the social status of the person who was going to live in it, for example, a tribe leader would have a larger house than a tribe member. All the buildings, however, were constructed from local materials that were easy to find such as bark, wood, rocks, reeds, grass, earth, snow, and other natural materials at hand.

In extremely cold weather their outside, slanting walls might be piled with snow, the interior could be floored with soft leaves or branches, and a fire could be placed inside with the smoke escaping from the hole in the roof. In the summer, families often moved into airier houses, cooking outside beneath a porch-like structure.

Thank you for using Vertically Challenged!

We hope you enjoyed the activities within this pack. To help us to continue to provide new activity packs, we'd like to ask you to tell us a little about what you did for National Science & Engineering Week.

Please take a few minutes to fill in this form. If you used this activity pack for NSEW, send in this completed form and we will send you a National Science & Engineering Week Certificate.

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Which dates did you do National Science & Engineering Week activities on? __________
What did you do?

Please make any comments about this activity pack, National Science & Engineering Week and/or other possible topics for future packs (feel free to continue on a separate sheet of paper).

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