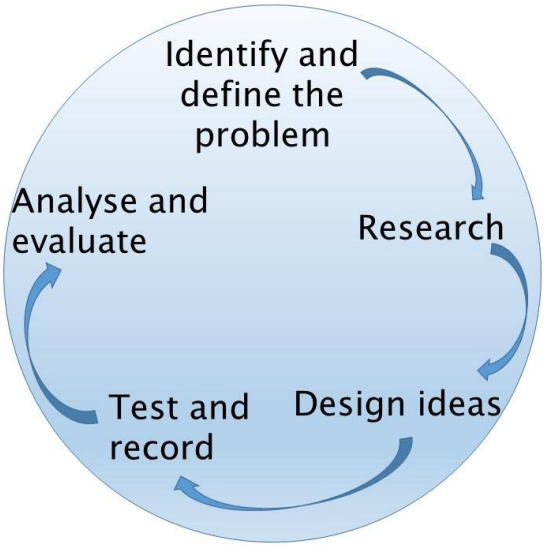
The Challenge

A school has decided to build a new Science, Technology, Engineering and Mathematics (STEM) facility and has asked students for design ideas. They hope the building will be environmentally friendly and cost effective.



Background Information

A passive building is one that requires minimal energy input but maintains a comfortable temperature year-round. There are a few important things which must be considered when designing a passive building. These include its orientation, shading, insulation, seals, windows, and the building materials used. Many councils will either send someone out to you or can send you equipment you can use to take measurements at different locations in your building to determine how passive and energy efficient it is. This will involve taking measurements at different times of the day and in different locations around the building, as well as completing a building inspection to look at the different materials used.

The more passive the building the more energy efficient it is, this means that less energy is needed for heating, cooling and lighting. A passive design is desirable as, not only does it greatly reduce electricity and gas bills, it is better for the environment.

Background Research

Using the Australian Government website: http://www.yourhome.gov.au/passive-design and any others you find useful, research passive design and answer the questions below.

1. Why does the orientation of a building make a big difference to how much light it gets?

_____

_____

Suggested site: http://www.yourhome.gov.au/passive-design/orientation

2. How might the orientation of a passive building in the northern hemisphere compare to that of a passive building in the southern hemisphere?

_____

_____

Suggested site: https://greenpassivesolar.com/passive-solar/building-characteristics/orientation-south-facing-windows/

3. What does thermal mass mean?

_____

_____

Suggested site: http://www.yourhome.gov.au/passive-design/thermal-mass

4. Give examples of building materials with high thermal mass.

_____

_____

Suggested site: https://www.smarterhomes.org.nz/smart-guides/design/thermal-mass-for-heating-and-cooling/

5. What are some ways of shading your house? Draw diagrams to show how they work.

Suggested site: http://www.yourhome.gov.au/passive-design/shading

6. Why are deciduous trees favourable in passive design for shading?

_____

_____

Suggested site: http://www.yourhome.gov.au/passive-design/shading

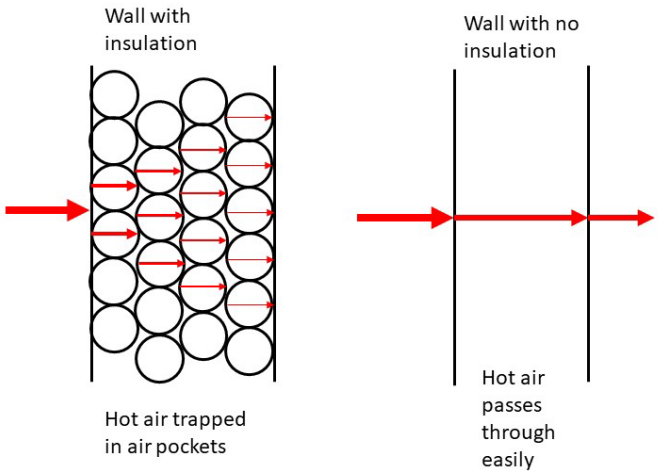
7. What are the advantages and disadvantages of having lots of windows on a building?

Advantages	Disadvantages

Suggested site: http://www.yourhome.gov.au/passive-design/orientation

Investigating Insulation

Most buildings have insulation in their roofs, and some will even have insulation in their walls. Insulation traps hot air which means less heat is lost to the outside in winter, and heat cannot enter in the summer. This helps to keep the building at a desirable temperature all year round, without having to use heating or air conditioning. There are many different types of insulation, natural and man-made, such as sheep's wool, polystyrene, expansion foam and wool fibre.



Objective

To investigate the efficiency of different types of insulation.

Equipment

- 4 x materials to be used as insulation
- 4 x glass beakers
- Cling film
- 4 x thermometers or temperature probes
- Ice-cold water

Method

1. Wrap each beaker in a different insulating material.
2. Pour the same volume of ice-cold water into each beaker.
3. Place a thermometer into each beaker and then use the cling film to seal the top of the beaker.
4. Record the initial temperature of the water in each beaker in the table provided.
5. Every minute give the water a swirl and record its temperature.
6. Repeat step 5 for 10 minutes.

Results and Analysis

Time (min)	Material 1 (°C)	Material 2 (°C)	Material 3 (°C)	Material 4 (°C)
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

1. Which material had the smallest change in temperature, and what was the change?

_____

_____

2. Which material was the most efficient insulator?

_____

3. Which material had the largest change in temperature and what was the change?

_____

_____

4. Which material was the least efficient at insulating?

_____

Evaluation

1. Was the thickness of the insulating material the same for each material type? Could this have impacted your results?

_____

_____

2. Why was it important to swirl the water before each measurement?

_____

_____

3. Do you think this was a fair test, explain your answer?

_____

_____

4. What improvements could be made to the test? (Explain why these improvements would make the investigation better).

_____

_____

_____

_____

5. What kind of jobs might require you to know about different types of insulation, and who might find this information important?

_____

_____

Investigating Thermal Mass

The thermal mass of a material (also known as its specific mass) will determine how long it takes to heat up and cool down. A material with a high thermal mass takes a long time to heat up, but once heated will retain the heat for a long time. It is good to build with materials which have a high thermal mass as it means in the winter the material will heat up during the day and will stay warm through the night and in the summer it will take a long time for the material to heat up.

Objective:

To determine which building material has the highest thermal mass.

Materials

- A range of building materials e.g. brick, tiles, concrete, slate, glass, wood
- Ice cubes
- Stopwatch
- 1 x 500ml beaker for each material
- Hot water source

Method

1. Pour 400ml of hot water into each beaker (make sure each is the same temperature).
2. Place each building material to be tested on top of a beaker (so it is heated from below).
3. Place an ice cube on top of each of the building materials.
4. Observe and record how long it takes for the ice cube to melt on each piece of material.

Results and Analysis

1. On which material did the ice take longest to melt on?

_____

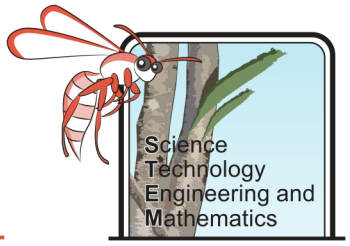
2. On which material did the ice melt the quickest?

_____

3. Which material had the highest thermal mass?

_____

4. Which material had the lowest thermal mass?



_____

5. Which material would be best to use to ensure passive design? Explain your answer.

_____

_____

Evaluation

1. Were all your pieces of ice the same size at the start?

_____

2. Were all your building materials in an area of equal light and heat, or were some closer to heat sources than others?

_____

3. Were all your materials similar thickness?

_____

4. Was your experiment fair? Explain your answer.

_____

_____

5. What changes could you make to your investigation to improve it?

_____

_____

6. What kind of jobs might require you to know about thermal mass and why would this information be useful?

_____

Investigating Colour

The colour of a building can impact how much warmth it absorbs. In Australia, because it is generally so hot, it is more desirable for a building to reflect solar radiation.

Objective

To investigate the impact of colour on how quickly a material heats up.

Materials

- Test tubes/tin cans painted different colours (black, white and silver)
- Test tube rack
- Thermometers or temperature probes
- Bungs/can lids with holes in them
- Heat lamp/Sun

Method

1. Place the different coloured test tubes in test tube racks or line the cans up.
2. Pour water into the test tubes/cans.
3. Place the thermometer/temperature probe through the bung with the hole in it so that the bulb is in the water.
4. Put the bung in the test tubes or lid on the cans/
5. Measure the temperature of the water.
6. Turn on the heat source and place it near the test tubes/cans to warm the water, or place test tubes/cans out in the full Sun.
7. Swirl the test tube/can before taking readings of the temperature every 30 seconds for five minutes and record the results in the table.

Results and Analysis

Complete the table below

Time (min)	Temperature of black test tube (°C)	Temperature of silver test tube (°C)	Temperature of white test tube (°C)
0			
0.5			
1			
1.5			
2			
2.5			
3			
3.5			
4			
4.5			
5			

	black test tube (°C)	silver test tube (°C)	white test tube (°C)
Total change in temperature (temperature at 5 minutes – temperature at 0 minutes			

1. Which test tube had the largest change in temperature?

_____

2. Which test tube showed the smallest change in temperature?

_____

3. What colour would you recommend painting your house to ensure a passive design? Explain your answer?

_____

_____

Evaluation

1. Did you use the same volume of water in each test tube?

_____

2. Why was it important to swirl the water before taking a temperature reading?

_____

3. Was your experiment a fair test? Explain your answer.

_____

_____

4. What improvements would you make to your investigation?

_____

_____

5. Other than in the building trade, who else could find this information useful for their job? Explain your answer.

_____

_____

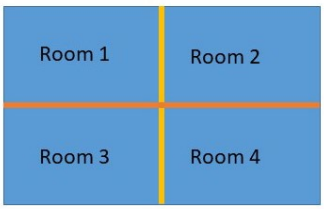
Open Plan Investigation

Objective

To determine if having an open plan design affects how passive a building is.

Equipment

- 2 x cardboard boxes the same size
- 5 x thermometers
- Heat lamp
- Extra cardboard
- Sticky tape
- Scissors



Method

1. Using the extra cardboard, construct four walls and put them into one of the boxes (so it is divided into quarters equally) this will represent a building with four small rooms.
2. Make small holes in the top of the cardboard boxes so that a thermometer can be inserted into each “room” and ensure boxes remain closed.
3. Ensure the heat lamps are equal distances from each box.
4. Turn the heat lamps on.
5. Measure the temperature in each room every minute for five minutes (by sliding the thermometer up and returning it quickly) and record in the results table.

Results and Analysis

Time (min)	Temperature Room 1 (°C)	Temperature Room 2 (°C)	Temperature Room 3 (°C)	Temperature Room 4 (°C)	Temperature open plan (°C)
0					
1					
2					
3					
4					
5					

1. Which room(s) had the smallest change in temperature, and what was the change?

_____

2. Which room(s) had the largest change in temperature and how much was the change?

_____

3. Overall would you recommend more open plan spaces or smaller rooms if you were designing a passive building? Explain your answer.

_____

_____

Evaluation

1. Were the boxes and cardboard thickness the same?

_____

2. Did you have the heat lamps at the same temperature?

_____

3. Was this a fair test? Explain your answer.

_____

_____

4. What improvements could you make to this investigation?

_____

_____

_____

_____

Investigating the Effectiveness of Eaves

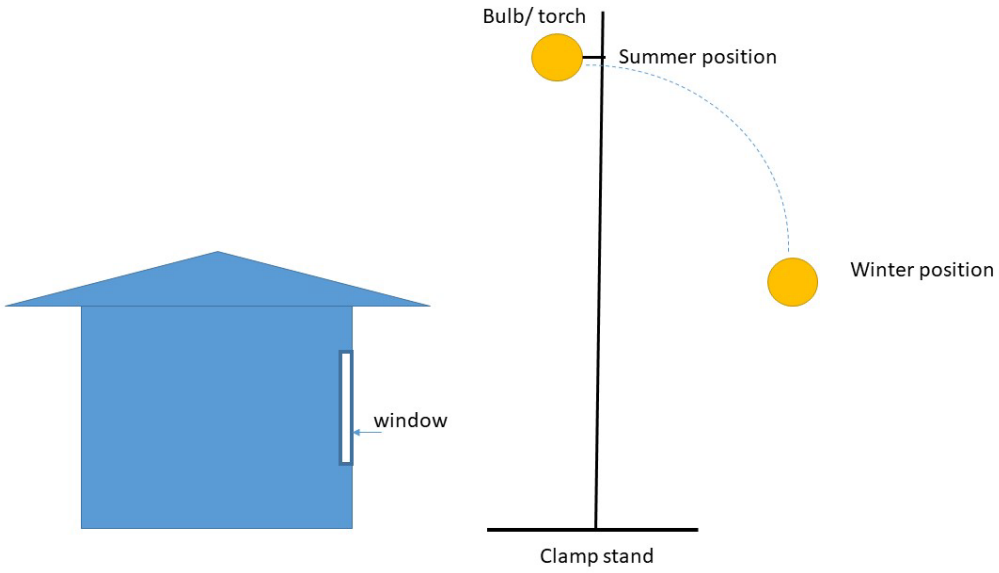
On most buildings the roofs continue past the edge of the walls of the house. The area of roof from the perimeter of the house to its edge is called an eave. Eaves create shaded areas below them and provide some protection from rain.

Objective

To investigate how effective eaves are as a means of creating shade for a building.

Equipment

- Model house with eaves and window and one without eaves (Can be made from cardboard, lego etc)
- Light meter
- Bright bulb/torch
- Meter rule
- Retort stand, clamp and boss head



Method

1. Place the light meter inside your model house
2. Place the torch/bulb in the summer position using the clamp stand.
3. Measure the light intensity and record it in the table.
4. Move the bulb to the winter position and measure the light intensity and record in the table.
5. Change the model so that it now has no eaves and repeat the investigation with the bulb/torch in the two different positions.

Results and Analysis

	Light intensity (lumens)
Summer (eaves)	
Winter (eaves)	
Summer (no eaves)	
Winter (no eaves)	

1. In which of the four scenarios did the house receive the most sunlight?

_____

2. In which of the four scenarios did the house receive the least sunlight?

_____

3. Were the eaves effective at blocking out sunlight?

_____

Evaluation

1. What were the strengths and weaknesses of this investigation?

Strengths	Weaknesses

2. How could you improve the investigation to make it truer to the real world?

_____

_____

3. Who might find this information useful for their work?

_____

_____

Critique of a Building

Objective

To critique the design of an existing building and suggest areas for improvement to make it a more passive design.

1. Choose a building in your school which you can complete an environmental assessment of. Complete the table below, adding in notes and any extra detail which will help you to write a report.

Building name/number	
Building location	
Orientation (which way the windows are facing)	
Shading (eaves, trees etc.)	
Sealing (tight doors and windows etc)	
Insulation	
Thermal mass of building material (high, medium, low)	
Windows (large, small, single, double or triple glazed)	
Colour (building, tiles)	
Other	

2. Take photos which will help support your report, for example of the eaves, the colour of the building, which way the windows are facing etc.

3. For the building you investigated complete the following (include photos if possible):

Building name/number:

Passive design features (positives):

Non-passive design features (negatives):

Suggestions to improve the building (make it more passive):

Design a Passive Building

Objective:

To design a passive building. You can complete this as a report with sketches and photos, or using Computer Assisted Design (CAD).

Considering the main factors which affect how passive a building can be:

1. What orientation will your building have (which way will it face)?

_____

2. Will you have eaves, and if so how big will they be?

_____

3. What other types of shading will you have?

_____

4. What building materials would you use?

_____

5. What type of windows would you install?

_____

6. How will you ensure tight seals around entrances?

_____

7. Will you use any insulation, and if so what kind?

_____

Step 1. Draw the four faces of the building, adding a scale, any colours and annotations, such as building material type.

Figure 1

Figure 2

Step 2. Draw a cross – section of the building (as if you had cut the building in half and opened it up), showing the walls and any insulation used.

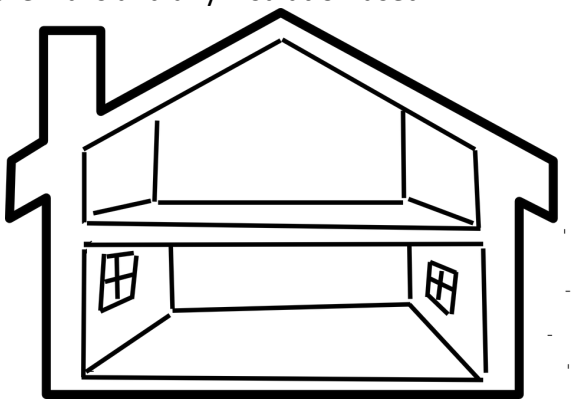


Figure 3

Step 3. Draw a plan of your building, showing how big the rooms will be, and if it is open plan or not. You will need to draw a plan for each level, if your building is more than 1 storey high.
Make sure you have labelled each design feature you have added, such as insulation/shading etc.