ROYAL ACADEMY OF ENGINEERING

TEACHER'S VERSION

DISASTER RESPONSE

How do engineers save lives in the aftermath of a natural disaster?

This resource aims to give students the opportunity to investigate the science, technology, engineering and mathematics (STEM) aspects of disaster response.

DISASTER RESPONSE

How do engineers save lives in the aftermath of a natural disaster?

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Steve Fitzmaurice, Kenneth Gibb, Nicola Greene, Tom Newby, Vanessa Pilley, Bob Reed, Elizabeth Sharpe.

Contents

Foreword

It isn't until technology fails that we really begin to notice it.

A well-engineered technology should never make us think; it should give us the capabilities to go about our daily lives, to enjoy life and to develop ourselves. We have become so accustomed to engineering in the UK that most of us can't operate without it. How would we get clean water without the taps we have in every building? How would we protect ourselves from the elements without the roofs over our heads? How are we supposed to learn without a table and chair? How are we supposed to enjoy privacy without a door? We can almost take these mundane technologies for granted because we have never known our world without them.

So to really learn about the difference that engineering makes to people's lives, it is helpful to change the context. With this excellent resource, you can explore engineering in the context of a disaster.

Natural disasters affected 2.9 billion people and killed 1.2 million people between 2000 and 2012. There were 5,618 officially recorded natural disasters over those 12 years – from major world events such as the Indian Ocean Tsunami of 2004 to more localised events such as the annual cyclone in Bangladesh or a drought in Texas. Disasters are getting more frequent and more intense as human population grows, resources such as water become more strained, urban migration increases and the changing climate brings more shocks and stresses.

The good news is that we are getting much better at coping with and responding to disasters; trends show that death tolls are falling. A key reason for this is that we are building infrastructure that is less vulnerable to hazards – so we are better prepared. In engineering, no news is good news – engineering only really gets attention when things go wrong! Increasingly it is only the major, sudden disasters that we hear about. But we must bear in mind that a disaster takes more livelihoods than lives and, since technology enables most livelihoods, there remains a lot more work to do.

Engineering is the creative application of science to solve problems for people. Engineers have to be good at *things*, and they must also be good at *people* too. An engineer has a fundamental responsibility to get their maths and science right: if they don't, a building could collapse, a train might derail or people might be left without heat or electricity. This resource pack is a fantastic opportunity for you to emphasise the importance of being good at people, maths and science – and of the role of engineering in our world. We hope that you enjoy using it.

Andrew Lamb

Chief Executive
Engineers Without Borders UK

Engineers Without Borders UK is an international development organisation that removes barriers to development through engineering. Their programmes provide opportunities for young people to learn about technology's role in tackling poverty. Supported by the EWB-UK community, their members can work on projects around the globe.

Introduction

The aim of this resource is to give students an insight into the roles of engineers following a natural disaster.

Engineers find solutions to problems. Sometimes it is easy to see an engineer's role, particularly when they are involved in the reconstruction of roads and buildings, or of power generation and supply. Sometimes, the engineer's contribution is in designing equipment that can be brought in to the disaster area, ready for use. Although engineers respond to the situation 'on the ground', they also contribute by trialling solutions in preparation for future needs. Alongside the activities, students will find quotes from practising engineers about the work they have been involved in.

This resource contains a collection of student activities and related resources to support classroom teaching at KS3. The context of disaster response provides human interest and provides opportunities for students to engage with relevant challenges and consider real-life solutions that demonstrate key ideas that they have met. Throughout the activities, students are asked to apply knowledge, skills and understanding. They are also asked to consider how they might be 'thinking like an engineer'.

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Information for STEM activity leaders

How to use this STEM resource

This STEM resource has been written for the leaders of STEM activities to use with key stage 3 students (age 11–14). However, there is no reason why younger students should not be given the opportunity to investigate the STEM aspects of disaster response. The activities could also be adapted and extended to provide stretch and challenge for older students.

The desired **learning outcome** is for students to create a presentation that provides a reasoned answer to the 'big question', *How do engineers save lives in the aftermath of a natural disaster?* Students should arrive at their answer having investigated solutions to challenges arising from the aftermath of natural disasters.

The **teacher's version** of the resource provides prompts, answers and notes to help support teachers, STEM ambassadors and STEM club leaders in their delivery of the resource. There is also a booklet of **student activity support sheets**. The **student version** of the resource includes all the **activity sheets**, but none of the prompts, notes and answers or support sheets. The intention is that teachers select only those support sheets which will enable each student to carry out a particular challenge effectively without 'spoon-feeding' them or denying them the opportunity to demonstrate higher order investigative and design skills.

Overview of the student activities

All of the activities are meant to be carried out in groups of four students. Working effectively as a team is an important engineering skill.

Introductory student activities

The introductory activities are short 'orientation' activities. Before students can progress to the problem-solving activities, they need to be aware of the range of types of natural disaster, and the kinds of problems associated with them. It is also helpful for them to have some sense of scale in terms of time and speed of disasters.

Problem-solving activities

The student problem-solving activities are organised into two groups: immediate problems and longer-term problems. Parts of each activity are signposted by the headings **Information**, **The situation** and **The challenge**. **Information** provides general information about the real world problem caused by a natural disaster and how engineers are involved in providing solutions; **The situation** and **The challenge** provide a more closely defined context and a brief for the problem solving activity.

These challenges involve either a mathematical focus or a science, design and technology focus, and are intended to show the importance of STEM subject knowledge, understanding and skills in solving problems. In each of the problem-solving challenges, students are also asked to 'think like an engineer' and to identify how they have done this.

Reflection, discussion and presentation are important elements of each of the challenge activities, and provide the basis for the final presentation activity; where time is limited it would be better to reduce the number of activities rather than the time for discussion, reflection and presentation.

Presentation activity

This is the plenary activity, in which students use the information and insights they have gained through the introductory and problem-solving activities to present an answer to the 'big question', '*How do engineers save lives in the aftermath of a natural disaster?*'

Working safely

STEM leaders should carry out their own risk assessment before undertaking any practical activity.

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1. Introductory activities

NOTES FOR STEM LEADER

Start with a brief presentation about natural disasters. A quick way to provide this is to create links from your presentation to relevant webpages, such as the BBC news website and others listed in 'Useful sources of information' at the back of this booklet.

Try to include examples of several different types of natural disaster and also of a range of locations: ask students to identify some of the locations on a world map.

Some recent examples:

- **Hurricanes/ superstorms:** Sandy, northeast USA, 2012; Katrina , southeast USA, 2010;
- **Earthquakes:** Christchurch, New Zealand, 2011; Haiti 2010
- **Earthquakes/Tsunamis:** northeast Japan, 2011
- **Wildfires:** southeast Australia, 2013.

Check that the type of disaster you will ask each group to consider in **Activity 1B** is included in your initial presentation.

Student Activity 1A

How much warning?

Information

Natural disasters include hurricanes, tornadoes, floods , earthquakes, tsunamis, volcanic eruptions, wildfires and drought.

Some natural disasters build up over months, others happen very fast.

Challenge

What warning is there of different disasters? How quickly do some disasters move?

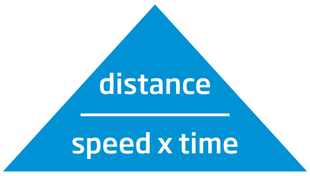
There are two tasks for you to carry out: a card sort and a set of warm-up calculations.

Card sort

1. Use the cards from **Student activity 1A support: Disaster card sort**. There are eight 'disaster cards' and three 'speed comparison' cards.
2. Place the disasters in order from top to bottom, with the ones where you might have least warning at the top and the ones with the most warning at the bottom.
3. Are there some disasters there would be no point in trying to run away from? Why not? Put the cards for these disasters to one side.
4. For the remaining disaster cards, put them in order of how quickly they move, with the fastest at the top and the slowest at the bottom.
5. Where should each of the 'speed comparison' cards go in this list?

Warm-up calculations

Use the formula: distance = speed x time



1. A wildfire is moving at 10 kph (3 m/s). How far will it have travelled in 10 minutes?
2. High winds are driving a wildfire directly towards a small town 5 km away. If the fire front is moving at 100 kph (28 m/s) how soon will it reach the town?
3. A tsunami warning has just sounded: the tsunami is 6 km off the coast and moving at 20 m/s. If it slows to 10 m/s as it moves onto the land, how long after that will it take to reach the base of a building 1 km from the shore? If you were on the edge of the beach when the alarm sounded, would you be able to reach the building and climb to the fifth floor before the tsunami arrived?

NOTES FOR STEM LEADER

Suggested time: 10 minutes

Support sheets available for this activity:

- Student activity 1A support: Disaster card sort

Warning times

The idea of moving to safety depends on there being somewhere safe that you can reach before the disaster arrives. This depends on how much warning you get, how close the nearest safe point is, how quickly you can move toward safety and how quickly the disaster is approaching.

There is usually at least several hours' warning of when a hurricane is likely to arrive, giving time to prepare and evacuate.

Floods, wildfires and tornadoes are often seasonal, so there can be some preparation, but the warning times for an event can vary, and the path of a tornado or a wildfire can change.

"I've worked for many years with Engineers Without Borders UK, and having developed my knowledge and skills with them I've now had the opportunity to work in disaster relief. I'm now a member of RedR UK and on the emergency roster for Save the Children."

Tom Newby, structural engineer

Tom Newby

Areas that are in earthquake zones may have some warning that a major event is likely, but beyond that there is no real warning. The warning available for a tsunami depends on the epicentre of the earthquake that caused the tsunami. Around the Pacific Ocean, there might be several hours' warning if the epicentre is on the other side of the ocean.

However, if the epicentre is relatively close to land, there may be only a few minutes between the earthquake and the arrival of the tsunami. Although a tsunami moves more slowly on land than over the ocean, it is still too fast to outrun on the flat: if there isn't time to drive out of the area, then the safest options are to get to higher ground or to the upper floors of a tall building.

Card sort

The card sort should provoke some discussion. For example:

- Speed of travel comparisons don't make any sense for droughts or earthquakes.
- The wind speed in a hurricane is not the same as the speed the storm travels at.
- The speed of a tsunami decreases as the water gets shallower. (Tsunamis travelling in deep ocean waters are very fast-moving but only a metre or so high.)
- Wildfires driven by wind are much faster.
- There are different types of volcanic eruption and the speed of the lava flow depends on the chemical composition of the lava; a pyroclastic flow moves much faster than an ordinary car can.

<table>
<tr><th>Natural hazard</th><th>Typical speed (kph)</th><th>Typical speed (m/s)</th><th>Comparison speeds (approximate value ranges)</th></tr>
<tr><td>Volcano: pyroclastic flow</td><td>>160</td><td>>44</td><td></td></tr>
<tr><td>Volcano: lahars (mix of rocks and water)</td><td>100</td><td>28</td><td rowspan="5">Car
50–100 kph,
15–30 m/s</td></tr>
<tr><td>Wildfire driven by high winds</td><td>100</td><td>28</td></tr>
<tr><td>Tsunami approaching the coast</td><td>80</td><td>22</td></tr>
<tr><td>Hurricane</td><td>70</td><td>19</td></tr>
<tr><td>Tornado</td><td>55</td><td>15</td></tr>
<tr><td>Tsunami moving inland</td><td>36</td><td>10</td><td></td></tr>
<tr><td>Wildfire</td><td>10</td><td>3</td><td rowspan="2">Running
15–30 kph, 4–8 m/s</td></tr>
<tr><td>Volcano: fast-moving lava</td><td>10</td><td>3</td></tr>
<tr><td>Volcano: slow-moving lava</td><td>5</td><td>1.5</td><td>Walking</td></tr>
</table>

Warm-up calculations

The calculations are meant to be a rapid warm-up activity using calculators, but could lead on to further discussion where there is time.

1. 1,800 m.
2. 178 s, or just under 3 m.
3. Probably. Time to land = 300 s. Time from there to building = 100 s. Total time = 400 s. Time to run to the building depends on your running speed and how long you took to react! Even with 0 s reaction time, at 5 m/s it would be 200 s, but then you still have to get inside and run up the stairs in the remaining time.

Student Activity 1B

Aftermath

Information

Natural disasters include:

- hurricanes
- floods
- tsunamis
- wildfires
- earthquakes
- volcanic eruptions
- drought
- tornadoes

There are many different kinds of engineer, but what they all have in common is that they use their STEM subject knowledge and skills to solve problems.

Challenge

What kinds of problems face survivors after a natural disaster? What might engineers do to help?

1. Work in a group of four.
2. Each group will consider a different kind of natural disaster: your teacher will tell you which disaster to work on.
3. You need a large sheet of paper. Write down the type of natural disaster at the top of the sheet.
4. Divide the sheet into two columns. In the left hand column, make a list of the problems facing survivors after this type of natural disaster. For each problem, use the right hand column to suggest what engineers might do to help solve the problem.
5. Compare your suggestions with those of at least one other group:
   - Which of the problems are specific to a particular context (not just the type of disaster, but where it happens, or the time of year, for example)?
   - Which of the problems are general ones, and are associated with any disaster?
   - Are there some problems that are more urgent than others? Why?
   - Are there some problems that are not so urgent initially, but become important within a few days of the disaster?

"I worked in Sri Lanka after the tsunami, in Bihar (India) after flooding, and in Haiti after the earthquake. I used to work on technical aspects. Now it's strategic planning, mentoring and technical support."

Bob Reed, water supply and sanitation engineer

Bob Reed

NOTES FOR STEM LEADER

Suggested time: 20 minutes

Support sheets available for this activity:

- n/a

Students might identify some or all of the following points:

- Disasters not only kill and injure people, and demolish homes and possessions, they also disrupt water and power supplies and can make normal travel on roads difficult or impossible.
- These are problems common to several kinds of natural disaster.
- While most natural disasters happen quite suddenly, the effects of a drought take longer to establish, and do not in themselves make transport difficult or impossible.
- Paradoxically, there can be a lack of drinking water after flooding because water supplies are contaminated.
- The most urgent immediate problems are rescuing survivors and providing somewhere safe to shelter, drinking water and food, and sanitation. There will need to be medical supplies and personnel to treat the sick and injured.
- Rescue might involve the supply and use of special equipment which has to be brought in or constructed from what is available.
- Where no shelter is available, it has to be brought in by relief agencies, along with emergency supplies of food and water. Some of this can take days to set up.
- Some of the support for survivors depends on work that is done long before the actual disaster, so that appropriate resources can be ready to send .
- People may be homeless and in need of shelter for weeks or even months after a disaster. Longer-term needs will include better shelter with more privacy and space than is acceptable for one night, reliable supplies of safe, drinkable water and food, and adequate sanitation. If these aren't provided, then people are likely to become ill.

Tom Newby

Truck delivering materials after the earthquake in Haiti in 2010.

Supplies ready to be sent to victims of the flood crisis in Thailand, November 2011.

Yuttasak Jannarong / Shutterstock.com

FEMA/Ed Edahl

Houston Astrodome, ready for the arrival of evacuees from Hurricane Katrina in 2005.

2. Problem solving activities: solving immediate problems

Student Activity 2A

Emergency shelter

Information

When people are unable to stay in their own homes after a natural disaster, the first place they seek shelter is often a local sports hall or community centre if there is one. It has been suggested that severe weather and flooding could become more frequent in future, so it will be important to plan for possible events like this, and know where people could be evacuated to in an emergency.

The situation

There has been severe flooding locally, and any large local halls that are not at risk of being flooded will be used for emergency shelter. The school sports hall needs to be used to provide temporary shelter for people whose homes have been flooded (mostly couples and families with young children). They have left their homes in a hurry, bringing whatever they can carry with them.

The challenge

How many people could you accommodate overnight in the sports hall, and how might you do this?

1. Survey the hall: create a rough initial plan (not to scale), showing the basic shape and marking where the doors are. Write your measurements down on this.
2. Decide how much space you will need for each family, couple or individual.
3. Make a first estimate of the **maximum** number of people you could accommodate.
4. Now create a scale plan of the hall, showing the space you are allowing for each family, couple or individual.
5. What assumptions have you made about what additional items you might need to provide and the amount of space needed for each individual, couple or family?
6. Compare your plan with the plans produced by other groups:
   - What different assumptions did other groups make?
   - Which plan fits in the most people?
   - Which would be the most practical?

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

"I have worked in India and Tanzania, running workshops for developing communities on the principles of disaster management and the causes of natural disasters."

Vanessa Pilley, environmental scientist

NOTES FOR STEM LEADER

Suggested time: 60–90 minutes

Support sheets available for this activity

- Student activity 2A support: Scale plans
- Student activity 2A support: Tessellation

Leave time for discussion and encourage students in each group to share their ideas with other groups at several points during this activity:

Sharing ideas after every group has made their preliminary sketch plan and first estimate will allow students to review their own assumptions and correct any miscalculations.

Sharing ideas once every group has produced a scale plan with their chosen solution gives an opportunity for students to discuss the range of solutions, and the things they thought were most important.

In this activity it is important to get students to draw out a plan right from the start to make any assumptions explicit. Initially, a simple sketch may be most effective for recording overall dimensions, but once students consider how many people may be accommodated it is worth students making multiple copies of some paper shapes representing basic units (e.g. a 'family space') to scale. Moving these shapes around on the plan in different arrangements can help students explore different solutions.

Student Activity 2B

What makes a good shelter?

(Left) A 'hexayurt' built from plywood sheet; (right) A family's tent next to a collapsed building after the earthquake in Haiti, 2010

Information

When most buildings in a region have been destroyed or are unsafe, people who can will leave to find shelter with relatives in another region. People who cannot leave will need temporary shelters to live in until they can rebuild their homes. Tents are often used for emergency shelter after a disaster, but they are not the only type of emergency shelter. The kinds of temporary shelters used depends on what can be made available quickly and what is best for local conditions.

In many parts of the world, it can be hot and sunny in the daytime but cold at night. Ideally, shelters should not only keep the inside warm when it is cold outside, but also remain at a comfortable temperature during the day. A good shelter also needs to keep people dry and protect them from UV radiation.

Bringing large amounts of resources into a region takes time and costs money.

- Building shelters from lightweight materials can reduce transport costs. It can also make it easier to construct the shelter onsite if individual pieces are light enough for one or two people to lift.
- Where 'scavenged' material can be recovered from the scene of the natural disaster, this can also reduce the need to rely on supplies which have to be brought in.

Tom Newby

"I worked in Haiti, following the devastating earthquake there in 2010. I ran a transitional shelter programme, planning and starting the construction of temporary schools and houses in the area around the epicentre."

Tom Newby, structural engineer

"I worked in Haiti following the 2010 earthquake where I was helping a team of Haitians to rebuild houses in rural communities."

Steve Fitzmaurice, civil engineer

The situation

The organisation you work for wants to produce a new design for a shelter that could be built by two people using mostly scavenged materials, or using lightweight materials which are shipped in. The shelter should be as light as possible, but must keep people comfortably warm even in cold weather.

The challenge

Design, construct and evaluate two model shelter solutions.

1. Find out what materials will be available.
2. Your group must create and evaluate two model shelters. Decide which basic model structure(s) you are going to construct, and what modifications, if any, you are going to make to the materials used in the construction. You will need to keep a record of your investigation as you work.
3. **Each shelter must have the same base area of 12 cm x 10.5 cm.**
4. Check that your plan will allow you to carry out the test methods that you have been shown before you build the shelter.
5. Build and test your two models.
6. Compare your results with those from other groups.
7. Present a short report or presentation that gives brief details of:
   - the materials and designs you used, with reasons why you chose them
   - how you carried out the tests you used in your evaluations and what the results were
   - what you discovered and what conclusions you reached.

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

NOTES FOR STEM LEADER

Suggested time: 120 minutes

Support sheets available for this activity

- Student activity 2B support: Model shelters

Setting the scene

If possible, show students some examples of real shelter designs (not just tents), and get them to consider why each design might have been used. Availability of materials is a major factor, whether these are scavenged or shipped in. For example:

- A common basic solution involves draping plastic sheeting over a simple framework; adding other materials such as blankets can improve the insulation and offer more privacy.
- 'Hexayurts' typically use plywood sheet; they have been used in Haiti following the major earthquake in 2010.
- Paper-tube 'logs' can be used to construct simple cabins. These have been used following earthquakes in India and Iran.
- There are proposed solutions involving folded plastic 'concertina' shapes that can be shipped folded and then unfolded onsite.

(See *Useful sources of information*)

Shelter designs

The templates provided are for two basic shelter shapes. Students will need to consider how they might adapt these basic designs to improve the performance.

Students might consider:

- doubling the thickness of the material used for walls and roof
- lining the inside of the shelter with reflective material (eg aluminium foil)
- lining the inside of the shelter with one or more layers to trap air (eg a layer of felt, or cotton wool held inside a cotton covering layer)
- using a framework with a covering that has air trapped inside it (eg packaging 'bubble wrap').

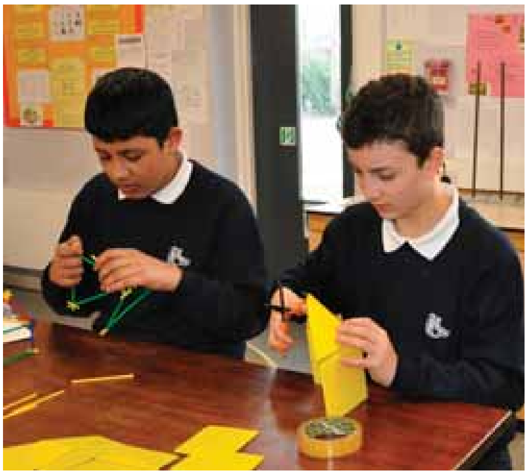
Testing the model shelters

The challenge focuses on mass of material used and thermal properties.

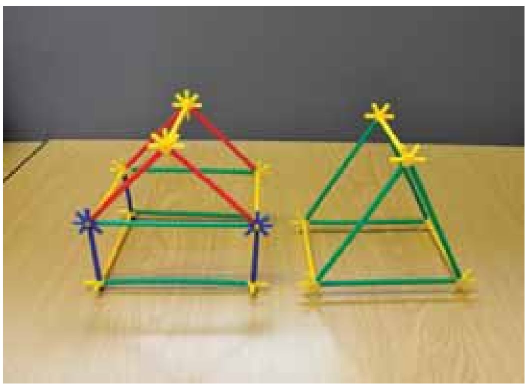
If students build models with the suggested base size the model should fit on a top pan balance to find the mass of material used.

A simple way to compare thermal performance is to put a beaker of hand-hot water inside the shelter and take the temperature of the water every minute as it cools down. **(SAFETY: take care with hot water; mop up any spillages.)** It would be helpful to compare this with an additional, identical beaker of water that is not in a shelter.

Note: It may be helpful to have a 'preliminary run' followed by discussion to debug and standardise the test methods: for example, students may need to be reminded that for a fair test all the beakers of water should contain the same amount of water, and that they should all be at the same starting temperature; they may also need to be made aware that removing the beaker to take the temperature is a different method from taking the temperature without removing the beaker.



Making model shelters from constructostraws and from corriflute



Model shelter frames made using constructostraws

If time allows, students could also evaluate other aspects of their chosen designs:

- Students could evaluate the suitability of the shelters for hot sunny conditions by recording the change in temperature inside the shelter as a bench lamp is placed a few centimetres above the roof and switched on. **(SAFETY: hot lamp surfaces. Check also that there is no risk of the model material overheating or catching fire. Do not leave unattended.)**
- Students could compare the effectiveness of the shelters in terms of blocking UV by placing UV-sensitive beads inside the shelters. They could then observe how quickly the beads changed colour when the shelters were put in bright sunlight, and how long it took the beads to lose their colour when removed from the sunny conditions.
- Comparisons of *how waterproof the materials are* would be much more straightforward than comparisons of *how waterproof the models are*, because of issues about water leaking through joints or seams. If students do test pieces of fabric by simply spraying water over a stretched sample of fabric, they may be surprised at how little water penetrates through even an untreated cotton sample (as long as nothing else is touching the fabric).

Background Science

- Warm objects transfer energy to cooler surroundings. The temperature of the object drops as energy is transferred. Warm surroundings transfer energy to cooler objects. The temperature of the object rises as energy is transferred.
- The bigger the temperature difference (the steeper the temperature gradient), the faster the rate of energy transfer, and the faster the drop in temperature. Once an object is at the same temperature as its surroundings, it will stay at that temperature.
- Any feature that slows down the transfer of energy will reduce the rate of cooling, and any feature that increases the rate of energy transfer will increase the rate of cooling:
    - Reflective layers reduce energy transfer by radiation.
    - Materials that are described as good insulators or poor thermal conductors reduce the rate of energy transfer by conduction.
    - Air is a relatively poor thermal conductor, so using materials that have air trapped in them reduces the rate of energy transfer by conduction.
    - Thicker layers of wall or roof material reduce the rate of transfer by conduction, because the temperature gradient between warm inside and cold outside is not so steep, and because more energy is being used to raise the temperature of the material.
    - Where air can get in or out through gaps in the fabric, this can allow energy transfer by convection: warm air escapes upward through holes near the top, and cool air is drawn in through holes near the base. **Note**: in this challenge, designs which include a base will need a closable 'door' to insert and remove the beaker of warm water; they may also need to include a hole for the thermometer or temperature sensor to poke through.

Student Activity 2C

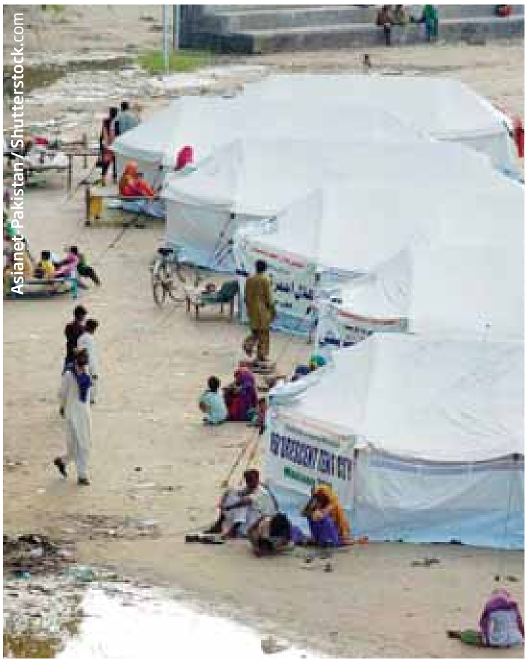
Tents, water and toilets!

Information

When most buildings in a region have been destroyed or are unsafe, people who cannot leave to find shelter with relatives in another region will need temporary outdoor shelters to live in until they can rebuild their homes. Often, relief agencies will organise the construction of temporary camps to provide shelter, water and toilets, and cooking facilities; they might also organise the delivery of food supplies.

Planning a temporary camp can involve surveying an open space and planning the best arrangement of tents or other shelters, along with things like water supply points and toilets. It can also involve arranging the initial delivery of tents (or other shelters) and arranging for the regular delivery of water and other supplies.

You would need to decide what size of tents would be most useful and how many you would need. Tents come in various sizes: some are meant for a family of four people, but there are also larger tents which can fit twelve or even twenty people in them. In most communities, you would expect a mixture of families, couples and individuals.



A relief camp in Pakistan, following flooding in September 2011.

The situation

A major earthquake has demolished many buildings and there are few buildings where people can shelter indoors. Whole, extended families are affected, so there is little option to stay with relatives in another region. Temporary camps need to be built in any open spaces. As well as shelters, people will need drinking water, toilets and somewhere to wash.

The challenge

How many people could you provide temporary shelter for on the school sports field or other local open space?

About this activity

In this activity you are modelling a real life situation, and to do this you may need to make some simplifying assumptions.

You may find it helpful to use a spreadsheet to allow you to try out different starting values and build a model.

There are several tasks involved in this activity. You will need to use the findings from the different tasks to reach your final estimate, so it is important to make a record of your investigations as you work. Your record should include:

- a description of what you were trying to find out
- any equations or starting information you used
- any assumptions you made
- examples of worked equations using different data if relevant
- what you found out: include your opinion on how realistic or otherwise your findings are. (What would you do to improve the usefulness of your model?)

The tasks you need to carry out

A first estimate of capacity

1. You will need a printed plan of the open space. Mark out the area of usable open space on your printed plan.
2. Measure the dimensions of the open space, and work out its area.
3. Estimate how much room you need to allow in order to pitch a tent for four people to sleep in.
4. Estimate how many of these tents you could fit on the sports field if you only put tents on it, and so how many people there might be. (How much space should you allow between tents? Why?)
5. How does the size of tent you use affect the maximum number of people you can provide shelter for? Investigate the effect of using tents for 8, 12 or 16 people instead.
6. What would be the most efficient solution, based solely on this model?
7. What might be the limitations of this model? What other factors would be important in deciding what size of tents to use?
8. Choose a 'best size' of tent and draw a block of 20 tents by 2 tents to scale on a piece of paper. Place this on your printed plan.
9. Make three more blocks of the same size. How many of these blocks could you fit on the site?
10. Make a revised estimate of how many people you can shelter.

How much water will they need?

1. Use your revised estimate for the number of people.
2. Use the additional information from *Activity 2C support: Facts and figures* to estimate how much water you will need for drinking and cooking.
3. How many bowsers (towable water containers) or water tankers would you need to deliver this amount of water every day?
4. How many 11,000-litre storage tanks would you need to store one day's worth of water?
5. Estimate the amount of field you need to leave without tents to allow for the water to be delivered and stored. How many tent spaces will this take up?
6. How does this affect your plan for the number of people you could provide shelter for? Write down your revised estimate.

How many toilets will they need?

1. Use your revised estimate for the number of people.
2. Use the additional information from *Activity 2C support: Facts and figures* to estimate how many toilets you will need for everyone on the site.
3. Estimate how much space the toilets will need. How many tent spaces is this equivalent to?
4. How does this affect your plan for the number of people you could provide shelter for?

'I worked in Brazil in an area that flooded every year. We built strong water tanks and toilets which were lifted off the ground to ensure that clean water and health were not affected during flooded times.'

Nicola Greene, civil engineer

Conclusion and evaluation

1. What is your final estimate of the number of people you could fit on the site?
2. What value does this give you for the area per person?
3. If you had to make rough estimates of capacity for other sites, how might you do this?
4. Compare your values with those of other groups: what reasons were there for any differences?

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

NOTES FOR STEM LEADER

Suggested time: 90 minutes

Support sheets available for this activity/challenge

- Student activity 2C support: Estimating capacity
- Student activity 2C support: Facts and figures

Additional resource, downloadable from the Royal Academy of Engineering website at www.raeng.org.uk/disaster-response

- Excel spreadsheet: Site capacity estimations

Setting the scene

It is important to relate the challenge to real examples drawn from a range of natural disasters in the UK and abroad. Although many or most students may have seen images of refugee camps, it is less likely that they will be familiar with the use of bowsers, water tankers and temporary water storage tanks. It is important to provide examples showing what these things look like and to establish a sense of how big they are.

(see *Useful sources of information*)

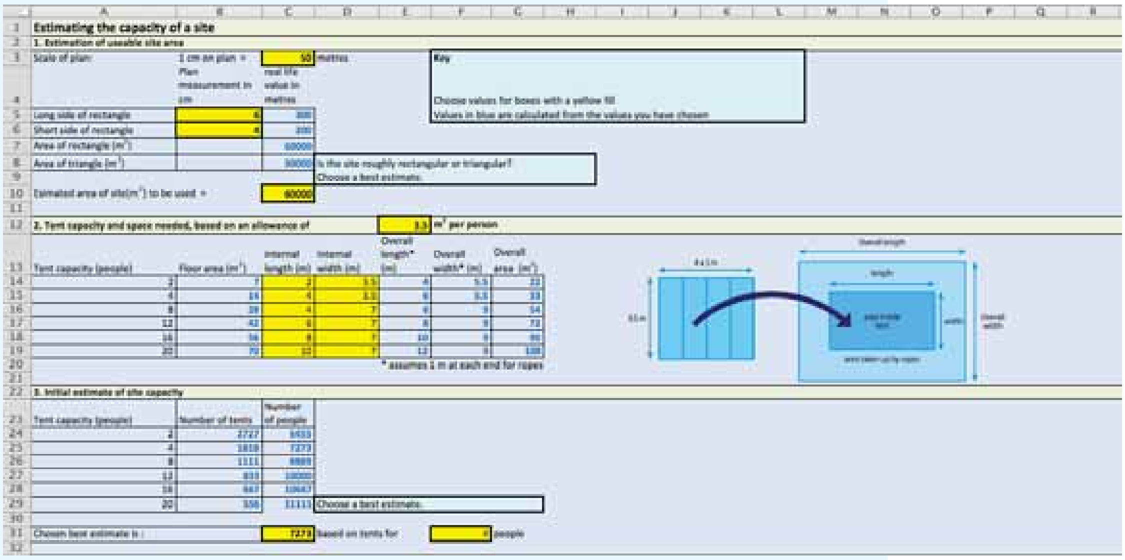
Models, pattern-spotting and predictions

This activity offers an opportunity for students to explore the consequences of setting different values.

There is a structured support sheet to take students through the different stages of the estimation process.

Students could create their own spreadsheet or use '*Site capacity estimations*', which is downloadable from the Royal Academy of Engineering website. This is set up with sample values entered, and students can use it to investigate the effect of changing the values for useable site dimensions, tent capacity and dimensions, proportion of site used for roads, daily water allowance, number of toilets and water storage arrangements.

The spreadsheet created for this activity follows the same pattern as the support sheet, but by removing the need to carry out calculations manually allows a greater emphasis on trialling different solutions. The first estimate of tent area and site capacity (see below) is also a good opportunity for more able students to explore patterns to make predictions: can they work out a formula to calculate the overall area of a tent, or how many tents will fit on the site for a given tent capacity?



A screenshot of the 'Site capacity estimations' spreadsheet

1. Estimating the size of the site

Choose a site that students will be familiar with.

You will need to provide a plan or an aerial image of the site you want to use: make sure that you include the correct scale on the image. Show this as a line marked with the equivalent distance rather than stating, for example '1 cm represents 50 m', as any change in scale when you produce the photocopy of your original will distort all the calculations.

The support sheet provides a structured framework for estimating the capacity of the site, with each group of students marking up their own printed copy of the plan. An alternative approach would be for students to overlay the image with a prepared transparent grid with squares that match the scale of the image, shade in the area and count the shaded squares.

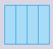
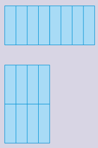
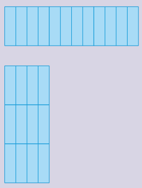
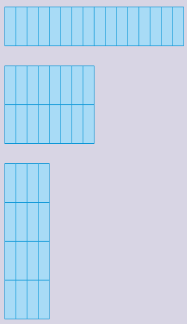
To estimate the area, students should first mark the image to show what they consider to be usable ground.

The quickest way to estimate the area is to find the largest rectangle or triangle that fits the space, and calculate the area of that. (As a refinement, students could do the same for the biggest piece of ground left over, then add these figures together to get a value for the total area.)

Ask each group to give their estimate and show the area they have been estimating. This is to give students the chance to check that they are using sensible values for the total area before they carry on with the rest of the challenge.

2. A first estimate of how many tents and how many people will fit on the site

The support sheet encourages students to sketch out floor plans for each tent to help them identify what assumptions they have made and what they are actually calculating.

Number in tent	Diagram of floor area	Floor area of tent (m²)	Overall area of tent (m²)	Maximum number of tents*	Maximum number of people*
4		4 x 3.5 = 14	(4 + 2) x (3.5 + 2) = 33	Site area /33 (1,515)	Tents x 4 (6,060)
8		8 x 3.5 = 28	(8 + 2) x (3.5 + 2) = 55	Site area /55 (909)	Tents x 8 (7,272)
			(4 + 2) x (7 + 2) = 54	Site area /54 (926)	Tents x 8 (7,408)
12		12 x 3.5 = 42	(12 + 2) x (3.5 + 2) =77	Site area /77 (649)	Tents x 12 (7,788)
			(4 + 2) x (10.5 + 2) = 75	Site area / 75 (667)	Tents x 12 (8,004)
16		16 x 3.5 = 56	(16 + 2) x (3.5 + 2) = 99	Site area / 99 (505)	Tents x 16 (8,080)
			(8 + 2) x (7 + 2) = 90	Site area / 99 (555)	Tents x 16 (8,880)
			(4 + 2) x (14 + 2) = 96	Site area / 96 (520)	Tents x 16 (8,320)

**Figures in brackets are for an example field size of 50,000 m².*

It is worth getting all the groups to compare their results again at this point and discuss any differences and the possible reasons for them. As can be seen in the table, the value each group provides for the overall tent area depends on which layout they use, but the overall ‘packing efficiency’ improves as the tents get larger. By now, students should be pointing out that these figures will be much too high, because no allowance has been made for roads or between rows of tents, or for toilets, water supplies and so on. Some students may also comment that they would not like to share a tent with other families, so they would not regard anything bigger than ‘family size’ as sensible, no matter how ‘efficient’ it might be.

At this stage each group should decide what size of tents would be most suitable and cut out a piece of paper that represents a block of 20 tents x 2 tents, at the same scale as the printed plan. Each group should discuss what would be a sensible width of road to put in between blocks. They should try this out for four blocks, then make a new rough estimate of how many people they would fit on the site.

Note: Most of the tents you will find on an internet search are for recreational camping, rather than the 'army' type canvas tents. If you look for tent dimensions on the internet or in catalogues, the dimensions given are for the area covered by the tent groundsheet (flooring), so you can use these figures to estimate how many people the tent would shelter. Although you might expect a two person tent to sleep two people, a four person tent to sleep four people, a six person tent to sleep six people and so on, this doesn't necessarily make allowance for whatever belongings they have brought with them.

3. Estimating how much water will be needed each day

Students will need to refer to the additional information on the 'Facts and figures' support sheet for this. The 'Oxfam' water tanks referred to on the 'Estimating capacity' worksheet and the 'Facts and figures' sheet are the smallest of a range of storage tanks. They have a volume of $11m^3$, equivalent to a capacity of 11,000 litres of water . Based on an allowance of 15 litres per person per day, one such tank could store enough water for one day for around 700 people.

4. Estimating how many toilets are needed

When considering the number of toilets needed, students may also want to consider the additional water needed for toilets, and some students may also want to include an allowance for showers and other washing facilities as well as toilet blocks. This could provoke quite a lot of discussion (for example, "How much water does a flushing toilet need?" "How much water should you allow for a shower?" "Does it need drinking quality water?"). It may be better left as a discussion point rather than adding to the estimations students need to carry out.

5. Conclusion and evaluation

By this point, their revised figure should be considerably lower than the one they started with. Each group should present their final estimate to the other groups, so that students can discuss the different values and how they were arrived at.

In addition to the water supplies, roads and toilets considered in the challenge, real site plans need to include firebreaks, communal washing facilities and communal cooking facilities or cooking facilities for each household. (For comparison, the *Sphere Project* handbook gives 'rule of thumb' figures for longer term camp-type settlements of 30 m^2 per person to as much as 45 m^2 per person. The lower figure is based on some communal facilities being available nearby, whereas the upper figure makes some allowance for recreation areas and household kitchen gardens.)

3. Problem solving activities: solving longer term problems

Student Activity 3A

Peace and quiet?

FEMA/Andrea Booher

There may be very little privacy in an emergency shelter

Information

Repairing or rebuilding homes after a natural disaster can take weeks or months, and people still need somewhere safe to live during that time. Conditions that are acceptable for the first few nights as emergency shelter are not acceptable for temporary accommodation over a longer period. As well as things like proper washing and cooking facilities, there is a need for personal space and privacy.

The situation

There has been severe flooding locally, and the school sports hall has been used to provide temporary shelter for people whose homes have been flooded (mostly couples and families with young children). It will take several weeks before some of the homes will be safe to live in. Families who still need to stay in the hall have also complained that the hall is very noisy, and they need some privacy. Some form of screening needs to be put up around each family space.

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

The challenge

Short version, concentrating on acoustic properties

1. Consider some possible screening solutions.
2. Compare the sound absorption/reflection properties of the screening materials available.
3. Identify the most suitable materials for screens based on this property.

Longer version, evaluating the stability of the structure as well

1. Consider some possible screening solutions.
2. Suggest two possible screening solutions that you could compare.
3. Construct prototype screens and compare the stability of the screens and how well they reduce the amount of sound reflected.
4. Produce a brief report, recommending the best solution.

NOTES FOR STEM LEADER

Suggested time: 90 minutes

Support sheets available for this activity

- Student activity 3A support: Sound test

Setting the scene

Spend a few minutes discussing ideas with the whole class.

If possible, have some examples of real emergency shelter conditions (such as those from 'Hurricane Sandy' that affected New York in autumn 2012). This is a real life problem and you can find examples of how different organisations have approached it on the internet. (See *Useful sources of information*.)

Some possible approaches

- 'Curtain on rigid frame' solutions: rigid support frame for curtains (same idea as in hospital wards); portable 'concertina' screens; clothes rails draped with sheets.
- 'Indoor tents' or 'oversized travel cot' solutions.
- Interlocking rigid pieces of cardboard or plywood.
- Single 'rigid sheet on support frame' solutions: display boards/room dividers.
- 'Combined storage and screening' solutions: lockers or shelving.
- Other 'self-supporting' structures made from a single material: similar to 'folded paper' furniture.

"I had considered becoming a lawyer so I could work in human rights or environmental protection – but actually as an engineer I could do things and see the results in action to a much greater extent."

Tom Newby, structural engineer

Background science

The sound levels in a space will depend on several factors. Curtains and soft furnishings reduce reflection; hard, smooth surfaces produce a strong reflection; 'bumpy' surfaces reflect the sound in different directions; there is also some diffraction at edges and through gaps, which can be significant, as well as direct transmission through walls, floors and barriers. For simplicity, this activity concentrates on the reflection and absorption only.

Structures will topple once the centre of gravity is not over the base, so stability is improved by lowering the centre of gravity (most of the mass near the base, use a weighted base) and using a wider base (roughly 'triangular' shapes with the point at the top). For a long, thin divider panel, using a 'wiggly' or 'concertina' structure makes it more stable because it effectively increases the base width.

Comparing acoustic properties and stability

Where time is limited, a focus on the acoustic properties is most appropriate, but a more 'complete' approach would be to consider the stability of proposed dividers as well.

The support sheet shows a standard arrangement for comparing reflection/absorption of sound. For fair comparisons, the materials used should all be tested as they will be used in the prototype screen structures (e.g. material that would be hung from a frame should not be tested lying flat on the bench).

Students need to identify materials and surfaces that absorb sound rather than reflect it, and should select materials that provide the greatest reduction in intensity of reflected sound. If you have sound meters or sound sensors, this could simply be a matter of choosing the lowest dB value of reflected sound. If you are using oscilloscopes, or sound editing software such as '*Audacity*' (see below), students need to identify the surface that gives the smallest amplitude waveform.

Constructing and testing complete model structures for stability is likely to need at least one more session. The simplest way to compare stability of screening solutions is to put the structure on a tray and tilt the tray until the structure starts to fall over: if the structure does fall over it may self-destruct!

'*Audacity*' software

'*Audacity*' software allows you to record and edit sounds using a microphone connected to your computer . It is free, open source software, and can be downloaded from **www.audacity.sourceforge.net/**

Student Activity 3B

Clean water? (Evaluating sand filters)

Elizabeth Sharpe

Assessing a site for a new water supply after a tsunami

Information

Following a natural disaster, water supplies may be disrupted and new supplies of water need to be set up. The problem is to turn a supply of muddy water into a supply of clean water, and the most common way of doing this is to allow the water to drain through a filter bed. There are two basic types of sand filter:

- The type that are usually used as part of a large scale, automated water treatment process are known as **rapid sand filters**. They remove suspended particles that make the water cloudy, but don't remove harmful microbes.
- The type of filters typically used where there is not a treated water supply are called **slow sand filters**, and take much longer to filter the water. They include a type known as **biosand filters**, where the process also removes most potentially harmful microorganisms. They run for a few hours each day to provide enough water for a single household . The low flow rate allows microorganisms to adhere to particles of sand throughout the filter. The water in the first few centimetres at the top of the filter contains enough oxygen for the microbes that feed on other, harmful microbes to survive there.

"I worked in Aceh, Indonesia from August 2007 to July 2008 to assist with redevelopment of rural water supplies after the December 2004 earthquake and tsunami."

Elizabeth Sharpe, hydrogeologist (water resources specialist)

"I worked in Bam (Iran) after the earthquake in 2004; in Kashmir (Pakistan) in 2005; in Bhutan, 2010; and again in Pakistan following their flood disaster in 2010. In each of these, I was helping to re-establish water supplies and sanitation systems. I also I worked with MSF (Medecins sans Frontières) in Mozambique on cholera and flood relief in 1999 and 2000."

Kenneth Gibbs, water supply and sanitation engineer

The situation

You have been asked to trial four different small-scale filter arrangements that could be set up with readily-available plastic drink bottles, and produce a short report about what you have found out. The water being treated will be fairly muddy, but the water produced by the filter in normal operation should be clear.

The challenge

Evaluate the performance of different sand filters.

The four filter arrangements will all use the same size of fizzy drinks bottle, but use different materials for the filter media.

1. Make sure the bottle cap is screwed on: it should have four small holes in it.
2. Roll a piece of scrap paper or card to create a cone. Place it into the upturned bottle to make it easier to pour in the sand or gravel without spilling.
3. The first filter is just sharp sand. Pour the sand into the filter until it is about 10 cm from the open end.
4. Attach the bottle to the support stand using two clamps, one around the neck of the bottle, the other near the top of the sand layer. You can hold it in place more securely if you also wrap a piece of gaffer tape around the bottle and the stand.
5. Set up the other filters in the same way, filling to 10 cm from the top of the filter, but with the following materials:
   - 10 cm depth of gravel first, then sharp sand on top
   - a mix of gravel and sharp sand
   - 10 cm depth of gravel first, then play sand on top.

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

Setting up a filter system

6. Place each filter in a tray or bowl on the floor, with a clean collecting container underneath the filter outlet.
7. Place the container of muddy water on a stool or bench above the filter.
8. Open the tap, so that water runs slowly into the filter. Adjust the flow from the tap to keep the water level in the filter steady at about one centimetre or so below the top of the filter bottle.
9. How long does it take for the filtered water to drip through and fill the container, and what does it look like? When the container is full, replace it with a clean, empty container.
10. Keep doing this until the water is running clear for two successive containers. Make a note of how long it takes to fill each container.
11. How much water did you need to run through the filter before the water ran clear? How much filtered water would the filter produce in an hour if you left it running?
12. Present a short report or presentation that gives brief details of:
    - how you carried out the tests you used in your evaluations and what the results were
    - what you discovered and what conclusions you reached
    - changes you might make to improve the performance of the filter.
13. A typical biosand filter can filter 12 to 18 litres of water per hour. Look at the diagram of the biosand filter on the support sheet. What are the differences between your best filter and the biosand filters that are actually used to provide clean water?

NOTES FOR STEM LEADER

60-90

Suggested time: 60–90 minutes

Support sheets available for this activity

- Student Activity 3B support: Setting up the filters
- Student Activity 3B support: A biosand filter

Preparation of resources for this activity

You will need to collect 2-litre plastic bottles with caps to use as filters.

Before the session you need to

1. Remove the base of each bottle, cutting as close to the base as possible: you should be able to cut round the bottle with ordinary scissors once you have made a small slit using a craft knife.
2. Drill four evenly spaced holes in each bottle cap with a 2 mm drill bit. (CARE! Ensure the cap is firmly clamped before you do this.)
3. Make up sufficient muddy water for the entire session. You could either make up a large quantity in a bucket then pour it into the 10-litre containers, or add the soil directly to the containers (a large paper funnel helps to reduce spillage!) and mix thoroughly with water in the container. Use one to two plastic cupfuls of soil to every 10 litres of water.

Setting the scene

If possible, show students some examples of 'real life filters', showing the construction and the appearance in use. (See '*Useful sources of information*'.) You might also mention domestic solutions that involve allowing muddy water to settle, then decanting off the cleaner water. Although students may be familiar with filtration as a technique for cleaning water, it is unlikely that they will have seen biosand filters before. These are small scale filter systems that can be used and maintained by families, that also remove most potentially harmful micro-organisms .

Evaluating the different filters

The first thing students should notice with each filter is that initially the filtered water is still dirty, and that it may take several 'sacrificial' cupfuls before the filter settles down to steady performance. During this time, the output rate may also slow noticeably as the filter material settles and compacts. The challenge focuses on the effects of changing the size of particles inside the filter and changing how the different sized particles are distributed. Typical flow rates could be a small cupful every five minutes or so, equivalent to around two litres per hour.

Students might suggest:

1. using filters with a greater depth (to see if it improves the effectiveness of the process so that the output water quality is improved)
2. using filters with a greater cross-sectional area (to give a faster flow rate for the same output quality).

Filter papers remove suspended solids from a suspension when the suspended particles are bigger than the pores in the filter paper. This is the basic principle underlying rapid sand filters, but instead of pores in the filter paper, there are gaps between sand particles. Suspended solids are trapped as they pass through the filter but some will penetrate deep into the filter bed before they are trapped. This suggests that there would be a minimum depth of filter to be effective. Eventually, the filter becomes clogged and has to be cleaned (by washing out the whole filter).

As water runs through the sand filter, the sand compacts; the finer the particles are, the smaller the gaps you might expect between them. With a slow sand filter, most of the suspended solids are trapped near the top of the filter, so when the filter starts to become clogged up, removing the top layer restores its performance. This is a much simpler maintenance process than washing out the whole filter.

The filters made by students are smaller and simpler than real household biosand filter units, as can be seen from the diagram on the support sheet '*A biosand filter*' showing the construction of a biosand filter. The biolayer builds up at the top if the sand is left undisturbed. The low flow rate allows microorganisms to adhere to particles of sand throughout the filter, and the water in the first few centimetres at the top of the filter contains enough oxygen for the microbes to survive there.

Extending the activity

Where time allows, students could try out the effect of using filters with different depths of filter medium and with different cross sections. They could also design a more permanent support stand that is robust, simple to construct, and could be built with readily available materials.

The activity could also be extended by carrying out the maths-based activity, 3C: *The right size of filter*.

Close-up of a filter in use

Student Activity 3C

The right size of filter

Information

A natural disaster may disrupt water supplies, so new supplies of water need to be set up. The problem is to turn a supply of muddy water into a supply of clean water, and the most common way of doing this is to allow the water to drain through a filter bed.

Slow sand filters have traditionally been used to filter water slowly and continuously. **Biosand filters** are a kind of slow sand filter that can work intermittently and are being used as a way for households to treat the water they need for themselves. The slow filtration process not only removes the suspended particles that make unfiltered water look cloudy, it also removes most potentially harmful micro-organisms.

The situation

You have been asked to suggest a suitable size of slow sand filter that could be sent to disaster areas. The bigger the cross-sectional area of the filter, the faster the output flow rate, but bigger filters use more materials and take up more room, so production and shipping costs are higher.

The challenge

Identify the best size of container to use for a household sand filter.

The household sand filter must meet the specification below:

- The filter must provide 40 litres of clean water each day.
- The output rate of a filter is described in $m^3/ m^2/$ hour, and the chosen sand filter arrangement will provide filtered water at a rate of 0.1 $m^3/ m^2/$ hour. (1 litre = 0.001 m^3; 1 m^3 = 1000 litres)
- Containers that could be used for holding the filter media are available in five diameters: 15 cm, 25 cm, 30 cm, 45 cm and 60 cm. All the containers are the same shape, with a square cross-section.

Which would be the best size to use?

Show how you arrived at your decision.

"I like the technical aspects of the work; thinking logically and systematically. But there is also a social element of the work we do – the projects we work on can have a huge impact on people's lives, hopefully improving them."

Steve Fitzmaurice, civil engineer

Source: CAWST – The Centre for Affordable Water and Sanitation Technology (www.cawst.org)

A child standing next to a biosand water filter

NOTES FOR STEM LEADER

Suggested time: 20–30 minutes

Support sheets available for this activity

- n/a

Students will need to decide the best way to approach this problem, and should be given the opportunity to share their decisions and show how they arrived at them. The calculations themselves should not take long.

Some students may calculate values for flow rate and time for the smallest container before considering other sizes; other students may decide to look at the idea of a 'sensible time' limit first then work backwards to find flow rates and container sizes. The second approach reduces the number of repetitive calculations, and instead concentrates on manipulating equations.

Sample strategy 1:

Step 1 Calculating the flow rate provided by each size of filter

Flow rate is 0.1 m^3 / m^2/ hour

Cross sectional area is given by d^2, and; d must be in m for area to be in m^2.

Flow rate for 15 cm diameter = 0.1 x 0.15^2 m^3/hr = 0.00225 m^3/hr or 2.25 litres/hour

Flow rate for 25 cm diameter = 0.1 x 0.25^2 m^3/hr = 0.00625 m^3/hr or 6.25 litres/hour

Flow rate for 30 cm diameter = 0.1 x0.3^2 m^3/hr = 0.009 m^3/hr or 9 litres hour

Flow rate for 45 cm diameter = 0.1 x 0.4^2 m^3/hr = 0.02025 m^3/hr or 20.25 litres/hour

Flow rate for 60 cm diameter = 0.1 x 0.6^2 m^3/hr = 0.036 m^3/hr or 36 litres/hour

Step 2 Calculating how long it will take each filter to produce the amount of water needed

$$\text{Time needed} = \frac{\text{amount needed}}{\text{flow rate}}$$

For 15 cm diameter container, time needed = (40 ÷ 2.25) hours = 17.8 hours

For 25 cm diameter container, time needed = (40 ÷ 6.25) hours = 6.4 hours

For 30 cm diameter container, time needed = (40 ÷ 9) hours = 4.4 hours

For 45 cm diameter container, time needed = (40 ÷ 20.25) hours = 1.98 hours

For 60 cm diameter container, time needed = (40 ÷ 36) hours = 1.11 hours

Students then need to decide what would be a sensible amount of time to allow for getting one day's worth of water.

Sample alternative strategy

Suppose time allowed to filter 40 litres water is no more than 5 hours, then the flow rate for that will be 40 litres/ 5 hours = 8 litres/hour, or 0.008 m^3/ hour.

Flow rate R_M of filter medium = 0.1 m^3/ m^2/hour

Required flow rate $R_A = R_M \times A$, where A is cross-sectional area measured in m^2

Area A of filter needed to achieve this rate = $R_A \div R_M$ = 0.008 ÷0.1 = 0.08 m^2

Area $A = d^2$,

Substituting for A, d^2= 0.08 m^2 so d= 0.28 m, or 28 cm. The nearest size to this would be 30 cm diameter.

SODIS/Eawag

Setting up bottles of water for solar disinfection

SODIS/Eawag

SODIS bags

Student Activity 3D

Solar disinfection

Information

Water supplied from taps in a temporary camp may look clean but still needs to be treated to kill harmful microbes before it is safe to drink. One way of doing this is to add chemicals, but this affects the taste of the water; another way is to boil the water, but this uses valuable fuel; another way is to use solar disinfection (SODIS).

Solar disinfection uses solar energy to kill microbes. The water is treated by putting it into clear plastic drinks bottles, then leaving the bottles out in the sunshine. This takes at least 6 hours, even in hot, sunny climates. UV radiation kills microbes. Some of the energy is also transferred to the water as sunlight passes through it, and the water gets warmer because it is absorbing energy.

The situation

Solar disinfection is going to be used to provide safe drinking water for the inhabitants of a temporary camp. Different sized bottles might be available. Sealable plastic bags suitable for storing food or liquids safely would also be available.

Some people say that putting the bottles on a shiny surface helps to make the process more effective.

To be effective, UV radiation in sunlight must reach all parts of the water in the container. The more UV that reaches the water, the more effective the treatment should be.

The challenge

Find out how differences in the way SODIS treatment is carried out might affect how effective it is. **Hint:** UV-sensitive beads change from white to coloured when exposed to UV radiation. UV beads float in water.

Some questions you might consider are:

- What containers work best?
- Should the containers be 'standing up' or 'lying down'?
- Does the surface that the containers are on make a difference?

Decide **how** you are going to investigate your chosen questions.

Write a brief report about what you have found out, suggesting what you think is likely to be the most effective way to carry out SODIS treatment.

About this activity

In this activity you are modelling a real life situation.

In real life, the treatment would take several hours in strong sunshine. As this is not the situation you are working in the water will not be fully treated.

DO NOT DRINK THE WATER.

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

Bottles and bags set up for testing; a bead that has turned orange is visible in the large, upright bottle

NOTES FOR STEM LEADER

Suggested time: 60 minutes

Support sheets available for this activity

- n/a

Preparation

If you have a mixture of different colours of UV beads, expose them to UV and sort them into separate colours before the lesson and label the packs with the colour of the exposed beads.

Setting the scene

This activity follows on from the filtering activity. It would be useful to show students some images of SODIS treatment. You may also need to demonstrate what happens to UV beads when you place them in sunlight and when you take them out of the sunlight again.

Evaluating different arrangements for SODIS

Solar disinfection uses the UV radiation in sunlight. UV-sensitive beads change from white to coloured when exposed to UV radiation: the more intense the exposure, the faster the beads will become coloured, and the longer they will take to lose the colour when no longer exposed. UV will be absorbed as it passes through the water, so the greater the depth of water, the less intense the radiation reaching it. This suggests that there should be a practical limit to the size of container used. Lying bottles on their side will also reduce the effective depth of water and at the same time increase the area of bottle exposed to direct overhead sunshine, with no bottle 'blocking' another bottle. Standing bottles upright in groups would have the opposite effect.

The warming effect of being left in the sunshine helps the process because convection currents circulate the water so it passes close to the surface of the container.

The easiest way to ensure that the UV beads sink to the bottom of the container rather than floating is to press the bead into the surface of a small blob of adhesive putty. The UV beads change colour very quickly in direct sunlight, so the containers need to be covered until students are ready to compare them.

The containers need to be left in a fairly sheltered sunny spot, and the longer that the bottles can be left out in strong sunshine, the more noticeable the warming effect will be. The beads will still work outside on a cool, dull or windy day, but the water will not warm up, so there will be less mixing by convection currents.

"It is important in every situation that people have clean water to drink, cook and bathe in. When people cannot access clean water they may become severely dehydrated, get water-based illnesses and in severe cases may die."

Nicola Greene, civil engineer

Queuing for drinking water after flooding in Pakistan in 2010

Student Activity 3E

Taps and waiting time

Information

When most buildings in a region have been destroyed or are unsafe, people who cannot leave to find shelter with relatives in another region will need temporary outdoor shelters to live in until they can rebuild their homes. Whenever a camp is set up, providing water is a priority.

Planning a temporary camp can involve surveying an open space and planning the best arrangement of tents or other shelters, along with things like water supply points and toilets. There are guidelines for deciding how many taps are needed and where they need to be so that nobody has to walk long distances or queue for hours.

The situation

There has been a major earthquake, and a temporary camp for 2,500 people has been set up. Adequate supplies of water for the number of people are delivered to the camp storage tanks, but pipes and taps need to be connected so that everyone has access to a water supply point, and the supply must meet the guidelines for queueing times. Your team has to organise temporary water supply points for everyone in the camp.

The challenge

Produce an initial report identifying how many supply points (taps) are likely to needed, and how the supply rate at each tap could affect queueing times.

About this activity

Use the information in Student activity 3E support: Facts and figures.

In this activity you are modelling a real life situation, and to do this you may need to make some simplifying assumptions. Your report must make it clear how you obtained any values, so identify any equations or starting information you used and any assumptions you made.

THINKING LIKE AN ENGINEER

If you are solving problems creatively, you are thinking like an engineer! What skills did you use to help you carry out this challenge?

NOTES FOR STEM LEADER

Suggested time: 20–30 minutes

Support sheets available for this activity

- Student activity 3E support: Taps and waiting time
- Student activity 3E support: Facts and figures

Setting the scene

Start by bringing out one or two containers filled with water (preferably 10 litres, but smaller ones will do). Get one or two of the students to try lifting one of the containers and carrying it across the classroom. (CARE NEEDED WHEN LIFTING AND CARRYING HEAVY OBJECTS!) *How easy/hard was it? How would you feel about carrying it to the other end of the school site? Several times a day?*

How long do you think it would take to fill this?

Show some images of people getting water from stand pipes in different situations. At least one of them should show people queueing. Have you had to do this (e.g. at a camp site, or after a burst pipe or other temporary disruption to the normal supply)? *How long did you have to wait?*

(See *Useful sources of information*.)

Carrying out the challenge

This activity offers an opportunity for students to produce a short report based on a series of relatively simple calculations and/or estimations. In producing the report, there are opportunities for students to produce generalised equations and to explore the consequences of setting different values. Students will need to decide what they need to find out, and divide up the tasks between different members of the group.

Student activity 3E support: Taps and waiting time takes students through some of the estimations they may need to carry out.

Suggested answers for 'Taps and waiting time' support sheet

1. The amount of water of water needed per person per day just for drinking and food preparation = **5** litres. Allowing extra for personal hygiene, the total amount could be around **15** litres per person.

"I was trained as a civil engineer but have always had an interest in water (hydro-power, dams, river engineering, etc.). Later, I developed an interest in water supplies for industry and for people which led to my joining UNICEF. With UNICEF, I became interested in the health benefits of water supply and sanitation, and how people behave with the facilities which we were trying to give them."

Kenneth Gibbs, water supply and sanitation engineer

2. The amount of water needed by a family of four = (**4 x answer to question 1**) litres.
3. Based on a guideline of 250 people per tap, a temporary camp of 2500 people would need at least **10** taps.
4. At a supply rate of 7.5 L/min, if each person uses 7.5 L per day then each tap would need to provide 250 x 7.5 = **1,875** litres and it would take a minimum of **250** minutes to provide this.
5. If each person uses 15 litres a day the total supply needed from each tap would be **3,750** litres and it would take a minimum of **500** minutes to provide this.
6. If each household has a 20-litre storage container and a 10-litre carrying container, it will need **(answer to q2)/ 10** journeys to collect enough water for the family for 1 day just for drinking and cooking.
7. If the tap delivers water at a rate of 5 L/min, it will take **2** minutes to fill the container;
8. If the tap delivers water at a rate of 10 L/min, it will take **1** minute to fill the container;
9. If the tap delivers water at a rate of n L/min, it will take **10/*n*** minutes to fill the container.
10. At 5 L/min, if there are 5 people in the queue it will take **10** minutes for all of them to fill their container;
11. At 5 L/min, if there are 10 people in the queue it will take **20** minutes for all of them to fill their container;
12. At *V* L/min, if there are *n* people in the queue it will take at least **10*n*/*V*** minutes for all of them to fill their container.
13. If there are typically 10 people ahead of you in the queue when you join it, it will take at least (**10 x 10**)**/*V*** minutes to get to the tap each time you join the queue.
14. If you have to walk 200 m to the tap, walking there and back each time at a rate of **1** m/s will take **400** s, or approximately **7** minutes .
15. The amount of time spent in getting water for a family each day would be **(number of journeys) x (walking time there and back + queueing time for each journey)**.
16. If nobody should queue for more than 30 minutes, the maximum number of people ahead of them in the queue should be **30/(time for each person to fill their container)**.

Going further

The activity could be extended to allow students to make further adaptations to the site plans they constructed for Activity 2C.

4. Presentation activity: How do engineers save lives?

Student activity

Use the information and ideas that you have gathered from the introductory activities and the problem solving activities to present your answer to the big question: *How do engineers save lives in the aftermath of a natural disaster?*

Presentation specification

The presentation must:

- include a supported answer to the 'big question', '*How do engineers save lives in the aftermath of a natural disaster?*'
- Include examples of problems experienced by the survivors of a natural disaster and how engineers help to solve them.

The presentation could:

- refer to identified events, such as the superstorm that affected New York in 2012, the earthquake and tsunami that affected the Tohoku region of Japan in March 2011, or the earthquake that hit Haiti in 2010
- include relevant information about particular natural disasters and relief efforts
- include relevant information from internet-based research, identifying the source of the information
- identify specific examples of the contributions made by one or more types of engineer
- describe one or more of the challenges you worked on, and what you learned from them about the role of engineers
- explain the relevant science, technology or mathematics knowledge you used for a problem-solving activity.

The presentation could take a number of forms and could include:

- text
- photographs
- diagrams
- charts
- data.

NOTES FOR STEM LEADER

Suggested time: 60 minutes

Support sheets available for this activity

- Student activity 4 support: Prompt sheet

The presentation is an opportunity for students to draw on all the information and insights they have gathered and for members of each group to work cooperatively to produce the presentation.

It is important for each group of students to have the opportunity to present their work to other groups. There should also be an opportunity for all students to contribute to this process.

The presentation produced by a single group might be a poster, or a talk supported by images and data. Where time and resources allow, it might be a short video presentation, a PowerPoint presentation or a Prezi presentation (see **www.prezi.com**).

The content of individual presentations will very much depend on which challenges the students have taken part in but the overall message that students should take away is that:

- **Engineers save lives after a natural disaster.**
- Engineers draw on scientific, technological and mathematical knowledge and skills to solve problems for people.
- They need to understand people as well as technology.
- They also need to be observant, creative, resourceful and able to work in teams.
- Some of the activities that will save lives after a disaster will have been carried out long before a disaster strikes.
- Engineers review what they have learned from a disaster to try and produce a better solution in future.

SODIS/Eawag

Disaster recovery STEM challenge day resource

Preparation

The lead teacher will need to complete the following tasks prior to the STEM day:

- Organise students into groups of four.
- Select which activities will be offered.
- Ensure all the materials and equipment needed are available.
- Book rooms for each of the chosen activities.
- Make copies for the students of all relevant printed materials.

MATERIALS AND EQUIPMENT	SUPPLIER
Audacity sound editing software	Downloadable from **www.audacity.sourceforge.net/**
constructostraws	Cochrane's of Oxford **sales@cochranes.co.uk**
corriflute fabrics, e.g. unbleached cotton, nylon UV beads	Mindsets **www.mindsetsonline.co.uk**
10-litre water container with tap	DIY suppliers, camping equipment suppliers

Some selection of activities will be necessary as there are more activities in this scheme of work than could be used in a single 8.30 am to 3.00 pm STEM day that includes a 20 minute morning break and a 40 minute lunch break.

The following page shows are some models that you might adapt.

Model 1: Whole day, focus on immediate problems	Model 2: Whole day, focus on 'Shelter' theme	Model 3: Whole day, focus on 'Water supply' theme
Introductory activities: Activity 1A: How much warning? Activity 1B: Aftermath	**Introductory activities :** Activity 1A: How much warning? Activity 1B: Aftermath	**Introductory activities :** Activity 1B: Aftermath
Activity 2: 1 or 2 from Activity 2A: Emergency shelter Activity 2B: What makes a good shelter? Activity 2C: Tents, water and toilets!	**Activity 2: 1 or 2 from** Activity 2A: Emergency shelter Activity 2B: What makes a good shelter? Activity 2C: Tents, water and toilets!	**Activity 2:** Activity 2C: Tents, water and toilets!
	Activity 3: Activity 3A: Peace and quiet?	**Activity 3: 1 or 2 from** Activity 3B: Clean water? Activity 3C: The right size of filter Activity 3D: Solar disinfection Activity 3E: Taps and waiting time
Activity 4: presentation	**Activity 4: presentation**	**Activity 4: presentation**

Model 4: Whole day, with a focus on maths-based activities	Model 5: Whole day, with a focus on science and technology-based activities
Introductory activities : Activity 1A: How much warning?	**Introductory activities :** Activity 1A: How much warning? Activity 1B: Aftermath
Activity 2: Activity 2A: Emergency shelter Activity 2C: Tents, water and toilets!	**Activity 2:** Activity 2B: What makes a good shelter?
Activity 3: Activity 3C: The right size of filter Activity 3E: Taps and waiting time	**Activity 3: 1 or 2 from** Activity 3A: Peace and quiet? Activity 3B: Clean water? Activity 3D: Solar disinfection
Activity 4: presentation	**Activity 4: presentation**

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
10 minutes	**Introduction** **Teacher** Introduces the day's challenge. Introduces the context using short presentations of slides and video clips to remind students of what is meant by the term 'natural disaster'. **Students** Locate some of the most recent examples on a world map.	STEM day lead teacher	Presentation about the challenge, including slides, video clips. Note: One or more of the slides could be world maps for students to identify locations.	Classroom or hall with projector or IWB facilities.	Awareness of the range of natural disasters and their impact.
10 minutes	**Introductory activity** **Activity 1A: How much warning?** **Teacher** Sets each of the tasks sets a time limit for groups to work on them and draws together ideas in rapid plenary . **Students** Carry out the card sort. Calculate answers to the questions in ' How much warning?'.	STEM day lead teacher	**Student activity sheets:** Student activity 1A: How much warning? **Students support sheets:** Student activity 1A support: Disaster card sort	Classroom or hall with projector or IWB facilities. Calculators	Awareness of the range of natural disasters and their impact. A sense of the speed of some natural phenomena. Simple calculations using a formula.
20 minutes	**Activity 1B: Aftermath** **Teacher** Introduces activity: Aftermath: *What kinds of problems face survivors after a natural disaster? What might engineers do to help?* Refers to the introductory presentation. Distributes any additional resources and manages for timing. Directs students' attention where they need help, but without 'giving them the answers'. **Students** Identify some of the problems facing survivors. Students may suggest where/ how engineers might be involved.	STEM day lead teacher	Presentation still available for reference or further discussion. Optional: additional extracts from articles, from news or rescue agencies. Paper for writing ideas on. **Student activity sheets:** Student activity 1B: Aftermath **Student support sheets:** n/a	Classroom, or hall with tables.	Identifying relevant problems: relating the physical effects of a natural disaster to human needs.

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
60–90 minutes	**2. Problem solving activities: Solving immediate problems** **Activity 2A: Emergency shelter** (Using the sports hall as an emergency shelter after flooding) **Teacher** Manages the survey of the sports hall and then manages resources and timing of investigation phase. Manages timing of presentations and leads any subsequent discussions. **Students** Use scale drawings and tessellations to explore how they could provide overnight accommodation in the sports hall. Give brief oral presentation to other groups.	Maths specialist	Large tape measure (several metres long) or ultrasound distance meter for measuring sports hall Tape measure for other objects Old clean sheet to lay on floor to place sleeping bags and other belongings on Sleeping bag – adult and child versions Pillow Rucksack or suitcase Sheet of A3 paper for each group Squared paper for creating templates Rulers Scissors Additional paper or card 'Blu-tack' or similar for holding paper pieces in place on plan Calculators **Student activity sheets:** Student activity 2A: Emergency shelter **Student support sheets:** Student activity 2A support: Emergency shelter Student activity 2A support: Scale plans Student activity 2A support: Tessellation	Sports hall, then a classroom with tables/benches large enough for group work with A3 paper plans. (Optional: room with access to computers for each group)	Working as part of a team Converting lengths in metres to equivalent in cm and vice versa. Producing scale diagrams Calculating areas and numbers of people Recording each part of the process Estimating values Trialling and evaluating different solutions to a problem; improving solutions to a problem

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
120 minutes	**2. Problem solving activities: Solving immediate problems** **Activity 2B: What makes a good shelter?** **Teacher** Presents images of different shelter solutions, plus basic information about the materials they are made from. Demonstrates relevant testing arrangements Manages resources and timing. Manages timing of presentations and leads any subsequent discussions. **Students** Build and evaluate two scale models in terms of mass of materials used and thermal properties. Give brief oral presentation to other groups.	Design and technology specialist, science specialist	PowerPoint presentation of shelter solutions. For model performance tests: ■ materials to create scale models of shelters, such as corriflute, cardboard, constructostraws, plastic sheet, bubble wrap, cotton fabric or nylon fabric ■ rulers ■ scissors (NB These will need to be sharp, 'heavy duty' scissors designed for cutting sheet material) ■ cutting boards (to protect benches during construction!) ■ top pan balance ■ beakers of hot water ■ thermometers or temperature sensors and datalogging equipment **Student activity sheets:** Student activity 2B: What makes a good shelter? **Student support sheets:** Student activity 2B support: Model shelters	Laboratory or workshop with computer, projector and whiteboard	Working as part of a team Constructing models from templates Designing and constructing models with a common base size Carrying out standardised tests to compare the performance of different shelter solutions Recording what has been done and what the relevant outcomes were. Comparing and evaluating different solutions

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
90 minutes	**2. Problem solving activities: Solving immediate problems.** **Activity 2C: Tents, water and toilets!** (Using a local open space as a temporary camp) **Teacher** Introduces scenario, provides image; manages resources and timing of investigative phase. Manages timing of discussions and presentations. **Students** Carry out tasks to determine how many people might be accommodated in tents and what their likely needs would be for drinking water and for toilets. Produce increasingly improved solutions. Give brief oral presentation to other groups.	Maths specialist	Aerial photos or plans of known scale, printed on A4 paper Highlighter pens or felt pens for marking out the useable area of the open space. Pencils and rulers for carrying out the area estimation. Additional information sheets and support sheets A4 plain for sketching out ideas. If students are trying out ideas using scale plans on paper or cut-out shapes: ■ Squared paper ■ Scissors **Student activity sheets:** Student activity 2C: Tents, water and toilets! **Student support sheets:** Student activity 2C support: Facts and figures Student activity 2C support: Estimating capacity **Additional resources (downloadable from www.raeng.org.uk/disaster-response)** Excel spreadsheet: Site capacity estimations	Classroom (with computers if students are to create PowerPoint presentations or use spreadsheets)	Relating dimensions on an aerial photograph to dimensions of real objects Estimating and calculating various quantities Using labelled sketches or diagrams to make assumptions explicit Carrying out repeated calculations, spotting patterns in data Using a spreadsheet if available to carry out repeated calculations as above , and to test out a model Evaluating and revising solutions in response to additional information Compare solutions with real life situations and practicalities.

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
90 minutes	**Activity 3: Solving longer-term problems** **3A: Peace and quiet?** Improving shelter conditions. Evaluating screening arrangements to improve privacy and reduce noise **Teacher** Introduces the challenge, provides materials for students to trial **Students** Test chosen screen materials for acoustic properties.	Science specialist/ Design and technology specialist	PowerPoint presentation of some 'real life' screening solutions for plenary discussion 'Standard' sound source, eg a recorded sound Two long cardboard tubes (eg for wrapping paper) plus clamps, bosses and stands to hold them in position Sound meters, or sound sensors (or microphones) connected to computers with sound editing software, or microphones and digital oscilloscopes Rulers Materials to create prototype screens for testing, eg sheets of cardboard, metal, paper, plywood, cloth, plus materials for support such as clamps, bosses and stands, dowel or other rods. **(see STEM leader notes on this activity)** **Student activity sheets:** Student activity 3A: Peace and quiet? **Student support sheets:** Student activity 3A support: Sound test	Laboratory or workshop with computer, projector and whiteboard, plus computers running digital oscilloscope or sound editing software (optional)	Absorption and reflection of sound by surfaces Carrying out standardised tests to compare the performance of different solutions Recording what has been done and what the relevant outcomes were. Comparing and evaluating different solutions Compare solutions with real life situations and practicalities.

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
60–90 minutes	**Activity 3: Solving longer-term problems** **3B: Clean water?** **Teacher** Introduces the challenge, supervises the construction and testing of filters **Students** Construct filters and evaluate four different filter media	Science specialist/ Design and technology specialist	PowerPoint presentation of some 'real life' solutions for plenary discussion For each set of four filters to be tested: ■ 4 x fizzy drinks bottles (2-litre or 1.5-litre), each with base cut off and 4 x 2 mm holes drilled in the cap ■ 4 x stands, each with 2 x bosses and clamps to support each filter ■ supply of clean collecting containers (eg small plastic beakers or drinks cups) for each filter in use at the same time ■ 4 x plastic equipment trays (or washing-up bowls) to stand the filter and collecting container in ■ supply of standard mix muddy water in a container with a variable flow tap ■ gaffer tape and scissors (additional support to hold the filter in place) ■ scrap A4 card or paper (to use as funnels for pouring sand/gravel into the filter bottles) ■ paper towels/mopping-up cloths . **(see STEM leader notes for this activity)** **Student activity sheets:** Student activity 3B: Clean water? **Student support sheets:** Student activity 3B support: Setting up the filters Student activity 3B support: A biosand filter	Laboratory or workshop with sinks	Carrying out standardised tests to compare the performance of different solutions Recording what has been done and what the relevant outcomes were Comparing and evaluating different solutions Comparing solutions with real life situations and practicalities.

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
20–30 minutes	**Activity 3: Solving longer-term problems** **3C: The right size of filter** **Teacher** Introduces challenge, manages plenary discussion **Students** Carry out calculations then use these values obtained to identify the best solution.	Maths specialist	Calculators and paper **Student activity sheets:** Student activity 3C: The right size of filter **Student support sheets:** n/a	Classroom	Identifying steps to a solution Calculating values using a formula Making decisions about best values to use
60 minutes	**Activity 3: Solving longer-term problems** **3D: Solar disinfection** **Teacher** Introduces challenge; manages practical investigation; manages plenary discussion **Students** Investigate the effectiveness of different containers and arrangements; provide brief report.	Science specialist	**Student activity sheets:** Student activity 3D: Solar disinfection **Student support sheets:** n/a Clean, empty water bottles / fizzy drinks bottles with caps: a selection from 0.5-litre 1-litre, 1.5-litre, 2-litre, with at least two of each size used UV-sensitive beads (all the same colour) Adhesive putty, eg 'Blu-tack' Resealable clear plastic food bags (optional) Aluminium foil or other reflective material Thermometers	Laboratory, with access to direct sunshine via open window or going outside	Behaviour of a smart material (UV beads) Carrying out standardised tests to compare the performance of different solutions Recording what has been done and what the relevant outcomes were. Comparing and evaluating different solutions Compare solutions with real life situations and practicalities.

TIME	STUDENT/TEACHER ACTIVITY	STAFFING	EQUIPMENT, MATERIALS AND RESOURCES	ROOMING	RELEVANT STEM SUBJECT KNOWLEDGE and ENGINEERING SKILLS
20–30 minutes	**Activity 3: Solving longer term problems** **3E: Taps and waiting time** **Teacher** Sets the scene; Sets the challenge manages timing **Students** Investigate the effect of changing supply rate on queue length and waiting times.	Maths specialist	Calculators Paper for report Water container(s) of known volume, filled with water: ideally 10-litre containers, but smaller containers would still be OK **Student activity sheets:** Student activity 3E: Taps and waiting time **Student support sheets:** Student activity 3E support: Taps and waiting time Student activity 3E support: Facts and figures	Classroom	Number work: calculations and estimations Identifying and using a simple formula Producing a written report
60 minutes	**Activity 4: Presentation activity** Presentations: *How do engineers save lives in the aftermath of a natural disaster?* **Teacher** Provides additional materials. Manages timing for production of presentations and for sharing of presentations. **Students** Collate materials from previous sessions then produce a final poster presentation.		Each group will need: ■ A3 sheet(s) of paper ■ marker pens or thick-nibbed felt pens ■ scissors ■ glue, sellotape or adhesive putty. Access to computers with software to support presentations, such as PowerPoint or Prezi (optional) Access to video camera (optional) **Student activity sheets:** Presentation activity: How do engineers save lives? **Student support sheets:** Student activity 4: Prompt sheet	Classroom or hall with tables for students to work on and then display posters on. Classroom with computers, projector and whiteboard (optional)	Working as part of a team Evaluation Communicating ideas

Using the activities for CREST Awards

Using the activities for CREST Awards

CREST is a widely recognised national award scheme for project work in science, technology, engineering and maths. It is coordinated by the British Science Association, a charity which exists to advance the understanding, accessibility and accountability of the sciences and engineering.

A CREST Bronze Award requires roughly 10 hours' work on a project. By carrying out several of the challenges, along with the plenary activity, it is likely students could fulfil the award requirements. Some students doing longer, more detailed projects may even consider working towards a CREST Silver Award.

Why link to CREST?

- It's a way for students' work to receive a national accreditation - a Bronze CREST Award is a significant achievement.
- It provides evidence of problem-solving skills and motivates students to go on to CREST at Silver and Gold level.
- CREST is recognised by UCAS as an indicator of relevant skills and achievements supporting university applications and it can also form part of your students' progress files.
- It motivates students of all ages and abilities.
- It develops students' understanding of 'how science works', preparing them for GCSE studies.
- It helps students to evaluate and conclude their own merits and achievements based on their own experiences.

The activities in this resource provide students with opportunities to meet the CREST Award criteria by:

- applying their scientific, technological and mathematical knowledge and skills in a real world context
- demonstrating creativity and innovation
- considering how the work of engineers contributes to the quality of people's lives
- communicating their work to others.

The challenges described in the student activities booklet provide initial contextual information and set the challenge. Teachers can choose whether or not to provide the relevant support materials that offer more detailed advice on how to carry out a particular challenge. Where time allows, several challenges also offer opportunities for more extended work.

To find out how to register your students for an award, or to find out details of your CREST Local Coordinator, visit the CREST website at **www.britishscienceassociation.org/crest** or email **crest@britishscienceassociation.org**

Useful sources of information

You can download a pdf version of the teacher and student booklets for this resource from the Royal Academy of Engineering website, at **www.raeng.org.uk/education/eenp/engineering_resources/default.htm**. There is also a downloadable spreadsheet to support Student activity 2C.

The following websites provide useful background information to support the activities.

Appropedia: **www.appropedia.org/** Portal for 'appropriate technology' solutions.

Design 4Disaster: **www.design4disaster.org/** Provides information on creative solutions to the problems caused by disasters.

Shigeru Ban **www.shigerubanarchitects.com/** Architect's website with information on disaster relief projects and paper tube structures.

Hexayurt Project: **www.hexayurt.com/** Information on construction techniques, examples of where hexayurts have been used.

Engineers Without Borders: **www.ewb-uk.org/** International development organisation.

Practical Action: **www.practicalaction.org/** International development organisation.

RedR: **www.redr.org.uk/** Organisation providing 'People and skills for disaster relief'.

Sphere Handbook: **www.spherehandbook.org/** Sphere project reference publication, detailing universal minimum standards for humanitarian response after disasters.

CAWST (Centre for Affordable Waste and Sanitation Technology): **www.cawst.org/index.php** For information on biosand filters.

SODIS: **www.sodis.ch/index_EN** Information on the SODIS process and how it is used.

National STEM centre e-library: **www.nationalstemcentre.org.uk/elibrary/** Holds a large range of resources, e.g. *Catalyst* article '*Solar disinfection of drinking water*', by Kevin McGuigan, at **www.nationalstemcentre.org.uk/elibrary/resource/7676/solar-disinfection-of-drinking-water**

Also useful:

Aid organisation websites: WHO, Oxfam, UNICEF, ShelterBox, International Red Cross.

Online media report websites e.g. BBC news, the *Guardian*.

As the UK's national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering. We provide analysis and policy support to promote the UK's role as a great place from which to do business. We take a lead on engineering education and we invest in the UK's world class research base to underpin innovation. We work to improve public awareness and understanding of engineering. We are a national academy with a global outlook and use our international partnerships to ensure that the UK benefits from international networks, expertise and investment.

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