urban science

Move It

Students investigate the impact the way we travel has on the urban environment. They explore possible solutions including calculating the amount of carbon emissions trees can sequestrate and alternative forms of travel. They understand how tackling transport can have a range of wider benefits.

A curriculum linked learning module for students aged 13-15 to develop competences in working scientifically.

Learning challenge: Move It – unlocking urban potential through changing the way we travel

At the moment, cars spend around 95% of the time parked, and only 5% of the time in use. Huge swaths of cities, either in car parks, garages, or street parking spaces, are used as storage for cars (while, at the same time, many cities struggle to find enough land to build housing to keep up with demand). There is a huge potential to create more space.

With a large shift to on-demand autonomous cars, something that some experts say could happen in a little more than a decade, parking space in prime urban locations could open up for other uses. A recent report estimates that 2 million people in L.A. will give up their cars for autonomous ride hailing in 15 years, and similar patterns will happen in other cities.

How can we harness the benefits of such change to make our cities more sustainable?

www.urbanscience.eu

Co-funded by the Erasmus+ Programme of the European Union

This learning module can be used flexibly within the curriculum to support key knowledge about physics, chemistry, biology and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. It is suitable for adapting as a STEM activity or Eco Club.

The topic of mobility links with climate change through the carbon emissions emitted by some forms of transport and connects with evidence for anthropogenic causes of climate change. Links can be made with photosynthesis through which plants remove carbon gases from the atmosphere. If chosen, links can be made with energy through using photovoltaic cells to power a model car.

This module starts with a tried and tested inquiry into car pollution and how many trees would need to be planted to absorb all the carbon emitted. This is a satisfying activity for students, but does not answer the question of how to address carbon emissions from vehicles; there is not enough space to plant enough trees to absorb the carbon. As a result, students are often left with a sense of disappointment. This learning module takes this inquiry as a jumping off point to explore more meaningful responses that ignite student's imagination. It asks why we need personal cars, are the better ways to provide personal transport on demand, and what wider system opportunities can be created by tacking this problem differently.

To deliver this module we recommend:

- Start with one or both of the Stage 1 activities to elicit current student understanding and how they predict transport might change in the future.
- Stage 2 provides a practical experiment to calculate if we can easily offset the emissions of transport. This could be used as a starter for the whole module.
- Stage 3 encourages students to explore new options for urban mobility. Several choices are offered including interrogating relevant data, new inventions and an option to create their own solar car.
- In Stage 4 you will provide suggestions for sharing and presenting results.

Subject

Biology	Chemistry	Physics	Raising Attainment
✓	✓	✓	✓

Programme of Study reference

1. Physics	Energy: • Renewable and non-renewable energy sources used on Earth, changes in how these are used.	4. Working scientifically	Students successfully completing this module will have had the opportunity to access these statements: 1c, 1d, 1e, 1f, 2a, 2b, 2d, 2f, 3ai, 3aii, 3av, 3avi, 3avii, 3b. Some will also have completed the following: 1b, 2g. See Annex 1 for full statements.
2. Chemistry	Earth and Atmospheric science: • Potential effects of, and mitigation of, increased levels of carbon dioxide and methane on the Earth's climate.		
3. Biology	Life on Earth is dependent on photosynthesis in which green plants and algae trap light from the Sun to fix carbon dioxide and combine it with hydrogen from water to make organic compounds and oxygen		

Sustainable Development Goals

All Urban Science modules try to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' and in addition focus on education for sustainable development and global education - SDG 4.7. Support and resources here:

http://www.teachsdgs.org/

Move It particularly supports SDG 11 'Sustainable Cities and Communities. By completing this module, which culminates in their designing low carbon transport systems, you will have contributed towards an understanding of this goal. Students will also have addressed SDG 13 'Climate Action.' Other resources can be found here:

http://worldslargestlesson.globalgoals.org/global-goals/sustainable-cities-and-communities/

Activities Overview

Stage 1	Time (mins)	Resources needed
Mobility Collage	35 mins	None required
Future Forecasts…what if?	20 mins	None required

Stage 2	Time (mins)	Resources needed
Calculating Carbon Absorption Rates of Trees	40 mins	Student Sheets 1 and 2
Thinking Hats	30 mins	Student Sheet 3

Stage 3	Time (mins)	Resources needed
Starting Off	20 mins	None required
Digging Deeper	20 mins (could be extended in to research project)	None required
Making Sense of Our Findings	30 mins (could be extended)	None required

Stage 4	Time (mins)	Resources needed
Presenting Results and Peer Assessment	50 mins (can extend to two lessons)	Student Sheet 4
The Iceberg	30 mins	Student Sheet 5

Health and Safety: please refer to the guidance provided on the Urban Science website before commencing the module.

www.urbanscience.eu/uk/learning-modules/health-and-safety/

STAGE 1 - Move It

Inquiry based learning stage			
Stage 1 - Initiating and eliciting	✓	**Stage 2 - Defining and responding**	
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. Students reveal their knowledge on the topic of mobility.
2. Students are able to find out information relevant to the topic.
3. Students can make predictions about their future.

Learning outcomes

1. Students discuss key scientific facts about mobility and the effects on society.
2. Students demonstrate the ability to quickly find out relevant knowledge.
3. Students debate how the future might change and the impacts this will have.

Overview of lesson

This lesson finds out what students know and feel about urban transport. It asks students to create stories about how transport affects urban areas and consider the consequences.

Lesson structure

Introduction:

The following videos provide short introductions to the challenges of urban transport and offer some new thinking.

- https://www.youtube.com/watch?v=eiv3oJlP5wU
- https://www.youtube.com/watch?v=_HnLhmXSpUs
- https://youtu.be/sYOOmZyiCe4

Main 1: Mobility Collage

Collages and montages are a good way to help students share their knowledge and views about a topic, and find out what they are interested in, in our case transport.

Working in groups, provide students with a range of pictures, graphs, newspaper cuttings and magazines, or ask students to find their own. Ask them to use these to create a collage on the theme of 'urban mobility'. Provide sheets of flipchart paper, glue and marker pens so students can create their collage and annotate it.

Examples of items to provide students might include: images of different transport types, graphs showing car usage, carbon emission from road transport, accident statistics, etc.

Ask each group to present their work; prompt them to share their thinking that went into their collage, for example what categories they used and what the key messages are. Encourage other groups to ask questions and discuss student perceptions of the issues.

Main 2: Future forecasts…what if?

Based on their collages, the teacher encourages students to produce 'scenarios' that predict how urban mobility will change in the future and effect this might have on society.

For example:

- What if…we all owned cars?
- What if…we ran out of fossil fuels?
- What if…we reduced the number of roads by 30%?

This activity allows students to explore open-ended questions and compare desirable, probable and possible futures. Students can be asked what ideas they have about reducing the impact of transport in urban areas.

The forecasts may be used as a basis for research into actual predictions and to likely changes in Stage 3 and 4.

Plenary: The messy wall

Create a messy wall (sometimes referred to as a working wall) where the student ideas and questions can be displayed alongside the key scientific concepts. Be sure to update your messy wall regularly throughout the module.

Inquiry based learning stage

Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	✓
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. Students investigate the impact of vehicle use on carbon emissions.
2. Students are able to make reasoned judgements.
3. Students are able to find out information relevant to the topic.

Learning outcomes

1. Students discuss evidence-based results and reach conclusions.
2. Students identify and list positive and negative consequences.
3. Students debate solutions to urban mobility.

Overview of lesson

A common response to addressing carbon emissions is to plan more trees; many governments advocate this but is this a viable solution? In these Stage 2 activities students will test if this is a viable option for mitigating the carbon emissions provided by transport around their school.

This stage can be simplified by providing students with car and tree data in advance.

Lesson structure

Introduction

You could easily start with this activity, or use it as a Stage 3 activity. However, in the context of this module it is pre-requisite for a more satisfying Stage 3 about systems and sustainability.

If you have already completed the iChange module then students will already be familiar with the contribution transport makes to carbon emissions.

This short video illustrates the different carbon emissions for different transport types.

https://www.youtube.com/watch?v=Heqd7IH7ZTA

Main 1: Calculating Carbon Absorption Rates of Trees

Trees play a vital role in absorbing carbon from the atmosphere and storing it. In this investigation students will calculate how much carbon a tree can absorb and compare this with the amount of carbon emissions from cars.

- Firstly, students need to select a tree and calculate its height (see Student Sheet 1). Depending on the age and ability of your students, select one method from Student Sheet 1 for students to use and provide them with a copy of the technique.
- Secondly, using a tape measure, students measure the circumference of their tree at a height of 1.2 metres from the ground. Again, they must record their result.
- Finally, using the carbon table in Student Sheet 2, students estimate the kg of carbon stored in their tree. They need to find the circumference of their tree in the left-hand column, the height of their tree on the top row, and then find where they intersect which shows the amount of carbon stored in their tree in kg. To convert carbon into carbon dioxide simply multiply by 4.

With this information, students can estimate the number of trees required to absorb all the annual CO_2 emissions from cars. They will need to know the average emissions per vehicle per year which is 121g of CO_2 per kilometre for new cars, the average car drives are 12,231 km/year and the total number of cars which is 32.5 million.

But how much space will these trees require? Forestry Commission guidelines suggest planting 1600 broadleaved trees per hectare or 2500 conifers per hectare. How much space will be required each and every year? How long will it take until all the land mass of the UK is planted with trees, and where do the humans go?

Main 2: Thinking Hats

Use Thinking Hats to explore the results and considering their response.

Split the students into groups according to a 'thinking hats' perspective in order that they can more deeply analyse the impact of planting trees on an urban environment. This is a 'critical thinking' tool developed by Edward De Bono. It involves using a 'hat' (metaphorical or real) to encourage thinking about an issue with a specific focus. There are six thinking hats in total with each hat offering a different focus. From the results of our trials we have decided to include some teacher 'facilitating questions' to guide the students to think in this way. See Student Sheet 3.

Introducing the article below (see web link) could also spark some discussion; it can sometimes be difficult for students to think of the negative impacts of planting trees. For example, here the trees were seen to detract from the beauty of the church and some thought it created a 'dark gloomy' atmosphere.

https://www.leicestermercury.co.uk/news/leicester-news/plans-fell-trees-make-gloomy-581064

Continued on page 9...

Lesson structure (Continued)

This decision was eventually reconsidered, but it remains controversial. Manchester City Council is part of the Northern Forest project and their 'City of Trees' website has many resources around the themes of Trees in Cities.

https://www.cityoftrees.org.uk/why-trees

Red hat - Feelings and emotions
- Based upon my emotions, do I think this is a good idea?
- How do I feel about these approaches/ these ideas?

White Hat - Information and Facts
- What facts, data, and information do we have?
- What facts, data, and information do we need?
- What information is missing?

Yellow Hat - Positives and strengths in relation to the issue being considered
- What are the strengths of these ideas
- What are the positive benefits.

Black hat - Problems in relation to the issue being considered
- What are the weaknesses?
- What may go wrong if we implement these ideas?
- What are the potential problems?

Green Hat - Creativity and new ideas
- What alternative solutions are possible?
- Could a recommendation be done in another way?
- What is a unique way of looking at the issue?

Blue Hat - Planning and organising ideas
- Where do we start?
- What things should we do first?
- What could be the 'action plan' and next steps for these ideas?

Each of the 'hat groups' feeds back their results to the whole group.

Student Sheet 1 - How to find the height of a tree

There are a variety of methods to do this using the skill processes of estimating, measuring and calculating.

Method 1

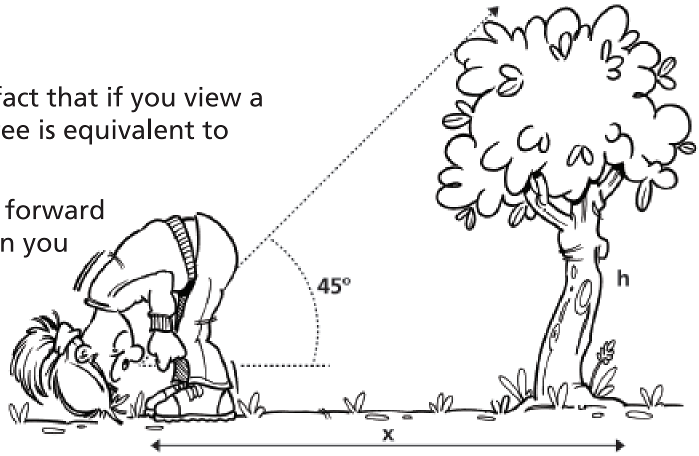
The simplest way is by estimating the height just by looking at the tree from a distance or comparing it with surrounding structures whose height is known. Children can do this initially and it will indicate how aware they are of the order of magnitude of the size of objects.

Once recorded they can then use increasingly sophisticated methods to improve their accuracy.

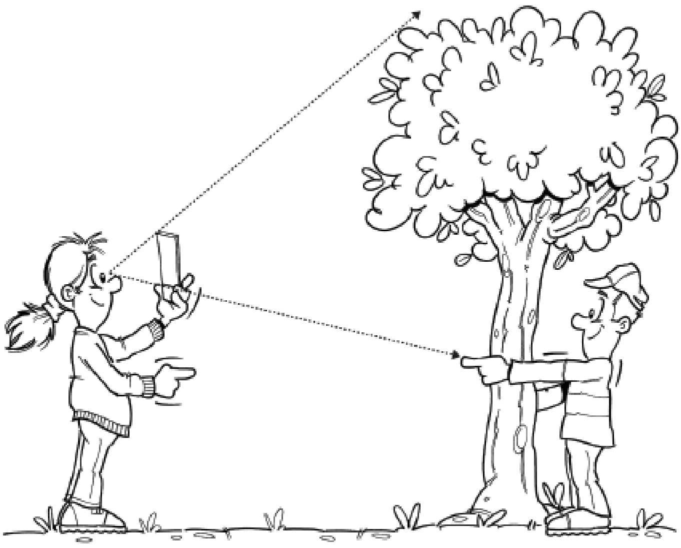
Method 2

This relies on trigonometry (and suppleness!) and the fact that if you view a tree top at a 45 degree angle then the height of the tree is equivalent to the distance that you are from that tree.

Walk away from the tree but at regular intervals bend forward and look through your legs back to the tree. Stop when you are at a point where you can just see the top of the tree and measure the distance along the ground from the tree to you. This is roughly equal to the tree's height.



Method 3



Ratio stick. Cut a strip of card so that it is exactly 30cm long and approximately 3-4 cm wide. Exactly 3cm from the bottom draw a line or arrow across the whole width. You are now ready to calculate tree heights.

In pairs, one person stand by a tree, the other with the card move away from the tree. Hold the card at arms length in front of your eyes until the top of the card is seen to just cover the top of the tree and the bottom is in line with the ground. Now direct the person by the tree to place their hand on the trunk and move it up and down until it is in line with the 3cm mark on the card. Return to the tree and measure the distance of the person's hand on the trunk from the ground.

As the hand was 1/10 along the card (3cm line is a tenth of 30 cm), the tree height must be 10X the distance measured between the ground and the hand.

Method 4

This is a method for a sunny day. Place a metre ruler upright on the ground and locate its shadow. Along the length of the shadow place a piece of ribbon or tape. This is now a "shadow metre" and can be used to measure the shadow of the tree in metres. But remember this will only work at this instance in time as the shadow metre will change with the time of day and the season. So to be really accurate mark the tip of the tree's shadow at the same time as you make the shadow metre. It may be interesting to try this at different times of the day or the year to see the variation and direction of shadows.

Method 5

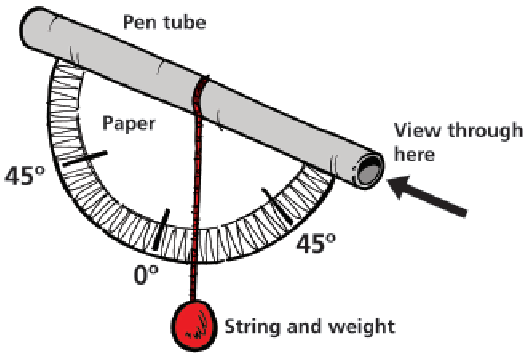
Make a clinometer. This is a device that also relies on trigonometry. A simple model can be made with a paper plate, a straw (or empty pen tube), some string and a weight (plasticine/washers).

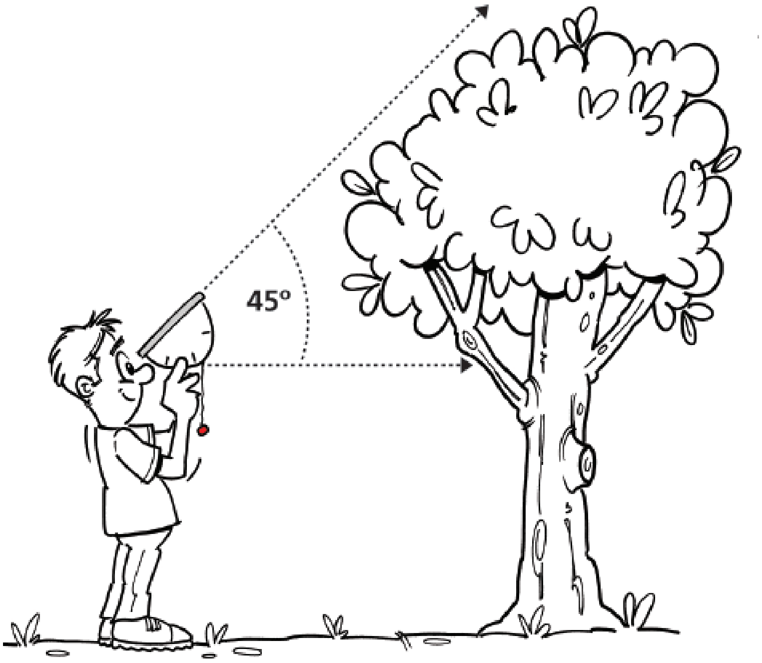
Cut the plate in half and glue a straw or an empty pen tube along the cut edge. This is a sighting guide. Exactly half way along the cut plate edge stick a piece of string with a weight on the end so that it dangles beyond the edge of the plate.

Continued on page 11...

Method 5 (continued)

You now need to be able to find the line that is 45º to the straw. If there is a pattern of crenulations along the outer curved edge of the plate it may be possible to calculate this position. Count the crinkles and locate the middle one. A line from here to where the string is attached will be 0 degrees. A position exactly half way between 0 degree and the cut edge of the plate is 45 degrees. Alternatively use a protractor (in fact the clinometer can be made using a protractor to replace the paper plate).



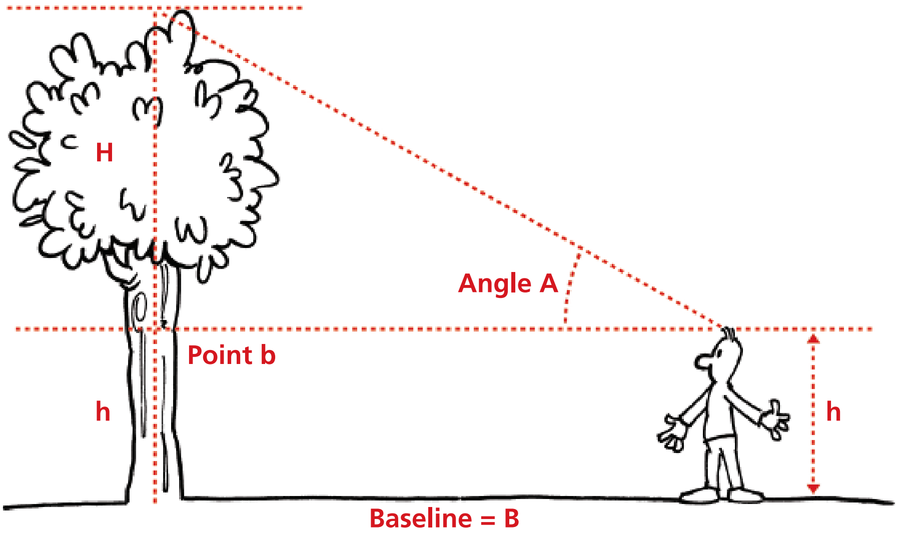


Now look through the straw so that the treetop is visible. Walk backwards away from the tree keeping the top in the sights. Your partner will need to follow you and note when the weighted string lines up with the 45 degree line. Stop and measure the distance that you are from the tree. This distance is equal to the height of the tree less your height. So find out how tall you are, add this to the distance from the tree and you have an accurate measurement of the tree height.

In this diagram (courtesy of Offwell Woodland & Wildlife Trust at www.countrysideinfo.co.uk) if angle A = 45º then H=B. So to find the tree height, (H+h) you must add B+h.

Tree height = B + h

Ideally pupils could try some, or all, of these methods to determine the accuracy of each one.



Student Sheet 2 - carbon conversion factors

Needle-leaf Tree Carbon Calculator

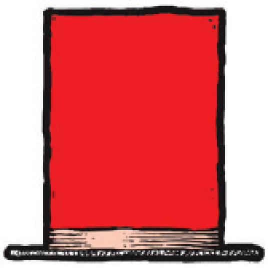
Needle-leaf / Carbon calculator / kgC

Height of your tree (in metres)

Circumference of your tree (in centimetres)	1-2	3-4	5-6	7-9	10-12	13-15	16-18	19-21	22-24	25-30+
Up to 10cm	1									
11-13	1	2								
14-17	2	2	3							
18-21	3	3	4	4						
22-28	5	4	6	7	7					
29-39	7	9	10	10	11	12				
40-54	17	19	22	23	25	27	29			
55-70	31	34	39	42	46	49	53	56		
71-94	49	54	61	66	73	78	83	88	93	
95-125		111	122	131	145	155	165	175	184	200
126-157			206	220	242	259	275	290	305	331
158-188			315	334	360	388	411	428	451	491
189-219			448	472	508	544	567	601	632	686
220-250			607	639	684	731	772	808	848	919
251-282				833	890	948	1001	1047	1099	1187
283-314				1057	1127	1198	1263	1322	1386	1494
>315 cm					1395	1481	1559	1632	1709	1840

Adapted from BBC Terrific Science

Student Sheet 3 - Thinking Hats

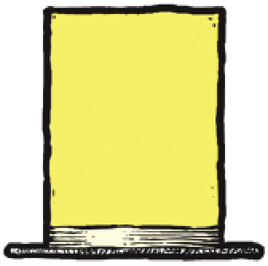


Red hat - Feelings and emotions

- Based upon my emotions, do I think this is a good idea?
- How do I feel about these approaches/ these ideas?

White Hat - Information and Facts

- What facts, data, and information do we have?
- What facts, data, and information do we need?
- What information is missing?



Yellow Hat - Positives and strengths in relation to the issue being considered

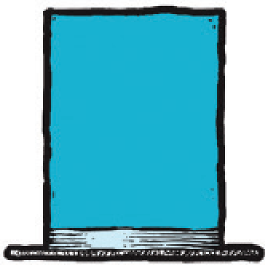
- What are the strengths of these ideas
- What are the positive benefits.

Black hat - Problems in relation to the issue being considered

- What are the weaknesses?
- What may go wrong if we implement these ideas?
- What are the potential problems?

Green Hat - Creativity and new ideas

- What alternative solutions are possible?
- Could a recommendation be done in another way?
- What is a unique way of looking at the issue?



Blue Hat - Planning and organising ideas

- Where do we start?
- What things should we do first?
- What could be the ‘action plan’ and next steps for these ideas?

Inquiry based learning stage

Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	
Stage 3 - Doing and making	✓	**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. Students are able to interrogate data.
2. Students are able to reach reasoned conclusions.

Learning outcomes

1. Students explain that urban mobility links with a range of environmental issues.
2. Students demonstrate that alternative ways to move around cities can reduce impact.
3. Students present recommendations for redesigning mobility in their community.

Overview of lesson

In this lesson students interrogate a range of data about urban environmental issues linked with transport. They then explore some alternatives and consider how best their local community can be improved now and in the future.

Lesson structure

Introduction

Huge swaths of cities, either in parking lots, garages, or street parking spaces, are used as storage for cars (while, at the same time, many cities struggle to find enough land to build housing to keep up with demand).

The focus of Stage 3 are several mini-challenges for students to follow. They will need to carry out online research and use scientific evidence to support their conclusions. It is not necessary to carry out all the mini-challenges, and these could be selected to support the theme of a STEM Club or curriculum-based lessons

Main: Starting off...

The starting point is to explore the impact of transport in the student's local city. Students use the CDRC data maps to explore mobility patterns, air pollution (NO_2, SO_2, PM10, travel to work by car), etc.

https://maps.cdrc.ac.uk/#/indicators/ee_wao/default/BTTTFFT/10/-0.1500/51.5200/

Student research questions:

- What patterns and trends can students identify?
- Can they find links between air quality and mobility patterns?

One solution might be electric vehicles. There is data available online; some interesting research on emissions from electric vehicles are found in the links below:

https://www.vox.com/2015/9/25/9398063/self-driving-electric-cars

https://www.theguardian.com/environment/green-living-blog/2011/jan/17/electric-car-emissions

Student research question:

- Are electric vehicles better for the environment than petrol/diesel ones?

Main 2: Digging deeper...

Emissions and car use data is a starting point to see how cities are over-run by cars and the air pollution impacts. The next part is to explore how much cars are actually used; most of the time they simply sit still and go nowhere (90% for most cars). What if we replaced all these cars with an efficient mobile based driverless car system? You simply call a car whenever you need it.

https://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html

Student research questions:

- Evidence the time cars are used vs parked.
- How much free space could be created within cities by substituting private car ownership with on-demand electric vehicles?
- Estimate how many on-demand electric vehicles might been needed to meet demand? (note...this is hard and will stretch more able students).

Here's an article to get started:

https://www.vox.com/a/new-economy-future/transportation

You could extend this activity into design and engineering to discuss the design of on-demand electric vehicles, or into the electronics for electric vehicles. Some useful solar vehicle information for schools can be found at:

https://www.greenpower.co.uk/

https://www.teachengineering.org/activities/view/duk_solarcar_tech_act

Continued on page 16...

Lesson structure (Continued)

Main 3: Making sense of our findings...it's the system

The enormous bulk of the potential lies not in replacing units in today's transportation system, but in generating new systems. It is the system benefits that are at once most difficult to predict and most rich with possibility. The final part is 'what to do with the spare road space?' Can this be a way to create more green corridors for walking and cycling? More play spaces? Areas for markets and pop-up shops? So, reducing car use has a positive impact on air pollution and climate change, and creates space for more fruitful community uses.

Student research question:

- How much free space can we claim back from cars?
- How would you redesign your community? Here is some inspiration. Produce a street plan.

https://www.vox.com/a/new-economy-future/cars-cities-technologies

Plenary

The messy wall created at Stage 1 can be updated with all the new information gained.

Inquiry based learning stage

Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	✓

Learning objectives

1. Students are able to communicate their results.
2. Students can apply a range of communication techniques.

Learning outcomes

1. Students select an appropriate communication technique.
2. Students present their results using their chosen technique.
3. Students critique the work of others.

Overview of lesson

In this lesson students think about how to communicate their results. They consider a range of options and then select the most appropriate. After communicating their own results, they listen to and provide constructive feedback to other groups.

Lesson structure

Introduction

Now that students have researched urban mobility, they need to present their results. If possible, invite a representative from the local government transport department to review their work and offer feedback.

Main 1: Presenting results and peer assessment

Students consider how to present their results. This is a generic list of ways students can consider.

- **Poster** - create a poster communicating your results and making recommendations for the café; the poster could include a picture of the café based on your recommendations.
- **Film** - create a 5-minute film communicating to the café owners how you carried out your research and the results; you could include interviews with potential customers..
- **Presentation** - deliver a 5-minute presentation for the café owners.
- **Report** - write a report laying out your recommendations and evidence.
- **Other** - add your own suggestion.

Use a 'plus – minus – interesting' table to peer review the results (see Student Sheet 4)

Main 2: The iceberg

Student might ask if some of their ideas are realistic, or why change is not happening fast enough. This requires some deeper digging into what drives and affects change. One useful model for this is the Iceberg Model (see Student Sheet 5).

- Trends and patterns:
- Can you see any positive trends towards improved urban transport?
- How about more electric cars? Autonomous vehicles?
- What about new inventions that nobody talked about 5 years ago?
- Do you feel that there are positive trends taking place? Are policy makers and politicians talking about these things too?

Underlying structures:

- Is climate change starting to affect how we act and take decisions?
- Are working habits changing the way we travel?

Mental models:

- Are we prepared to change the way with think about our freedom to own a car and use it whenever we like?

Plenary

Ask students to share their reviews of each presentation. Groups can review their work and consider ways to improve it in the future.

Student Sheet 4 - Review form

Use the table below to note your comments on each presentation.

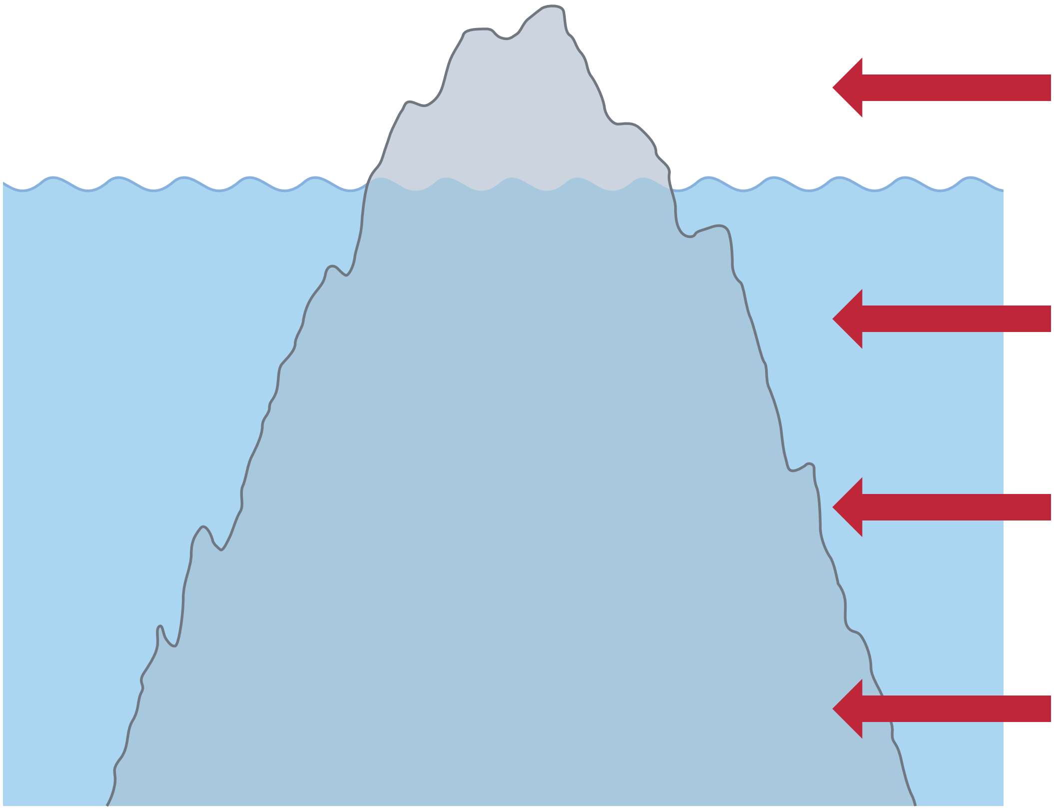
Positive: In this step, simply enumerate all of the positive things you can think of. Don't be critical, simply spill out all the positive points that you can think of.

Minus: In this step, enumerate all of the negative things you can think of. Again, don't be critical, simply spill out all the negative points you can think of.

Interesting: In this step, enumerate all the interesting points that you can think of. Rather than positive or negative, they are simply points of interest to you.

Positive	Minus	Interesting

Student Sheet 5 - The Iceberg



Events: What is happening?

Patterns & Trends: What trends have there been?

Underlying Structures: What influences the patterns?

Mental Models: What assumptions or beliefs and values do people have about the system?

Annex 1 - Key Stage 4 Working Scientifically Statements

Through the content across all three disciplines, students should be taught so that they develop understanding and first-hand experience of:

1. **The development of scientific thinking**
    a. the ways in which scientific methods and theories develop over time.
    b. using a variety of concepts and models to develop scientific explanations and understanding.
    c. appreciating the power and limitations of science and considering ethical issues which may arise.
    d. explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments.
    e. evaluating risks both in practical science and the wider societal context, including perception of risk.
    f. recognising the importance of peer review of results and of communication of results to a range of audiences.
2. **Experimental skills and strategies**
    a. using scientific theories and explanations to develop hypotheses.
    b. planning experiments to make observations, test hypotheses or explore phenomena.
    c. applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments.
    d. carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.
    e. recognising when to apply a knowledge of sampling techniques to ensure any samples collected are representative.
    f. making and recording observations and measurements using a range of apparatus and methods.
    g. evaluating methods and suggesting possible improvements and further investigations.
3. **Analysis and evaluation**
    a. applying the cycle of collecting, presenting and analysing data, including:
        i. presenting observations and other data using appropriate methods.
        ii. translating data from one form to another.
        iii. carrying out and representing mathematical and statistical analysis.
        iv. representing distributions of results and making estimations of uncertainty.
        v. interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.
        vi. presenting reasoned explanations, including relating data to hypotheses.
        vii. being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.
    b. communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations.
4. **Vocabulary, units, symbols and nomenclature**
    a. developing their use of scientific vocabulary and nomenclature.
    b. recognising the importance of scientific quantities and understanding how they are determined.
    c. using SI units and IUPAC chemical nomenclature unless inappropriate.
    d. using prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano).
    e. interconverting units.
    f. using an appropriate number of significant figures in calculations.