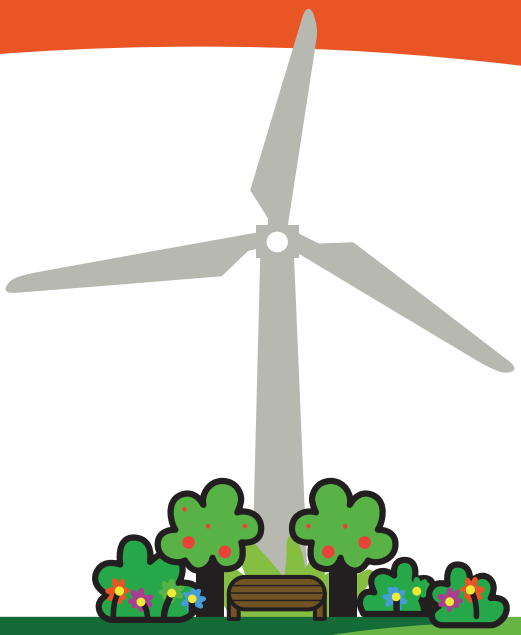
urban science



Breathless

Air pollution is still an issue which blights many cities. Students will interrogate data to understand this key issue, and work with friends and family to present science-based solutions.

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

Learning challenge:

Air quality is a major concern for cities. Air pollution seriously affects human health, with potentially deadly and debilitating effects. Good air quality is essential for the ecosystems on which cities depend. Air pollution represents a serious threat not only to the environment but also to a country's economy.

During spring 2020, the COVID-19 pandemic dramatically slowed world economic growth and had a big impact on air pollution levels across the globe. This was plotted by one of the world's most extensive air data archives run by the UK's Department of Environment Food and Rural Affairs (DEFRA) – 'The Air Data Archive'. Citizens in communities across the globe need to make sense of this data and what this means for future air quality.

During this module students will be given the opportunity, after learning more about the topic of air pollution, to look at global, national and local data and think about community solutions. Throughout they will be encouraged to engage friends and families in their communities in learning about the issues and solutions. There is a strong emphasis on data collection and, by following the successful examples of UK schools in London and Leicester, adding to the solutions and their own local data sets.

This learning module can be used flexibly within the curriculum to support key knowledge about chemistry 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.

www.urbanscience.eu

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

To deliver this module we recommend:

- Start with the Stage 1 activities to elicit current student knowledge and generate interest in the topic.
- Stage 2 encourages students to gather and check data, and start reflecting on what it means to them.
- Stage 3 is the practical challenge where students collect data about air pollution around their school.
- In Stage 4 you will provide suggestions for sharing and presenting results.

Subject

Biology	Chemistry	Physics	Raising Attainment
	✓		✓

Programme of Study reference

1. Chemistry	Earth and atmospheric science • common atmospheric pollutants: sulphur dioxide, oxides of nitrogen, particulates and their sources.	2. Working scientifically	Students successfully completing this module will have had the opportunity to access these statements: 1c,1d,3ai,3aii,3aiii,3av,3avi,3avii. See Annex 1 for full statements.

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/

This module has strong links to SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable, and SDG 12: Responsible consumption and production.

Activities Overview

Stage 1	Time (mins)	Resources needed
Inspirational Videos	10 mins	None required
5-Whys	10 mins	None required
Data Race	30 mins	Student Sheet 1
Plenary	10 mins	None required

Stage 2	Time (mins)	Resources needed
Fact Checking	10 mins	None required
Where Is the Impact?	20 mins	None required
De Bono Thinking Hats	20 mins	Student Sheet 2
Filter for Focus	10 mins	None required

Stage 3	Time (mins)	Resources needed
Writing a Science Report	10 mins	Student Sheet 3
School Air Pollution Survey	40 mins	See individual experiments for resource needs
What Next – the Action Plan	10 mins	Student Sheet 4

Stage 4	Time (mins)	Resources needed
The Science Report	20 mins	None required
Presenting Results	40 mins	Student Sheet 5

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

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

STAGE 1 - Houston…we have a problem

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 understand that they have 'something interesting to say' about the topic of air pollution and are listened to.
2. Students are able to find out information relevant to the topic.
3. Students can make predictions about their future.

Learning outcomes

1. Students make observations in their community.
2. Students ask questions about their observations.

Overview of lesson

In this lesson students start to explore local and global air pollution levels. They learn how to find out about air pollution: what are air pollutants, what causes them, what does this mean for health? They link this to chemistry knowledge on atmospheric pollution. They take this knowledge home as they are given the opportunity to play 'air pollution bingo' with family and friends, thus recognising the importance of a community response to these issues.

Lesson structure

Introduction: Inspirational videos

This topic is introduced by showing this thought provoking video produced by the Guardian newspaper.

www.youtube.com/watch?v=i915nt8c3yU

" Most of Britain's cities have had illegally polluted air for nearly a decade and the effect of air pollution is particularly bad on children. Ahead of Clean Air Day, we conducted an experiment to assess the air quality on a school run in central London, using new state-of-the art monitors that can measure air pollution in real time."

(The Guardian, June 2019)

Next show this unique time lapse video produced by the University of Leicester during the COVID-19 pandemic. It shows time lapse imagery from the University of Leicester. It reveals startling reductions in air pollution. Scientists were plotting nitrogen dioxide emissions from power stations. After lockdowns started happening around the world due to COVID-19, they adapted their model to see the affect lockdowns were having on air pollution. The images show a stark and 'breath taking' reduction in emissions over a few short weeks.

https://le.ac.uk/news/2020/april/07-air-quality-plots

Main 1: 5 Whys

After watching the videos, it is important that the students talk about the issues. The following technique can be used to help them process this information and delve into why the COVID-19 lockdown has had such an impact on air pollution and start to consider how they might take action

This is a simple technique to get students asking questions. The aim is to ask 'why' questions in response to five consecutive answers. For example:

Q: Why do you exercise? A: Because it's healthy.

Q: Why is it healthy? A: Because it's good for me.

Q: Why is it good for you? And so on.

The technique can encourage students to examine and express the underlying reasons for their behaviour and attitudes. It promotes an enquiring stance and challenges students to examine their thinking and reasoning.

Main 2: Data Race

In this very active activity students race to be the first ones to get the answers to a series of questions on atmospheric air pollution (see Student Sheet 1). This activity aims to ensure that the student's knowledge about atmospheric pollution is accurate and allows the teams to start to discuss solutions.

The teacher sets students off on a 'race' to find out key bits of information on this topic. It is important to set a suitable time limit. The BBC Bitesize website has a good section based on this aspect of their GCSE course.

http://www.bbc.co.uk/bitesize/guides/zxy4xfr/revision/6

The activity is a quick way of gathering and sharing information about the topic. It can lead to discussions about the nature of information and data sources, and the teacher can raise questions about the accuracy and sources of the information, and suggest other ways of approaching the topic. This can be a useful mechanism for ascertaining the level of knowledge on a particular topic. It is also a good and efficient mechanism for getting students to find knowledge in a short period of time.

Continued on page 6...

Lesson structure (Continued)

The instructions below can be placed onto a PowerPoint slide.

- At the word 'Go', one person from each group takes a card from the teacher, takes the first question only and takes it back to the group.
- You can answer your question using your own knowledge, or by searching

  www.bbc.co.uk/bitesize/guides/zxy4xfr/revision/6

- Write down the answer on a separate piece of paper; a second person takes this to the teacher.
- The answer is checked. If it is accurate and complete, the second question is collected...and so on.
- If any answer is inaccurate or incomplete, the 'runner' will be sent back to the group to try again!
- The first group to complete all the answers 'wins'.

Plenary

Students who have previously completed an Urban Science module will be used to setting up a 'messy wall'. The recent 'Clean Air Campaign' undertaken by Friends of the Earth has some useful resources and techniques.

https://cdn.friendsoftheearth.uk/sites/default/files/downloads/Clean%20Air%20Schools%20Pack_web%20version%202018.pdf

At this stage we recommend the following sections:

- The diagrams on page 4 are an excellent diagrammatic representation of the key elements of air pollution and so are good for a 'messy wall'.

Homework:

- We recommend Clean Air Bingo (page 11) as another opportunity for students to discuss these ideas with others, this time at home.

Student Sheet 1 - Data Race

Q: What happens when fuels are burned?	**Q: Carbon dioxide is an atmospheric pollutant, where does it come from?**
Q: Carbon monoxide (CO) is an atmospheric pollutant, where does it come from?	**Q: Particulate carbon (C, soot) is an atmospheric pollutant, where does it come from?**
Q: Unburned hydrocarbons are atmospheric pollutants, where do they come from?	**Q: Sulphur dioxide (SO_2) is an atmospheric pollutant, where does it come from?**
Q: Nitrogen oxides (NOx) are atmospheric pollutants, where do they come from?	**Q: How is sulphur dioxide pollution created?**
Q: How does sulphur dioxide cause acid rain?	**Q: What are the effects of acid rain?**
Q: Why is NOx gas a pollutant?	**Q: How is NOx gas made?**

Student Sheet 1 - Data Race

Source for answers - https://www.bbc.co.uk/bitesize/guides/zxy4xfr/revision/6

Q: What happens when fuels are burned?

A: A number of atmospheric pollutants are produced.

Q: Carbon dioxide is an atmospheric pollutant, where does it come from?

A: Complete combustion of any fuel containing carbon atoms.

Q: Carbon monoxide (CO) is an atmospheric pollutant, where does it come from?

A: Incomplete combustion of any fuel containing carbon atoms.

Q: Particulate carbon (C, soot) is an atmospheric pollutant, where does it come from?

A: Incomplete combustion of any fuel containing carbon atoms.

Q: Unburned hydrocarbons are atmospheric pollutants, where do they come from?

A: Hydrocarbon fuel molecules which have not been oxidised.

Q: Sulphur dioxide (SO_2) is an atmospheric pollutant, where does it come from?

A: Combustion of a fossil fuel which contains sulphur impurities.

Q: Nitrogen oxides (NOx) are atmospheric pollutants, where do they come from?

A: Oxidation of atmospheric nitrogen inside the engine of a car, lorry, etc.

Q: How is sulphur dioxide pollution created?

A: This is produced when sulphur atoms which are present in some fossil fuels are oxidised.
Super answer: describe the equation.

Q: How does sulphur dioxide cause acid rain?

A. Sulphur dioxide is further oxidised in the atmosphere to sulphur trioxide (SO_3). This gas dissolves in rainwater to make acid rain, which is a dilute solution of sulfuric acid (H_2SO_4).

Q: What are the effects of acid rain?

A: Acid rain harms and kills plants and animals, especially those that live in aquatic environments. It can also damage man-made objects like statues and buildings.

Q: Why is NOx gas a pollutant?

A: NOx gases can cause acid rain, and they also react in the atmosphere with other pollutants to make photochemical smog. Smog can have major health effects, causing asthma attacks and even death.

Q: How is NOx gas made?

A: Nitrogen is not present in fuels, but the high temperatures and pressures inside a car engine can cause the nitrogen and oxygen in the air to react together to make oxides of nitrogen.

STAGE 2 - Breathe deeper

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 distinguish between facts and opinions.
2. Students are able to express their own views and justify them.
3. Students can interrogate a range of opinions.

Learning outcomes

1. Students research and analyse a range of viewpoints.
2. Students test evidence for themselves.
3. Students know about the common atmospheric pollutants: sulphur dioxide, oxides of nitrogen, particulates and their sources.

Overview of lesson

In this lesson, students delve deeper into the topic of air pollution, hopefully inspired by the changes in air pollution levels during COVID-19. They will start to plan and think about how to measure air pollution in their local environment and how they can push for change nationally.

Lesson structure

Introduction: Discuss their 'bingo' homework from last session.

- Did they find that parents and friends knew as much as they did about air pollution?
- Were they surprised by the recent data on COVID-19?

Main 1: Fact checking

Introduce the air pollution fact sheets. It is a good idea to have these on the 'messy wall' (see plenary below).

https://schools.leicester.gov.uk/media/5696/fact-sheets.pdf

Students start the completion of this table.

https://schools.leicester.gov.uk/media/5724/pollutants-summary-table-to-complete.pdf

They are unlikely to finish this. It is intended as an ongoing activity during this and the next few sessions. It does contain all the necessary information for this aspect of their GCSE syllabus and is a great summary for revision.

These fact cards are taken from the extensive set of resources set up by the Leicester City Council Environment Team.

Main 2: Where is the impact?

This activity sets students atmospheric air pollution knowledge into the context of the COVID-19 lockdown of 2020.

The Primary Science Teaching Trust (PSTT) in collaboration with the Royal Society of Chemistry have produced an excellent set of slides that form the basis for an exhibition (slides 3-12). Despite the name the PSTT resources are also aimed at secondary aged students. They aim to allow students to investigate atmospheric pollution using the Defra Air Data Archive.

https://pstt.org.uk/resources/curriculum-materials/citizen-science-air-pollution

'This 'stand-alone' classroom presentation provides a brief look at levels of air pollutants in cities around the UK before and after the COVID-19 lockdown was introduced on 23 March 2020. Slide notes give background information and answers to questions that you might ask the children.' (Primary Science Teaching Trust)

Sourcing local photographs would also add a great context to the exhibition. There are many powerful images on Instagram, Pinterest and in local newspapers, for example

www.leicestermercury.co.uk/news/leicester-news/amazing-effect-coronavirus-lockdown-leicesters-4037671

Main 3: De Bono thinking hats reflection

Split the students into groups according to a 'thinking hats' perspective in order that they can more deeply analyse the exhibition and the implications for UK air pollution. 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. Also included are some teacher facilitation questions to guide students to think in this way. See Student Sheet 2.

Continued on page 11...

Lesson structure (Continued)

Red hat – Feelings and emotions.

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

Creating a poster based on their thinking hats – students document their thinking hats discussions in the form of a poster. They share this with the rest of their class.

Plenary

From their poster discussion, students use the 'filter focus' technique to start to think about what they want to do about this issue. As described in the learning challenge for this module, our focus is about the evidence for local air pollution, getting more data and then how to use this evidence. This technique should clarify why and how they will go about this. However, it might take some facilitation to enable this to happen effectively.

Filter for focus:

- In pairs or groups students work together to agree the top five most important words gathered from the group presentations.
- When ready, each group takes it in turns to write their key items on the board.
- Other groups do the same, but can only add words that are not already there.

The activity encourages students to focus on the most important aspects of this topic. When it works well, it can help students to clarify their understanding of the essential features of this theme.

Students add their filter focus phrases and their thinking hats posters to their messy walls.

Homework

History timeline to play at home:

https://schools.leicester.gov.uk/media/6125/ks-2-histroy-lesson-timeline-cards.pdf

This is another opportunity for students to share their learning at home.

Student Sheet 2 - De Bono Thinking Hats

Red Thinking Hat - Feelings

- How does this exhibition make you feel?
- What do I like about it?
- What don't I like about it?
- What are my likes, dislikes, worries, concerns etc?

White Thinking Hat - Information and Facts

- What information do I have?
- What are the facts?
- What information do I need?
- What do I want to know?

Yellow Thinking Hat - Strengths

- What are the good points of the exhibition?
- Why can we do this?
- Why is this a good thing?
- What are the strengths/ benefits?

Black Thinking Hat - Problems and Limits

- What is wrong with these?
- Will they work?
- Are they safe?
- Can it be done?

Green Thinking Hat - Creativity & New Ideas

- What new ideas are possible?
- What is my suggestion?
- Can I create something new?
- What are the weaknesses?

Blue Thinking Hat - Planning and Managing

- Do you know of any such buildings?
- Where are we now in this school/in the UK?
- What are the next steps to get more?

STAGE 3 - Measuring local air pollution

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 plan and carry out an investigation.
2. Students can use primary and secondary data to understand an issue.
3. Students can recognise and consider limitations in their method.
4. Students can apply their scientific knowledge to a local context.
5. Students can work collaboratively and communicate their results with others.

Learning outcomes

1. Students co-operate with others by taking part in activities that lead to a 'science report'.
2. Students plan and carry out surveys to collect primary data.
3. Students interrogate secondary data to find trends and patterns of change.
4. Students make recommendations based on their research.

Overview of lesson

Students plan and research what they need to know about plotting air pollution around their school. This is in response to a letter from their local authority air pollution team. Students assess levels of air pollution through a range of tests. It is possible to complete the planning within one session by spreading the tasks across a number of student teams. However, these are tests that need to be carried out over time and these Stage 3 activities could last several weeks. Setting up the data collection is not time consuming, and it is possible to return to find the results later.

Lesson structure

Introduction: Writing a science report for their local authority

Describe and discuss a letter received from the local authority air pollution team (see Student Sheet 3). This asks for help in both carrying out school air pollution surveys and also for ideas to change the behaviour of their community towards air pollution. A good example to describe is the 'idling campaign' carried out by students in Leicester city schools:

www.leicestermercury.co.uk/news/leicester-news/leicester-kids-take-drivers-who-2348790

The actual activities carried out will depend on the time and funding available to the school. It is possible for all students to carry out some basic activities and hopefully additional funding will offer more opportunities. Students can also learn from the experiences of other students that have taken part in longer term projects. We have summarised the main UK air pollution school activities currently available and where support can be found. In addition, this guide produced by the National Education Union is a good background to the issues for all who work in city schools.

https://neu.org.uk/media/3246/view

It is also important for students to understand what writing a science report means. At a minimum the 'class report' should include:

Section 1: Background science information.

- Could include the table from Fact Checking (Stage 2) or the results of student De Bono thinking hats.

Section 2: Results from their surveys (see plenary below).

Section 3: The class/school action plan (see plenary below).

Section 4: Key resources used, for example:

- Cleaner Air 4 Schools: a guide produced by the London Sustainability Exchange.

https://www.london.gov.uk/sites/default/files/ca4s_toolkit.pdf

- Air quality education resources produced by Leicester City Council.

https://schools.leicester.gov.uk/services/environment-health-and-well-being/air-quality-education/air-quality-education-resources/

- Friends of the Earth Clean Air Project

https://friendsoftheearth.uk/clean-air/results

- National Education union 'Air pollution guidance for school and college staff'

https://neu.org.uk/media/3246/view

- PSTT Air Pollution Research

https://pstt.org.uk/resources/curriculum-materials/citizen-science-air-pollution

Main 1: School air pollution survey

This is a summary of air pollution tests that can be carried out by school students. We have included links about how to do these and have included some results where they have been undertaken in the past. We recommend students work in small groups and feedback their results to the rest of the class. These will be added to the 'Local Authority Report'.

Continued on page 15...

Lesson structure (Continued)

There are a number of current or recent projects involved in measuring school air pollution. The following are both produced by local authorities and are excellent. They give good guidance to the background science and review suitable monitoring activities for school students.

1. Choose How You Move: air quality experiments and guides for home and school. This was produced by the Environment Team at Leicester City Council during the COIVD-19 lockdown. As a result, many of the activities are useful for a 'blended learning' experience.

www.choosehowyoumove.co.uk/wp-content/uploads/2020/04/Air-quality-experiments-and-activities-for-home-and-school-v6.pdf

2. Cleaner Air 4 Schools: a guide produced by the London Sustainability Exchange.

www.london.gov.uk/sites/default/files/ca4s_toolkit.pdf

Low/no cost activities

The Cleaner Air for Schools link provides detailed information on each of the tests below (see page 23 onwards).

Bio indicators of pollution – Lichen and tar spot fungus.

These surveys look both for lichens that are known to grow particularly well when they are close to sources of ammonia and nitrogen oxides, and those that do not like excessive nitrogen in any form. They are well known indicators of air quality. Tar spot fungus is also a good indicator. The Opal surveys are the activities mostly quoted and used in schools.

http://www.opalexplorenature.org/airsurvey

Although schools cannot now enter their results, the data is a great repository of useful local data for them to explore.

http://www.opalexplorenature.org/dataexplorer/

Particulate emissions measurement

- **Air pollution catchers**
  Student's look at soot particles under a hand lens. Although often used with very young students, this is a useful activity for older GCSE students if they are tasked with evaluating whether the results are accurate and how they can be improved.
- **Surface wipe analysis**
  Another survey for particulate emissions. As before, this activity can be used with older students if they analyse the format/results and look for modifications.

Delving deeper – more complex surveys

The following activities are more costly, but students will get meaningful results that can add to the local air pollution data set. Some schools have undertaken fund raising to make them happen and several Local Authorities have given grants.

- **Ghost wipes**
  These are used to monitor air quality in schools by measuring the amount of heavy metals in air-borne particulate pollutants (such as lead, beryllium, cadmium, zinc and other harmful elements) that collect on surfaces. These provide an accurate measure of harmful pollutants in the air. The cost is £700 for 15 sites with 30 samples.
- **Diffusion tubes**
  These are primarily used to measure the levels of harmful nitrogen dioxide in the air by use of a specialised sampling tube. These provide an accurate measurement of levels of nitrogen dioxide. Recently the charity Friends of the Earth provided diffusion tubes to UK schools. Although now finished, the results from the schools are extensive and provide a brilliant data set for analysis.

https://friendsoftheearth.uk/clean-air/results

This led to the 'Air Pollution Unmasked' report. There are results for most areas in the UK so it can be a valuable analytical exercise for the students.

Continued on page 16...

Lesson structure (Continued)

Plenary : What next – the action plan.

The results from the student tests will take place over time, possibly a few weeks; flexibility is important here. However, meaningful results can happen over the course of one week for those operating a more traditional curricular style. As they arrive, they should be added to a section of their messy wall. It is also worthwhile setting a longer-term homework to run parallel to these testing sessions.

Although this link to a clean air plan is aimed at teachers, governors and school leaders, students working at this level should be able to devise and come to a consensus for their school. This will form part of their science report.

https://schools.leicester.gov.uk/media/5967/making-a-clean-air-plan-for-your-school-checklist.docx

They could use a target board evaluation (Student Sheet 4) to vote for the most popular measures.

Student Sheet 3 - Letter

Dear Students

I am writing to request your help in investigating the quality of air surrounding your school. You are no doubt aware that air pollution in urban areas is a critical health issue, and we are particularly concerned to ensure air quality levels surrounding schools is accurately assessed and plans put in place to improve it where necessary.

We would like you to help with two key tasks:

Firstly, to collect primary data about air quality surrounding your school, and to assess secondary data.

Secondly, using the data collected, create an air quality action plan including recommendations for technical and behavioural changes.

We look forward to reading your report.

Kind Regards

Air Pollution Team.

Student Sheet 4 - target board evaluation

Use the target board below to evaluate your priorities for taking action.

- the centre of the target is equivalent to a “very important” action.
- the external ring “not at all important”.

The target board, with all positioned actions, will be hung on the messy wall.

STAGE 4 - Taking action – breathe freely

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 present their report to their Local Authority representative/school leader. They can also think about how to communicate the results of their study on issues surrounding air pollution. We have aimed though this module to get students to think about and move from personal responsibilities to wider community actions.

Lesson structure

Main 1: The Science Report

Students in this session will submit their report with results to the local authority air pollution team/school leadership team. As part of the report they will present solutions and how they will campaign to reduce air pollution around their school.

See Stage 3 for the suggested report format.

Main 2: Presenting results

Here is a generic list of some activities that students could undertake after reflecting on the lessons learned.

- **Poster** - create a poster campaign communicating your results and making recommendations for their clean air community.
- **Film** - create a 5-minute film communicating to the school leaders and governors about how you carried out your research and the results.
- **Presentation** - deliver a 5-minute presentation for the school leadership team and governors.
- **Other** - add your own suggestion.

Student Sheet 5 offers feedback sheets to use during presentations.

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 5 - Review form

Review plans

This activity can be used to analyse or appraise anything in a structured way.

Student name: .....

Topic: .....

Strengths

Weaknesses

Enablers

Barriers

Opportunities

Threats

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.