urban science

The city below our feet

Students investigate the characteristics of soils, their role in role in urban environments and how soils can be preserved. They use their knowledge of the properties of soils to explore how to reduce flooding in cities.

Soils can be a good starting point to investigate ecosystems and biodiversity. Soils play a vital role in sustaining human welfare, agricultural productivity and environmental stability. The study of soil as a science has provided us with a basic understanding of the physical, chemical, and biological properties and processes essential to such a complex ecosystem.

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

Learning challenge: The city below our feet

Soil represents an essential and limited resource from which 95% of our food production is dependent and a home for living systems. Soils are increasingly under pressure from intensive agriculture resulting in reduced fertility, erosion and biodiversity loss; and if soil is unable to provide food for us?

But soils do not only provide food, they are part of ecosystems which provide ecosystem functions from flood prevention to carbon sequestration; vital in mitigating the climate crisis.

www.urbanscience.eu

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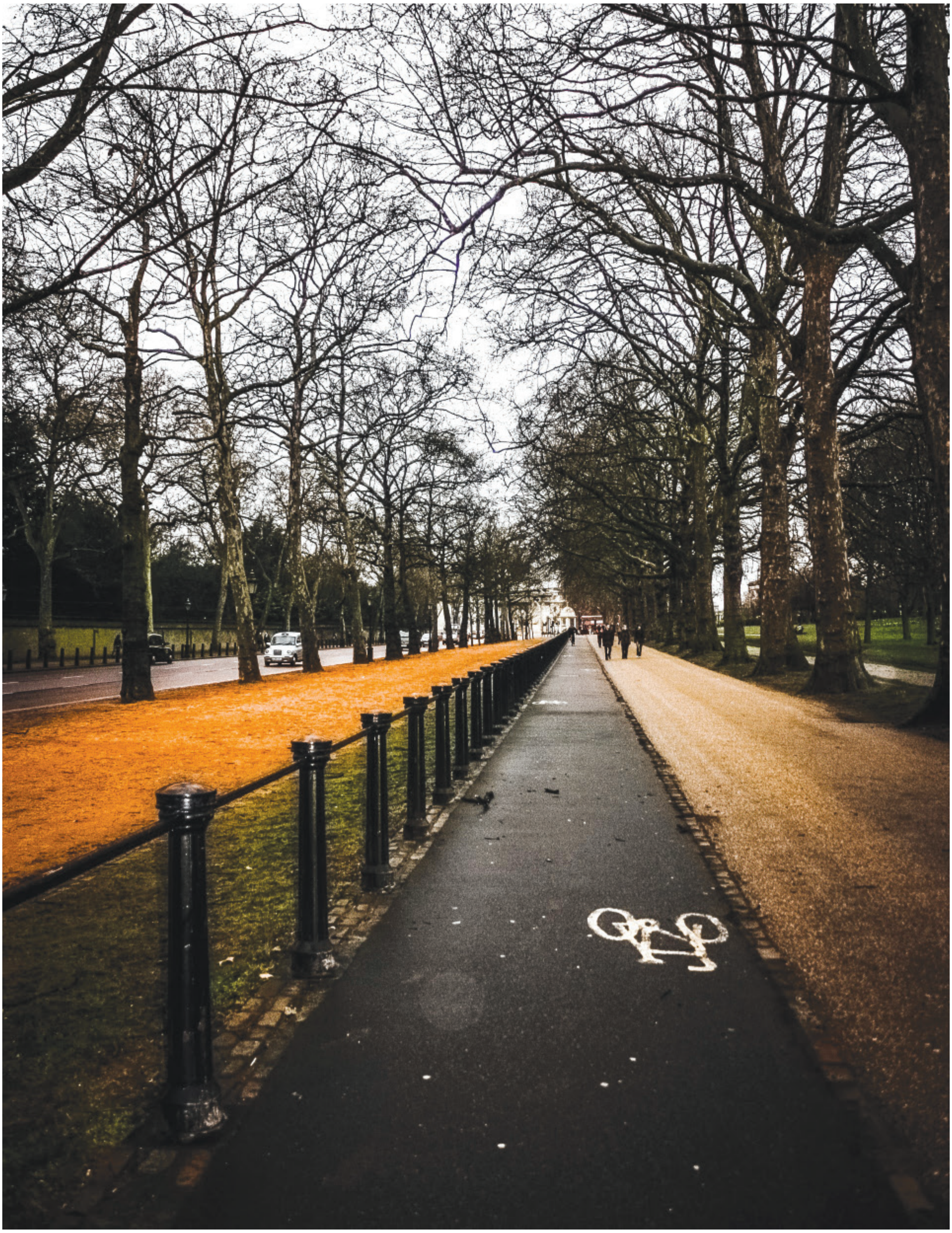
This learning module can be used flexibly within the curriculum to support key knowledge about biology and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. It is suitable for adapting as a STEM activity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

The topic of soils links with climate change through higher temperatures increasing decomposition and mineralisation of organic matter in soil, reducing fertility. Soil moisture content is also affected increasing erosion and the necessity to water crops. Links can also be made to the vital role of soils in cycling organic waste into nutrients for plants (the nutrient cycle).

Flood regulation and prevention is another one of the vital services that healthy soil delivers. Cities may come to increasingly rely on this service as extreme weather events such as floods become more frequent and severe. Permeable soil can also protect from heatwaves by storing large amounts of water and keeping temperatures down. This latter point is particularly important in cities, where hard surfaces (soil sealing) can create the 'heat island effect'.



To deliver this module we recommend:

- Start with the Stage 1 activities to set the scene and focus students attention. Start a messy wall to record student work throughout.
- Use the Stage 2 activities to introduce some basic information about soil analysis which prepares students for the Stage 3 challenge.
- Stage 3 is the practical challenge where students gather data and make conclusions.
- In Stage 4 you will provide suggestions for sharing and presenting results.

Subject

Biology	Chemistry	Physics	Raising Attainment
✓			✓

Programme of Study reference

• Biology (Key Stage 4)	**Builds on soils as an ecosystem from KS2/3** Evolution: • evolution occurs by the process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees. Ecosystems: • levels of organisation within an ecosystem. • some abiotic and biotic factors which affect communities, the importance of interactions between organisms in a community. • how materials cycle through abiotic and biotic components of ecosystems. • the role of microorganisms (decomposers) in the cycling of materials. through an ecosystem • organisms are interdependent and are adapted to their environment. • the importance of biodiversity. • methods of identifying species and measuring distribution, frequency and abundance of species within a habitat. • positive and negative human interactions with ecosystems.	• Working scientifically	Students successfully completing this module will have had the opportunity to access these statements: 1d,1f,2b,2c,2d,2f,2g, 3ai,3av,3avi,3avii,4b Some will also have completed the following: 1c,2e, 3aiv,3b,4a 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 11: Make cities and human settlements inclusive, safe, resilient and sustainable; and SDG 15: Life on land.

4 QUALITY EDUCATION · 11 SUSTAINABLE CITIES AND COMMUNITIES · 15 LIFE ON LAND

Activities Overview

Stage 1	Time (mins)	Resources needed
What is Beneath Our Feet?	20 mins plus time for walk	None required
5 Whys	20 mins	None required
A-Z	25 mins	Student Sheet 1

Stage 2	Time (mins)	Resources needed
Defining Your Study	20 mins	Tape measure, spade, trowel, collecting tray.
Soil Texture	10 mins	Print guidance notes from web-link if required.
Soil Layers	15 mins plus time for soil to settle.	Glass jar, water.
Soil Creatures	10 mins setup then 20 mins review and discussion.	Ring stand, funnel, clear plastic bottle, mason jar, rubbing alcohol, lamp.
Soil Recipe	30 mins	None required

Stage 3	Time (mins)	Resources needed
Sealing the Soil	10 mins	None required
Soil Erosion Experiment	45 mins	3 plastic bottles, soil, clear cups, wire coat hangers, scissors, mulch, sod of grass, watering can, tape, measuring jug.
Sustainable Drainage Systems	30 mins	None required
Plenary	25 mins	None required

Stage 4	Time (mins)	Resources needed
Presenting Results and Peer Assessment	50 mins	Student Sheet 2

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 - The City Beneath Our Feet

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 make observations and question their findings.
2. Students are able to research a topic.
3. Students can make links between different topics to deepen their understanding.

Learning outcomes

1. Students make observations in their community.
2. Students ask questions about their observations.
3. Students research information about soil, cities and climate change.

Overview of lesson

In this lesson students are encouraged to investigate the topic of soil by exploring their local community, making observations about its 'surfaces' and find connections between soil, cities and climate change.

Lesson structure

Introduction:

The key aim of this lesson is to introduce students to the world beneath their feet, and start connecting this with the food they eat and the air they breathe.

Main 1: What is beneath our feet?

Arrange for students to take a walk in their community; this could be done as a homework task walking to or from school. During their walk, ask students to record and describe the different kinds of surfaces they have walked on. They could estimate the proportions of each and extrapolate the results across their town or city.

In class, ask students to summarise the results of their observations; most will probably report walking on concrete, tarmac and perhaps some on grass. But what lies beneath these surfaces? (soil)

Main 2: 5 Whys

This simple technique gets students asking questions; in this case to interrogate the findings of students from the observations made during their walk. The aim is to ask 'why' questions in response to five consecutive answers.

For example: Q: Why was there a lot of concrete? A: To make pavements. Q: Why do we need lots of pavements? A: for people to walk along? Q: Why do they need to be made of concrete? A: To stop them getting muddy. Q: Why is that a problem? And so on.

The technique can help students see, examine and express underlying reasons behind a phenomenon.

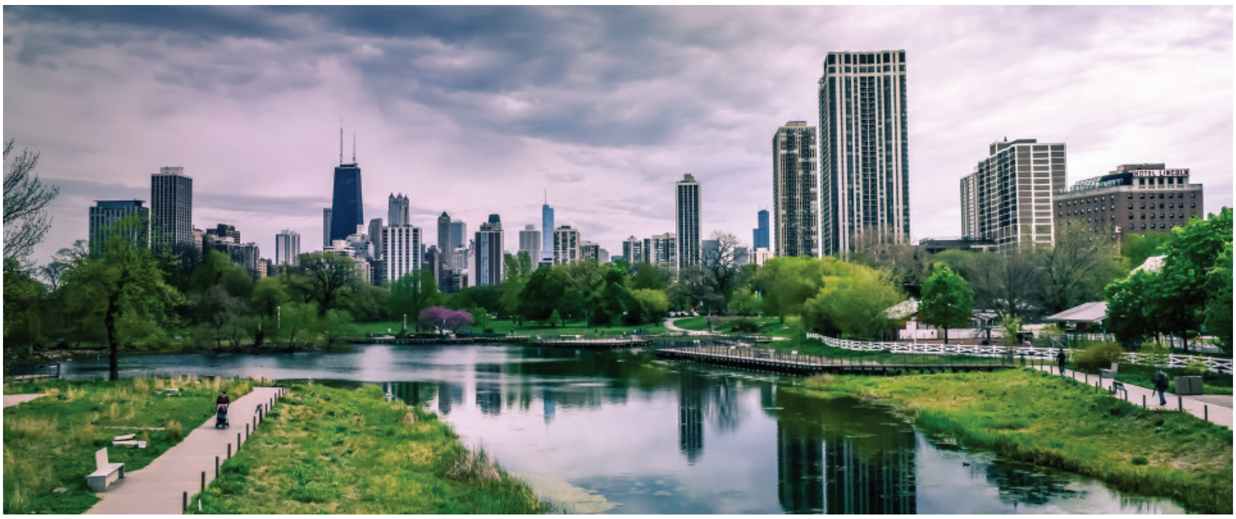
Main 3: A-Z

This activity is focused on students finding out about soils, cities and climate change. Provide students with copies of the A-Z sheet (Student Sheet 1), and ask them to complete the grid with words associated with soil, cities and climate change. They might wish to carry out some online research to help them.

When students are finished, ask them to look at their sheets and find links between as many of the words as possible. For example, the words 'erosion' and 'runoff' might be linked by the theme of flooding. The purpose here is to encourage students to think more holistically about soil, cities and climate change, and start to see how they link together.

Plenary: The messy wall

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



Student Sheet 1

Complete the grid with as many key words as you can for the chosen topic.

Topic: .... **Name:** ....

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P
Q	R	S	T
U	V	W	X
Y	Z	**Instructions:** 1. When you have completed a topic, write down as many key words as you can from memory. 2. Compare your list with a partner and add anything that you may have missed.	

STAGE 2 - The City Beneath Our Feet

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 soil is an ecosystem which link with and support other ecosystems.
2. Students are able to carry out simple investigations.
3. Students are able to record data.
4. Students are able to make conclusions and present results.

Learning outcomes

1. Students carry out simple experiments and record results.
2. Students record their conclusions and present results.
3. Students describe soil as an ecosystem.

Overview of lesson

In this lesson students think more deeply about soil as a living ecosystem which responds to a range of different factors. They undertake a range of investigations unearthing the properties of soil.

The City Beneath Our Feet - understanding the situation

Lesson structure

Introduction

You might want to start this lesson with a short video about soil to either refresh student's knowledge or prepare them for the tasks to come.

https://thekidshouldseethis.com/post/soil-101

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

Main 1: Defining your study

Each student (or in groups) needs to identify an area of open ground 20cm x 20cm; this will be their soil sample. Using a suitable tool, cut around the edges of the same area to a depth of 10cm and then carefully remove the soil into a prepared tray. Students now have their sample to use with the different explorations below.

Main 2: Soil texture

Understanding the texture of soil can tell us a lot about its properties. Students can assess soil texture and physical properties with a simple test. This is demonstrated in the video link below.

https://youtu.be/wspKtgHzT-c?list=PLPFv9syphoctmEv2Xdz-8HGrQRw8WS_2I

And also using the guide in the booklet below (page 10).

https://www.opalexplorenature.org/sites/default/files/7/image/SOIL%2016pp%20booklet_0.pdf

Main 3: Soil layers

Ask students to place some of their sample into a clear bottle and add water. They should observe trapped air bubbles coming to the surface showing that soils contain significant amounts of air trapped within them.

Then ask students to shake their sample to mix the soil and water; allow to settle. What can be observed now? Students should be able to observe that soil is made of a number of different sized particles, many of which will not be immediately apparent.

A more detailed description can be found at:

https://hgic.clemson.edu/factsheet/soil-texture-analysis-the-jar-test/

Main 4: Soil creatures

Prepare a Berlese funnel, named after the Italian entomologist who first developed a trap to collect the macrofauna of soil by creating a temperature gradient in the sample so that living organisms will move from the high temperature areas and fall into a container. You will find detailed instructions here:

https://www.soils4teachers.org/files/s4t/lessons/berlese-funnel.pdf

You can use the sample of macrofauna collected to practice taxonomy skills. Useful guides and keys can be found here:

https://www.opalexplorenature.org/sites/default/files/7/image/Invertebrates%2520guide-%2520UPDATED%2520FINAL.pdf

https://ypte.org.uk/factsheets/minibeasts/print?hide_donation_prompt=1

Main 5: Soil recipe

To complete this stage, ask students to produce a 'soil recipe' describing a fertile soil based on their investigations above. Ask students to consider some parameters which could affect soil fertility: temperature, pH, nutrients from decaying plants, temperature, water, light. As a result, students should be able to recognise soil as an ecosystem and that this supports other ecosystems.

Plenary: The messy wall

Update the messy wall with new information and the soil recipe.

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 recognise and consider limitations in their method.
3. Students can apply their scientific knowledge to a local context.
4. Student can link their learning with other sustainability issues.

Learning outcomes

1. Students plan and carry out an investigation to test the suitability of materials and habitats to regulate water flow.
2. Students identify and explain the benefits of different approaches to regulating water flow, and the role soil plays in this.
3. Students reach conclusions based on their data and make links with the wider urban system.

Overview of lesson

This lesson looks at how reducing areas of soil and vegetation in urban areas has an influence on flooding and drainage of water.

The City Beneath Our Feet - investigating urban drainage

Lesson structure

Introduction

In recent years, the climate crisis has been linked more strongly with increased flooding. This risk is increased in urban areas where large areas of open land have been covered with concrete and tarmac; this is called soil sealing. This video provides a good introduction to soil sealing and the challenges it creates, and sets the scene for this stage.

https://www.youtube.com/watch?v=YU6jz061kTs

Main 1: Sealing the soil

It is important students have a clear understanding of the term soil sealing at the start of this stage. The video in the introduction offers a good starting point as does the website below.

https://www.recare-hub.eu/soil-threats/sealing#what_is_soil_sealing

Main 2: Soil erosion experiment

To explore the effects of soil sealing in a practical way, the following experiment is helpful for students. In the experiment, students consider the effects of different vegetation types on water drainage. The experiment is described in detail here:

https://www.soils4teachers.org/files/s4t/lessons/lessonplan-erosion-model.pdf

The experiment can be adapted in different ways. For example, add more stones to the surface of one bottle to mimic an urban hard surface or even cover it in concrete. It is helpful to ask to ask students how to best mimic different urban conditions to make the experiment more realistic. You can also ask students to make hypothesis in advance and record their results using different display methods.

If you can build larger storm simulation plots, then you can record the rate of water runoff over time.

https://www.geography-fieldwork.org/a-level/water-carbon/flooding/method/

Main 3: Sustainable Drainage Systems

In natural habitats, water flow is regulated by plants, animals and the absorptive capacity of soil. For example, beavers modify river hydrology by cutting wood and building dams; one reason they are being reintroduced to parts of the UK.

https://asknature.org/strategy/stream-remodeling-alters-ecosystems/

Another example, stream surfaces are generally pervious allowing water to pass through into the soil not just continue downstream. In urban areas where streams have been changed by humans using impervious surfaces, the result can be more water being retained within the stream leading to it bursting its banks.

https://asknature.org/strategy/hydrological-regimes-maintain-organisms/

This pervious nature of streams is being mimicked in some towns and cities in an approach called Sustainable Drainage Systems (SuDS). SuDS work to capture water and release it more slowly into rivers and streams, thus avoiding the rapid runoff of water which creates flash floods. An outline of how SuDS work can be found here:

http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/suds/what.html

The explanations above might be sufficient to provide students with ideas for re-designing their local community to increase areas of vegetation and reduce soil sealing, perhaps incorporating SuDS into their plans. If you want to take this further, students could re-design their soil erosion experiment to investigate which surfaces could act as both pavements/roads and reduce water runoff.

Continued on page 12...

Lesson structure (Continued)

Plenary

Ask students to present their results by creating a table to record their findings. Based on the results, and research into SuDS, ask students to make recommendations for reducing soil sealing in their community.

Take the discussion further to link with broader sustainability issues. How might more vegetation increase urban biodiversity? Will more green spaces increase health and well-being? Influence air pollution? A connections circle could be used to explore these and other effects in more detail.

https://thesystemsthinker.com/learning-about-connection-circles/

STAGE 4 - The City Beneath Our Feet

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 developed their results, they need to provide feedback. If you have used a real-world context, consider who the results need to be presented to and develop feedback suitable for the target group; this could be a resident's group, architects, town planners or others affected by flooding.

Main: 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.
- **Film** - create a 5-minute film communicating how you carried out your research and the results; you could include interviews with community members affected by flooding.
- **Presentation** - deliver a 5-minute presentation for town planners.
- **Report** - write a report laying out your recommendations and evidence.
- **Other** - add your own suggestion.

Student Sheet 2 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 2 - 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.