Using Urban Science to teach climate change

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Abstract This article describes how a homework task on climate change is being developed as part of a larger project on sustainability issues – Urban Science. The ultimate aim of this European project is to improve the teaching of scientific enquiry so that students develop the competences to actively contribute to creating sustainable cities, to understand how cities consist of linked systems that affect each other and to gain scientific skills for employment, thereby becoming more motivated to study science. It was found that students can research and present information in spider diagrams and relate this to everyday life. Although this was at a relatively high level, they were not linking different aspects of climate change. The idea of creating a 'messy wall' from the students' work during stage 1 of the Urban Science project is discussed.

Teaching about climate change gives an opportunity to teach science as a unified set of ideas that are all easily related to daily life. The topic is clearly current, benefits from a significant media profile and should easily engage key stage 4 (KS4) students (ages 14–16). Many of them will have watched BBC television's Blue Planet series and become concerned about how the plastic waste ends up in the oceans and affects food webs and whole ecosystems. Further concerns centre on how plastics are made from non-renewable fossil fuels. The challenge is to enable students to understand how this is intrinsically linked to climate change and a sustainable future for our planet.

Climate change in the curriculum

Climate change is only mentioned in one sentence of the subject content in the KS4 programme of study of the English National Curriculum – in the section on 'Chemistry, Earth and atmospheric science', which is the last topic (DfE, 2015). In Scotland and Wales the situation is very different, as described in the issue of *Education in Science* featuring 'Sustainability education' (Fleming, 2018).

In the AQA scheme of work there are two lessons with the following lesson objectives:

- evaluate the quality of evidence in a report about global climate change given appropriate information;
- describe uncertainties in the evidence base;
- recognise the importance of peer review of results and of communicating results to a wide range of audiences;
- describe actions to reduce emissions of carbon dioxide and methane; and
- give reasons why actions may be limited.

However, if you study the subject content items linked to climate change in the National Curriculum, there are 24 biology items, 8 chemistry items and 4 physics items (Boxes 1–3) that are relevant. There are also opportunities to link 'systems thinking' to 'dealing with climate change'; for example, the English KS4 programme of study mentions that '*science is vital to the world's prosperity*' (DfE, 2015: 3). Not addressing this would have massive economic implications. Also, Ross (2014: 105) argues '*The National Curriculum in England is a list of concepts that we wish them to understand. However, the concepts need to be embedded into a meaningful context, such as climate change*'.

Approaches to tackling the issues of climate change

Three possible approaches to teaching about climate change are:

- **Discuss global warming and climate change at any opportunity.** It would make sense to develop scientific thinking about climate change earlier in the curriculum and discuss global warming and climate change at any opportunity, in particular when teaching about big ideas in science such as energy and ecology (Harlen, 2015). Most science teachers will probably do this. However, just discussions may not be enough to get students engaged.
- **Wait for the Earth topic to come up.** Another option is to not mention climate change until it comes up explicitly in the topic of Earth and atmospheric science. If that is your choice as a teacher, you need to take the opportunity to encourage your students to link all the biology and the few physics topics done earlier as a revision task.

Box 1 Subject content – biology (KS4 National Curriculum)

- living organisms may form populations of single species, communities of many species and ecosystems, interacting with each other, with the environment and with humans in many different ways
- living organisms are interdependent and show adaptations to their environment
- 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
- organic compounds are used as fuels in cellular respiration to allow the other chemical reactions necessary for life
- the chemicals in ecosystems are continually cycling through the natural world
- the characteristics of a living organism are influenced by its genome and its interaction with the environment
- evolution occurs by the process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees
- enzymes
- factors affecting the rate of enzymatic reactions
- the importance of cellular respiration; the processes of aerobic and anaerobic respiration
- carbohydrates, proteins, nucleic acids and lipids as key biological molecules
- the process of discovery and development of new medicines
- the impact of lifestyle factors on the incidence of non-communicable diseases
- photosynthesis as the key process for food production and therefore biomass for life
- the process of photosynthesis
- factors affecting the rate of photosynthesis
- 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 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
- the uses of modern biotechnology including gene technology; some of the practical and ethical considerations of modern biotechnology

This will only work if there is enough time to discuss any misunderstandings, the evaluation of scientific evidence and arguments, and possible implications and mitigations. This will then contribute to the development of scientific thinking as set out in the KS4 programme of study of the National Curriculum, in particular '*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*' (DfE, 2015).

- **Make climate change a topic in itself.** This involves embedding the teaching as part of a larger project on 'climate change', which is more focused on 'working scientifically'. The first step could be a homework task to develop scientific thinking, for instance to create a poster on the issues of climate change and what to do about this in the future, considering scientific facts, possible myths and responsibilities. To produce high-quality work the students would have to read extensively to make sense of this complex topic. They would need to discuss and evaluate opinions on climate change with scepticism, giving them a great opportunity to improve their scientific literacy, develop understanding of citizenship and play a part in a democracy (Wellington and Osborne, 2001). Teachers can assess students' current levels of

Box 2 Subject content – chemistry (KS4 National Curriculum)

- life cycle assessment and recycling to assess environmental impacts associated with all the stages of a product's life
- the viability of recycling of certain materials
- carbon compounds, both as fuels and feedstock, and the competing demands for limited resources
- evidence for composition and evolution of the Earth's atmosphere since its formation
- evidence, and uncertainties in evidence, for additional anthropogenic causes of climate change
- potential effects of, and mitigation of, increased levels of carbon dioxide and methane on the Earth's climate
- common atmospheric pollutants: sulfur dioxide, oxides of nitrogen, particulates and their sources
- the Earth's water resources and obtaining potable water

Box 3 Subject content – physics (KS4 National Curriculum)

- conservation of energy in a closed system, dissipation
- calculating energy efficiency for any energy transfers
- renewable and non-renewable energy sources used on Earth, changes in how these are used
- radioactive materials, half-life, irradiation, contamination and their associated hazardous effects, waste disposal

> understanding and suggest the next steps only when students have the opportunity to write and talk at length about their understanding of a scientific idea or concept (Ofsted, 2013).

We suggest the third way and, in this article, we describe using an international perspective to introduce a project on sustainability issues: Urban Science. Then a homework task is discussed as an example of stage 1 of this project.

An international perspective

With regard to 'working scientifically', '*Teachers should feel free to choose examples that serve a variety of purposes, from showing how scientific ideas have developed historically to reflecting modern developments in science and informing students of the role of science in understanding the causes of and solutions to some of the challenges facing society*' (DfE, 2015).

In an issue of *School Science Review* focusing on 'Education for sustainable development', Max Hogg (2010) explains how science teachers can use global-learning approaches to encourage learners to develop their 'working scientifically' and 'scientific thinking' skills. He offers practical solutions for teachers, such as drawing on students' own experiences for group-work activities and thinking carefully about how subjects link with others. Two case studies are described of schools that have a partnership with African schools. These are well-resourced projects that benefit all parties involved.

Teachers who are involved with projects like this are often those who get involved with European projects. In a *School Science Review* issue focusing on 'Energy and climate change' we wrote about how projects such as SUSTAIN and CODES could help develop enquiry-based learning and the use of a network, with the aim of learning more about collaborations within schools and communities that foster sustainable development (Tas *et al.*, 2014).

The Urban Science Project

Urban Science is a new European project (Erasmus+), which aims to improve the teaching of scientific enquiry so that students are more motivated to study science and develop the competences to contribute actively to creating sustainable cities, understanding how cities consist of linked systems that affect each other, and gain scientific skills for employment.

A framework document has been developed that lays out the principles and thinking behind Urban Science (available from www.urbanscience.eu/uk). It is intended as a practical document for teachers and educators both to develop their own learning modules and to understand how ready-made resources have been created. It also provides a theoretical background to the development of Urban Science learning. Links and references are provided throughout the document to enrich the knowledge of those who wish to delve deeper.

The framework is an evolving process where draft modules are trialled and reviewed. They are available on the website (www.urbanscience.eu/uk). Further iterations of this document will follow as we become more established in our approach based on practical success in classrooms across Europe.

An enquiry cycle based on the Enquiring Minds model (Morgan *et al.*, 2015) is adopted (Figure 1):

- **Stage 1**: Eliciting the knowledge, interests, ideas and motivation of students; discovering what they already know about climate change and why it matters (or not) to them. The teacher's role is to help students draw on their own lives and experiences to discover things that interest them, make them excited, curious and want to ask questions. An example of this could be showing the class several pictures of situations that can be attributed to climate change, such as deforestation and large cattle farms, as possible causes, and a polar bear on dry land and extreme weather conditions as consequences. This could start the discussions for making a poster as described in more detail below.
- **Stage 2**: Shaping, defining and focusing an idea or question, and making plans to research it further; students dig deeper into climate change, identifying an area of interest and meaning for them. The teacher's role is ensuring students can advance their enquiries meaningfully; providing frameworks and learning so that students can organise their research. An example of this could be that students wonder about how to reduce their carbon footprint.

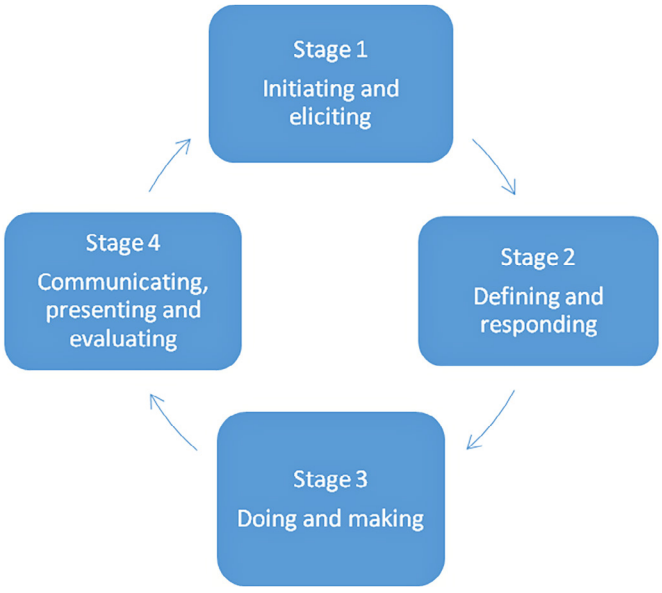

Figure 1 The Future Lab *Enquiring Minds* model (Morgan *et al.*, 2015)

This would mean they need to first discuss what contributes to their carbon footprint and what the science is behind this. They will then need to do some initial research on what is published on this.

- **Stage 3**: Students research, design and construct in order to make a contribution in their chosen enquiry, during which they engage in a variety of tasks depending on the nature of their enquiry; this is an opportunity to set their GCSE 'required practical' assessments into a real-life context. For example, after investigating the variety of plant species found in their school grounds they can further research the effect of climatic changes on plant phenology. Meanwhile the teachers encourage students to manage their time, identify clear goals and monitor their progress.
- **Stage 4**: Students communicate, share and present their new knowledge and understanding with others. Innovative mechanisms of celebrating their work and ideas are being explored, including 'Forum theatre', school radio programmes (using their podcasts) and presenting at the annual local authority science fair. It is a central theme of Urban Science that they share their work with their peers within their own and at other schools

It is important to decide which approaches match essential principles for effective enquiry and sustainability learning. Box 4 shows a teaching and learning framework that can provide for this. The idea is that Urban Science uses outdoor enquiry-based learning whereby urban areas become living laboratories that help students explore how science can create healthier and sustainable places to live. It is solutions-based, placing a strong emphasis on creativity and problem solving to ensure scientific understanding can be applied in a meaningful context. Eventually, there will be a complete bank of resources and lesson plans that schools could choose to use as presented, to revise or to select from.

Urban Science enables the United Nations' Sustainable Development Goals (SDGs) to be tackled and understood by linking ideas. It is an attempt to steer science education towards a more holistic and interconnected view, which incorporates understanding through knowledge and emotions and uses science as the means of bringing healthy and vibrant cities into reality.

It makes sense to tackle climate change in a project like this because Urban Science attempts to go beyond the narrow confines of the curriculum and inspire students to take more ownership of their learning. For example, students could measure the circumference of a tree and ask, '*If this tree was felled and used for biofuel to provide heating and hot water, how many of you could it support over the next year?*' (Tilling, 2007). Such an activity could lead to a discussion about the sustainability of biofuels and deforestation. A standard biodiversity monitoring activity in the school grounds can become an opportunity for students to link this to climate change.

Box 4 A teaching and learning framework

Approaches should match essential principles for effective enquiry and sustainability learning, through providing a teaching and learning framework that:

- understands and builds on the learner's prior experiences;
- is meaningful and relevant to the learner's own life;
- provides first-hand experiences inside and outside the school in a range of settings and contexts;
- encourages solutions based on understanding, values and shared responsibility;
- allows learners to explore their values and vision for their future;
- takes place in a range of contexts spatially and temporally;
- involves learning through curriculum subjects, interdisciplinary teaching and the whole school (internal organisation, use of buildings and grounds);
- builds capacity for change;
- provides opportunities to think, learn and act holistically;
- stimulates critical thinking, develops creativity in responding to environmental challenges and actively encourages participation addressing local environmental issues, relating them to global themes;
- cultivates an appreciation for the natural world and understanding of the dependence of human wellbeing, healthy societies and economic activity on the natural world;
- provides opportunities for feedback, thereby allowing for progression to greater understanding.

Homework task on creating a poster of climate change

Urban Science is taking up the challenge and opportunity of creating learning that develops a more systemic appreciation of the SDGs as interrelated processes that make up the world we rely on. In the following example, Maarten Tas's year 11 (age 15–16) combined science group was set the homework 'research' task of creating a poster on climate change ahead of starting the Urban Science topic on biodiversity. The task was:

> *To make a spider diagram, mind map or concept map on how climate change affects us, what we do that affects climate change and how we can deal with climate change in the future.*

The very best posters showed evidence of sustainability competencies, such as the ability to look for clear evidence of impact of climate change in their everyday life and look for solutions. Poster 1 (Figure 2) is a good

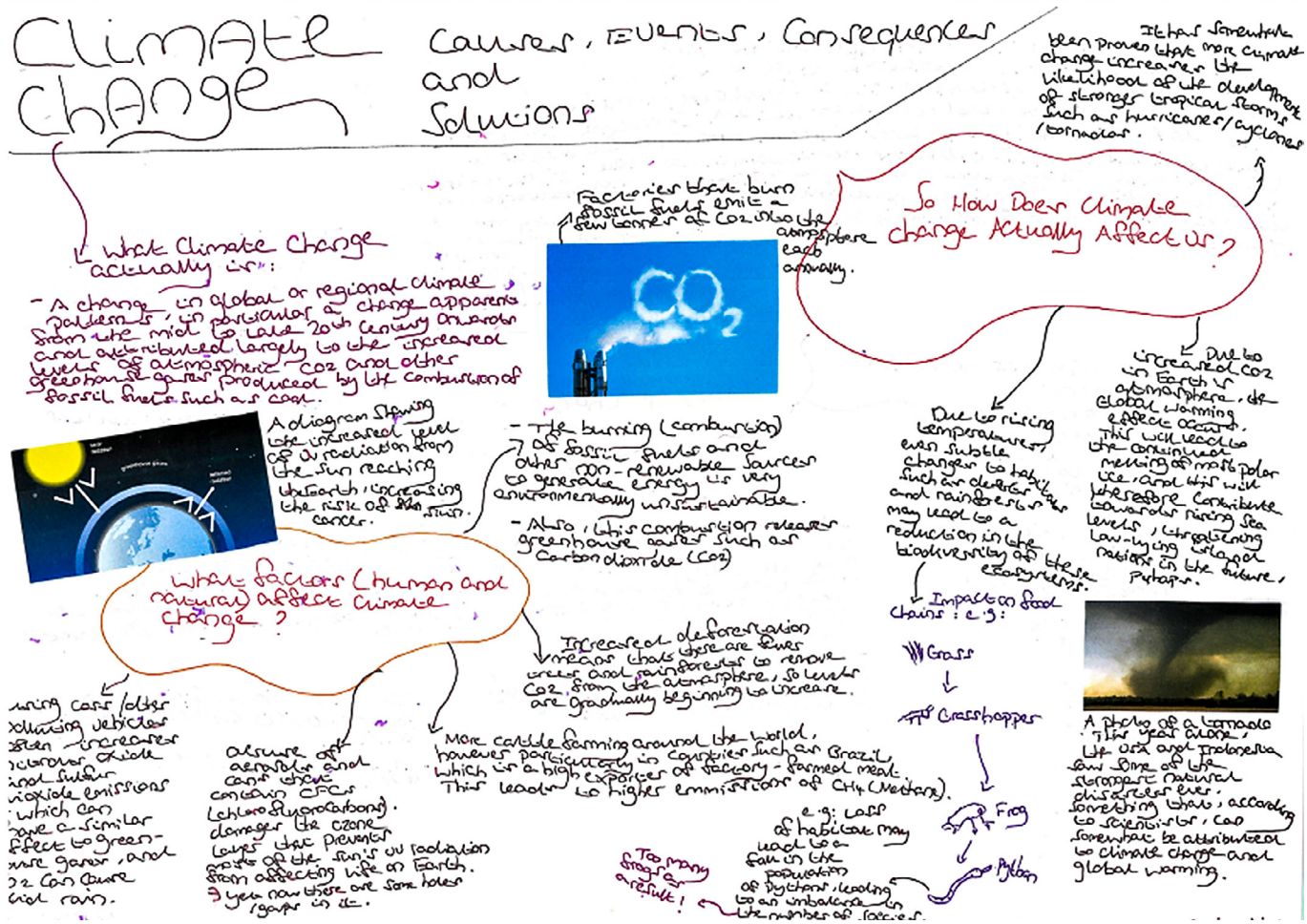

Figure 2 Poster example 1

example of student research into how climate change affects us. Poster 2 (Figure 3) shows how a student thinks about a sustainable future and the importance of policy, such as the Paris agreement.

All posters were put on a big wall in the classroom, not necessarily as display but more with the idea of creating a 'messy wall' (Figure 4) that can be developed over time. This is an important first stage of the Urban Science project. One reason for creating this interactive wall was that, although the students were able to draw on information to create their individual posters, none was really linking the different aspects related to climate change. The idea of such a messy wall is to fill it with as much detail as possible, in the form of facts, impressions, poems, sketches, photos, and so on. It forms an ongoing map to which students can contribute further over time. Messy walls help to capture the real 'texture' of something, which is impossible to do in any one medium. The students can then start to refine and focus on specific areas of the topic. The purpose of this technique is that the students create links across sustainability and science ideas.

Throughout the rest of the year the students will take part in a number of other Urban Science modules. The messy wall spider diagrams will aid their progression and help them understand how these topics, such as biodiversity, energy and air pollution, are all interlinked. An issue with this is that different teachers may teach different topics. This means the teacher who has set the homework task and displays the messy wall needs to discuss with the other teacher(s) how to integrate climate change into the other topics. Later in the year the teacher will also have the opportunity to use the messy wall as a revision tool to link chemistry, biology and physics concepts.

The posters, in particular, can also be used as formative assessment tools as the students progress through the KS4 topics and have the opportunity to add comments and ideas and make connections.

The following extracts from posters give some examples.

Dealing with misconceptions (see extract of poster A, Figure 5)

Although the points raised on this poster are valid, it detracts from the human cause of global warming and can elicit a very useful discussion on whether these natural factors have a real impact over the next 20 years and what our responsibilities are. A useful set of resources for teachers to help with this debate are the *Beacons Guides to Climate Change* (www.beaconsdec.org.uk/climate-change).

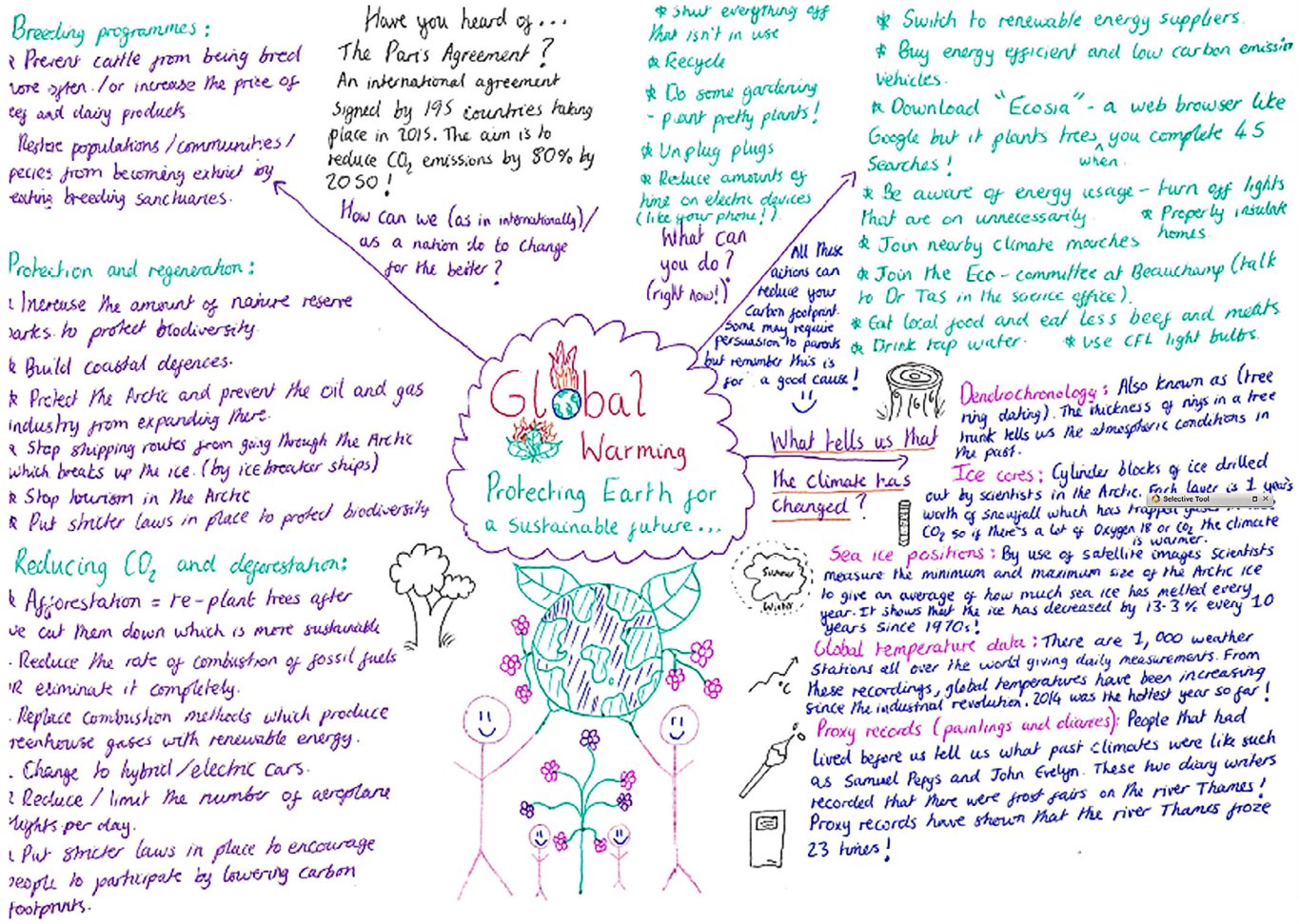

Figure 3 Poster example 2

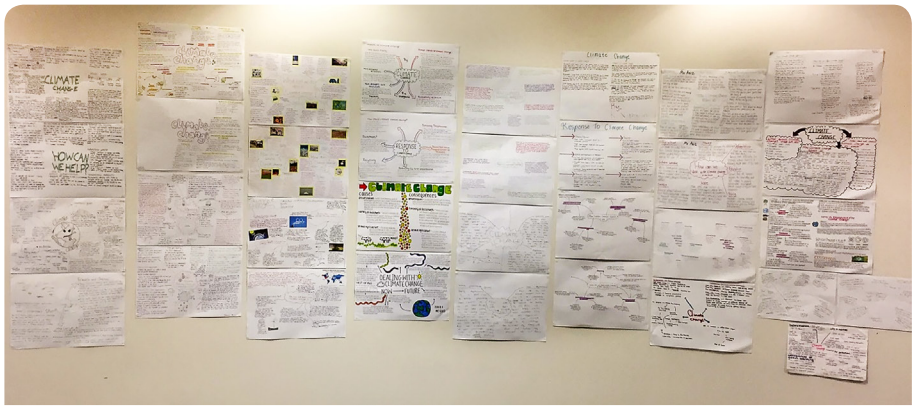

Figure 4 The start of our messy wall

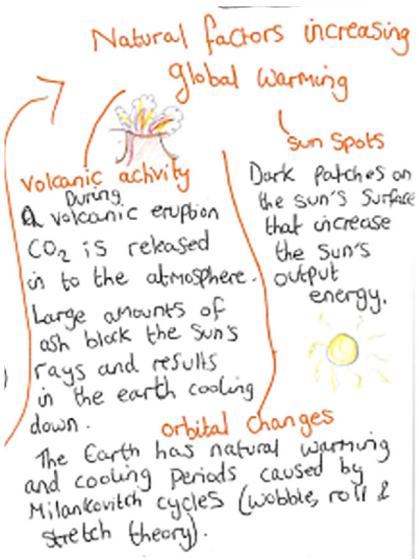

Figure 5 Extract from Poster A

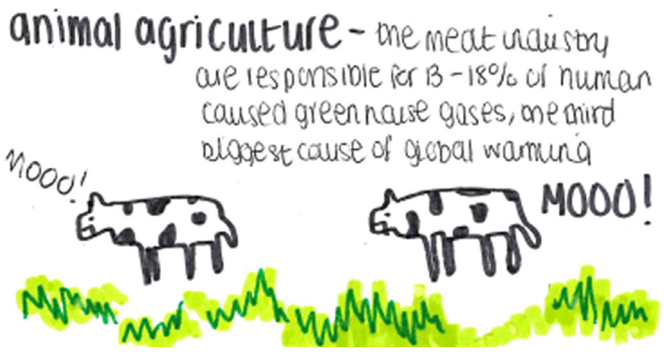

Figure 6 Extract from poster B

Progression of science concepts (see extract of poster B, Figure 6)

Some students need to include a more detailed exploration of the key science ideas. This poster extract shows the student has not identified methane as a greenhouse gas.

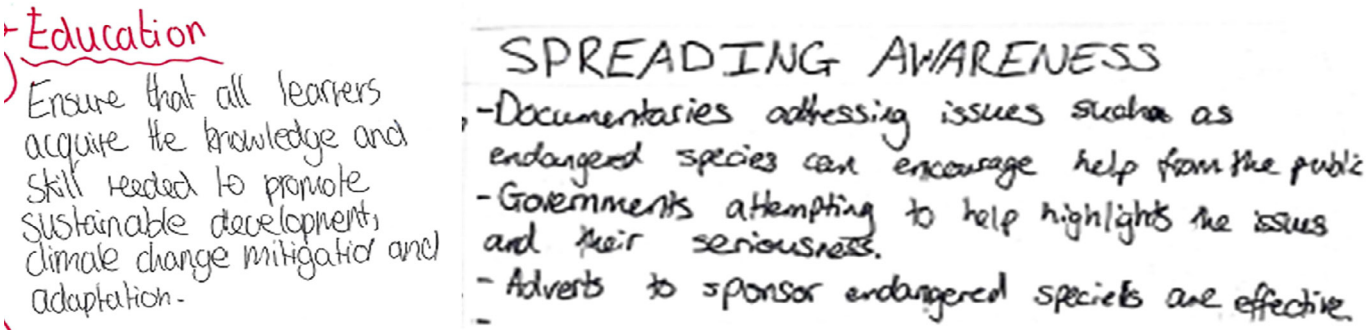

Figure 7 Extracts from poster C and D

Other skills (see extracts of poster C and D, Figure 7)

These extracts show that there are opportunities for celebrating other than straight science competencies, such as a broad understanding of the need to change behaviour.

Conclusions and recommendations

This homework task has opened up the possibilities to develop both the science and sustainability competencies within the framework of the current National Curriculum in England KS4 programme of study. The messy wall is a relatively easy way for teachers to revisit climate change across all topics, especially if the group of students is taught mostly in the same classroom. It therefore would be a good idea to start this in the beginning of year 10 (age 14–15). This gives students and teachers plenty of opportunity to use global learning approaches to develop their scientific thinking and literacy skills and, more importantly, to discuss how issues of climate change can be dealt with at home, in the community, nationally and internationally. For teachers who want more support, the Urban Science project is planning to provide training and the website will give an indication of when this is available. There are also opportunities for teachers to be involved in trialling and developing the learning modules.

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Further resources

Intergovernmental Panel on Climate Change: www.ipcc.ch/.

United Nations, Sustainable Development Goals (SDGs): www.un.org/sustainabledevelopment/sustainable-development-goals.

Urban Science project: www.urbanscience.eu/uk.

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