# INQUIRY AND ASSESSMENT UNIT

# GLOBAL WARMING

Global warming – how can we cool it?

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# GLOBAL WARMING

## GLOBAL WARMING – HOW CAN WE COOL IT?

## Overview

### KEY CONTENT/CONCEPTS

- Greenhouse effect
- Carbon cycle
- Global warming

### LEVEL

- Lower second level
- Upper second level

### INQUIRY SKILLS ASSESSED

- Forming coherent arguments
- Working collaboratively

### ASSESSMENT OF SCIENTIFIC REASONING AND SCIENTIFIC LITERACY

- Scientific reasoning (argumentation; making comparisons)
- Scientific literacy (analysis and interpretation of scientific data; using scientific data)

### ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Worksheets
- Student devised materials (written arguments)
- Presentations

**Classroom materials for this Inquiry and Assessment Unit are available at WWW.SAILS-PROJECT.EU**

# 1. INQUIRY AND ASSESSMENT UNIT OUTLINE – GLOBAL WARMING

The **Global warming** SAILS inquiry and assessment unit aims to enable students to consider scientific data and determine whether or not the evidence supports the phenomenon of global warming. An additional activity presents an opinion piece, which the students should critique to judge its scientific merit. This activity may be implemented at lower or upper second level depending on the curriculum's objectives, and is proposed as a *bounded inquiry*.

The key skills that can be developed through these activities are *forming coherent arguments, working collaboratively* and *scientific reasoning*. Students also enrich their *scientific literacy* through the evaluation and use of scientific data/ information. The assessment method emphasised is that of self-assessment, and rubrics are provided for students to use for evaluation of their own work.

The unit was trialled by teachers in Denmark, United Kingdom and Belgium, producing four case studies of classroom implementation. These four case studies describe the experiences of students at both lower and upper second level, aged 14-18 years. The participating classes consisted of both mixed and single gender (all-girls), and students were of mixed ability. The key skills assessed were *forming coherent arguments, scientific reasoning* and *scientific literacy*, with an emphasis on the analysis and interpretation of scientific data and distinguishing opinions from facts. The assessment methods used include self-assessment, peer-assessment, classroom dialogue and evaluation of student's worksheets and other artefacts.

# 2. IMPLEMENTING THE INQUIRY AND ASSESSMENT UNIT

## 2.1 Activities for inquiry teaching & learning and their rationale

The activities in the **Global warming** SAILS inquiry and assessment unit were developed by the team at Malmö University as part of the SAILS project. In this unit, two activities are outlined. The first activity – "Greenhouse" – was developed by the OECD [1] as a sample science task for PISA assessment, and was adapted for the SAILS project. In this first activity (A: Interpreting the evidence), students are provided with graphs that show the emission of carbon dioxide to the atmosphere over a 135 year period, and the fluctuation in the average global temperature over the same time period. The students are first asked to support the proposed argument that "the increase in mean temperature in Earth's atmosphere is caused by the increased emission of carbon dioxide," and then are asked to argue against the same statement. This activity develops students' skill in *forming coherent arguments*, while also increasing their *scientific literacy* by encouraging critical thinking. In the second activity (B: Forming scientific arguments), an opinion piece on the topic of global warming is provided and students are asked to produce a written response. They should use their knowledge about global warming, the carbon cycle and scientific methods, to address the arguments presented. Students should evaluate the opinion piece, and identify which arguments are based on facts and which are based on values and opinions. In this way they develop their *scientific literacy*, becoming better equipped to evaluate the opinions of others, and to become critical thinkers.

Opportunities within this unit allow for the assessment of the inquiry skill of *forming coherent arguments*, by asking the students to form conclusions and support these using reasoned arguments and evidence. In addition, there is scope for development of the skills of *working collaboratively, scientific reasoning and scientific literacy*.

## Activity A: Interpreting the evidence

| | |
|---|---|
| **Concept focus** | Greenhouse effect and global warming<br>Interpretation of scientific data to provide evidence to support or to disprove the idea of global warming |
| **Inquiry skill focus** | Forming coherent arguments<br>Working collaboratively |
| **Scientific reasoning and literacy** | Scientific reasoning (problem-solving, making comparisons)<br>Scientific literacy (explaining phenomena scientifically) |
| **Assessment methods** | Classroom dialogue<br>Peer-assessment<br>Self-assessment<br>Student devised materials<br>Presentations |

This activity was developed by the OECD, Take the Test Sample Questions from OECD's PISA Assessments, http://www.oecd.org/pisa/pisaproducts/Take%20the%20test%20e%20book.pdf, 2009. Information on licencing of this activity is available at the end of the unit.

### Rationale

In this activity, students are provided with information regarding the greenhouse effect, and the concept of global warming is introduced. They are then provided with scientific data, and asked to interpret the data to provide evidence that can support or disprove the hypothesis that the increase in the mean temperature of Earth's atmosphere is caused by the increased emission of carbon dioxide.

### Suggested learning sequence

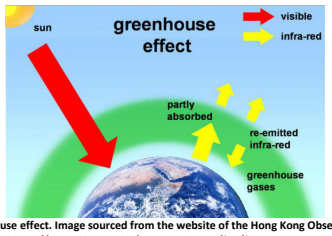
1. The lesson starts with an introduction to the greenhouse effect and global warming. A whole-class debate or small group discussion can be used as a warm-up activity to review prior knowledge and preconceptions. A student handout may be provided, such as that shown in Figure 1.

2. Students are then asked to consider two graphs, one detailing carbon emissions since the Industrial Revolution and the other showing mean global temperature over the same time period. A student handout or worksheet is proposed for this activity (Figure 2).

[1] OECD, Take the Test Sample Questions from OECD's PISA Assessments, http://www.oecd.org/pisa/pisaproducts/Take%20the%20test%20e%20book.pdf, 2009 [accessed October 2015]

**The Greenhouse Effect: Fact or fiction?**

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth. The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world. Most of the radiated energy from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere. As a result of this the average temperature above the Earth's surface is higher than it would be if there was no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term *greenhouse effect* (see image below).




**Greenhouse effect. Image sourced from the website of the Hong Kong Observatory:** http://www.hko.gov.hk/climate_change/faq/faq_e.htm#Q4

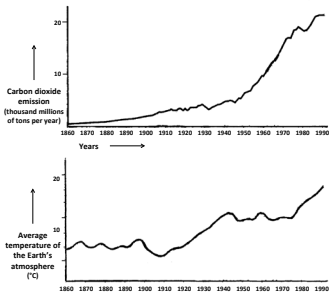
The greenhouse effect is said to have become more pronounced during the twentieth century and the first part of the twenty-first century. It is a fact that the average temperature of Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

**Figure 1:** Handout to introduce the topic of global warming.

**Activity A: Interpreting the evidence**

*Based on "Greenhouse," by the OECD, Take the Test Sample Questions from OECD's PISA Assessments, http://www.oecd.org/pisa/pisaproducts/Take%20the%20test%20e%20book.pdf, 2009.*

Student A is interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth. When searching for information, he finds the following two graphs.




**Graphs showing emission of carbon dioxide and mean global temperature from 1860 to 1995.**

From these two graphs, student A draws the conclusion that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

**Task 1.** Where in the graphs can support be found for the conclusion made by Student A that the increase in mean temperature in Earth's atmosphere is caused by the increased emission of carbon dioxide? Give supportive arguments for this conclusion with reference to the graphs. Use the rubric to check your answer.

**Task 2.** Another student, Student B, thinks that the conclusion by Student A is wrong. She compares the graphs and claims that some parts of the graphs do not support the conclusion that the increase in mean temperature in Earth's atmosphere is caused by the increased emission of carbon dioxide.
Identify the parts of the graphs that do not support the conclusion by Student A and present supportive arguments for the conclusion made by Student B. Use the rubric to check your answer.

**Figure 2:** Student worksheet for Activity A: Interpreting the evidence.

3. The students are given asked to consider the statement "From these two graphs, student A draws the conclusion that it is certain that the increase in mean temperature in Earth's atmosphere is caused by the increased emission of carbon dioxide." Students are asked to form arguments in support of Student A, using evidence from the graphs.
4. After completion of this task, students can engage in peer- or self-assessment. Rubrics are provided, which detail the criteria for assessing skill in using scientific information (see assessment of activities for inquiry teaching & learning section of this unit, Table 1).
5. In the second task in Activity A: Interpreting the evidence, students are asked to consider the conclusions drawn by Student B, who thinks that the conclusion by Student A is wrong (Figure 2). Student B compares the graphs and claims that some parts of the graphs do not support the conclusion that the increase in mean temperature in Earth's atmosphere is caused by the increased emission of carbon dioxide. Students are now asked to form arguments in support of Student B, again using evidence from the graphs.
6. Students can again engage in peer- or self-assessment using the provided rubrics to assess their skills in using scientific information (assessment of activities for inquiry teaching & learning section of this unit, Table 1).

## Activity B: Forming scientific arguments

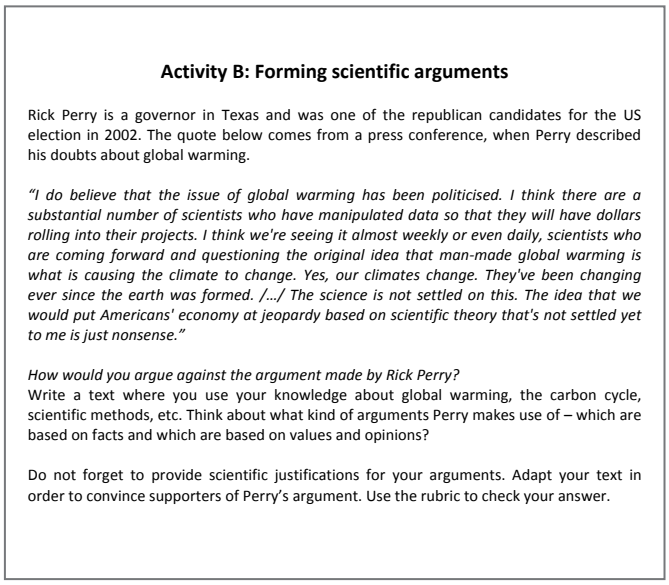
| | |
|---|---|
| **Concept focus** | Greenhouse effect and global warming<br>Distinguishing opinion from facts |
| **Inquiry skill focus** | Forming coherent arguments<br>Working collaboratively |
| **Scientific reasoning and literacy** | Scientific reasoning (argumentation)<br>Scientific literacy (analysis and interpretation of scientific data) |
| **Assessment methods** | Classroom dialogue<br>Peer-assessment<br>Self-assessment<br>Student devised materials |

### Rationale

In this activity, the students read a quote from Governor Rick Perry, from a press conference when Perry described his doubts about global warming. Students are asked to evaluate the quote and distinguish the parts that are scientific evidence and those that are opinion. In this way, they can develop their skills of critical thinking and evaluating evidence to form their own opinions.

**Suggested learning sequence**

1. The students are asked to carefully review the quotation from Governor Rick Perry, shown in Figure 3.
2. The teacher asks the students, "How would you argue against the argument made by Rick Perry"
3. Students are asked to write their response, presenting their arguments, which should be based on their knowledge of global warming, the carbon cycle and other scientific methods.
4. The teacher can prompt the students, by asking them to consider the types of argument used by governor Perry, "Which arguments are based on facts and which are based on opinions and values?"
5. The assessment of the students' written work can be carried out using peer- or self-assessment, using a rubric (see assessment of activities for inquiry teaching & learning section, Table 2). Aspects for evaluation are analysis of Perry's argument, counter argument offered and justified, and use of scientific information to do so.



**Activity B: Forming scientific arguments**

Rick Perry is a governor in Texas and was one of the republican candidates for the US election in 2002. The quote below comes from a press conference, when Perry described his doubts about global warming.

*"I do believe that the issue of global warming has been politicised. I think there are a substantial number of scientists who have manipulated data so that they will have dollars rolling into their projects. I think we're seeing it almost weekly or even daily, scientists who are coming forward and questioning the original idea that man-made global warming is what is causing the climate to change. Yes, our climates change. They've been changing ever since the earth was formed. /…/ The science is not settled on this. The idea that we would put Americans' economy at jeopardy based on scientific theory that's not settled yet to me is just nonsense."*

*How would you argue against the argument made by Rick Perry?*
Write a text where you use your knowledge about global warming, the carbon cycle, scientific methods, etc. Think about what kind of arguments Perry makes use of – which are based on facts and which are based on values and opinions?

Do not forget to provide scientific justifications for your arguments. Adapt your text in order to convince supporters of Perry's argument. Use the rubric to check your answer.

**Figure 3:** Student worksheet for Activity B: Forming scientific arguments.

## 2.2 Assessment of activities for inquiry teaching & learning

This unit is particularly suitable for assessing the skills of *forming coherent arguments* and *scientific reasoning* (argumentation, comparing), and developing students' *scientific literacy* by encouraging students to evaluate scientific data and to make reasoned decisions. Students are facilitated to work collaboratively and collate ideas based on views from team members.

Suggested assessment rubrics are provided for use as peer- or self-assessment tools for evaluation of *forming coherent arguments* and using *scientific information* (scientific literacy).

**Table 1: Assessment of skill of using scientific information, Activity A: Interpreting the evidence**

| Skill assessed | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| **Using scientific information** | Makes reference to both graphs (as a whole). | Makes reference to both graphs (as a whole and in detail). | Makes reference to both graphs (as a whole and in detail). |
| | Presents supportive arguments for at least of one of the student's conclusions. | Presents supportive arguments for both of the student's conclusions. | Presents several supportive arguments for both of the student's conclusions. |
| | Attempts to provide scientifically reasonable justifications for arguments. | Provides scientifically reasonable justifications for arguments. | Provides scientifically valid justifications for arguments. |

**Table 2: Assessment of skills considered in Activity B: Forming scientific arguments**

| Skill assessed | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| **Analysing arguments** | Identifies any of Perry's arguments. | Justifies whether a selected argument made by Perry is based on opinions and/or scientific facts. | Identifies whether Perry's arguments are based on opinions and/or scientific facts. |
| **Providing counter arguments** | Provides a counter argument to any of Perry's arguments. | Provides counter argument to more than one of Perry's arguments. | Provides counter argument to Perry's arguments. |
| **Justifying arguments** | Bases own arguments on opinions and/or scientific facts. | Bases own arguments on scientific facts. | Bases own arguments on scientific facts. |
| **Using scientific knowledge** | Attempts to use scientific concepts, models, and theories for supporting arguments. | Uses scientific concepts, models, and theories for supporting arguments. | Uses relevant scientific concepts, models, and theories in a correct way for supporting arguments. |

# 3. SYNTHESIS OF CASE STUDIES

The **Global warming** SAILS inquiry and assessment unit was trialled in three countries, producing four case studies of its implementation – **CS1 Denmark**, **CS2 United Kingdom**, **CS3 United Kingdom** and **CS4 Belgium**. The case studies were implemented by teachers with some experience of teaching through inquiry, but the students had varied experience. Those in **CS1 Denmark** and **CS2 United Kingdom** had no prior experience in inquiry, while the students in **CS3 United Kingdom** and **CS4 Belgium** had some experience of inquiry in their classrooms. The unit was implemented in one or two lessons, up to 120 minutes duration.

The case studies describe classroom experiences at both lower and upper second level. **CS3 United Kingdom** and **CS4 Belgium** describe implementation at upper second level, although with two different age ranges, 14-15 years and 17-18 years, respectively. In **CS1 Denmark** and **CS2 United Kingdom** the unit was implemented with students from lower second level. Most implementations describe classes of mixed ability and gender, although in **CS3 United Kingdom** the class was "set 2 of 8," a class of uniform ability formed as a result of standardised testing in the previous school year, and students in **CS2 United Kingdom** were all girls.

The key skills assessed in the case studies were *forming coherent arguments* and *scientific reasoning* (argumentation). In addition, some teachers also assessed students' skill in *working collaboratively* and their *scientific literacy*, evidenced by their ability to analyse and interpret scientific data and distinguish opinions from facts. Self- and peer-assessment were also widely used for evaluation of skills, as well as classroom dialogue and student artefacts.

## 3.1 Teaching approach

### Inquiry approach used

The inquiry approach used in all the case studies is described as a *bounded inquiry* approach, i.e. it was guided in the sense that the teacher prompted engaging questions but there were open inquiry opportunities where students had freedom in addressing the questions.

### Implementation

The **Global warming** SAILS inquiry and assessment unit was implemented in full in all case studies (Activities A and B), although the manner in which it was implemented varied depending on students' level and local curricula. Implementation of the unit took place in one or two lessons, as detailed in Table 3. In general, the teachers did not significantly change the unit and trialled it as proposed.

In **CS1 Denmark**, the unit was implemented as part of a topic on energy and environment. The teacher provided an outline of the work on the blackboard, in order to optimise the students' understanding of the tasks to be undertaken. Students were allowed to choose whether to work alone or in pairs, and all but one student chose to work with a peer. In **CS2 United Kingdom**, the implementation was in a single class, so although the entire unit was provided, students were allowed to select a single task that they wished to complete.

In **CS3 United Kingdom**, the teacher noted that engaging students in the task was something of a challenge because it was very wordy with a lot of "dense" text. This teacher suggests that the unit needs more visual appeal – to make it look more

**Table 3: Summary of case studies**

| Case Study | Activities implemented | Duration | Group composition |
|---|---|---|---|
| **CS1 Denmark** | Activities A-B | One lesson (120 min) | • Worked in pairs, one student worked alone (19 students)<br>• Student selected; mixed ability, mixed gender pairs |
| **CS2 United Kingdom** | Activities A-B | One lesson (50 min) | • Groups of 2-3 students (single sex, female)<br>• Teacher assigned "pods" of 6 students; mixed ability |
| **CS3 United Kingdom** | Activities A-B | Two lessons (60 min each) | • Groups of 4 students (20 students)<br>• Teacher assigned; similar ability and mostly mixed gender |
| **CS4 Belgium** | Activities A-B | One lesson (50 min) | • Groups of 3-4 students (three classes)<br>• Student selected; mixed ability and gender |

interesting and less scary. References to the non-English language text had to be made with a number of groups on a number of separate occasions, despite an earlier whole class explanation. The teacher also mentioned that identifying the specific tasks within the text was an issue. Students were able to identify the first task fairly easily, but most of them failed to identify where the second task was. They also struggled to handle the two arguments simultaneously. This suggests that the task should be modified or that the teacher should closely facilitate the students' learning.

In **CS4 Belgium** the implementation was with upper second level students, who would continue on to study sciences or engineering in university. The teacher provided the material in English to the students, and did not translate the tasks to Dutch. The teacher suggests that future implementation of similar tasks might be done in cooperation with language teachers, allowing students to develop their skills in reading scientific texts. This teacher carried out analysis of grades assigned by self-, peer- and teacher-assessment, and discussed the analysis with the students, to highlight the need to be critical in examination of others' opinions during assessment.

#### Adaptations of the unit

No significant changes were made in the implementation of this unit in **CS1 Denmark** or **CS3 United Kingdom**. While the implementation in the other two case studies mostly followed that of the proposed inquiry and assessment, some modifications were made. These were to suit the level of the students, the skills chosen to be assessed or to align with state curricula or teaching strategies.

In **CS2 United Kingdom**, the teacher made several changes to the student handout. There were two reasons identified for these changes – first, to personalise the handout to make it more accessible and, second, to increase the challenge. As this was an all-girl school, the teacher included images of two girls to represent "student A" and "student B" in the worksheet for Activity A (Figure 2). In addition, female names were given to the two students (Linda and Alifa), to allow the students to identify more greatly with the students in the task. The teacher provided additional graphs and diagrams to increase the challenge and to allow the students to further develop their skills in analysing and interpreting scientific data. These images included English text, to avoid confusion created by use of non-English text in the original documents provided to the teachers trialling this unit.

In **CS4 Belgium**, the assessment rubrics were used for both self- and peer-assessment. The teacher modified the handout to include a section for student responses and for the assessment.

## 3.2 Assessment strategies

Within the four case studies, the inquiry skills of *forming coherent arguments* and *working collaboratively* were assessed, as well as *scientific reasoning* (argumentation) and *scientific literacy* (analysis and interpretation of scientific data), as detailed in Table 4. The assessment methods used include self-assessment and peer-assessment, as outlined in the assessment of activities for inquiry teaching & learning section of this unit, as well as classroom dialogue, teacher observation and evaluation of student artefacts (worksheet, student devised materials or presentations).

**Table 4: Inquiry skills identified by teachers in the case studies**

| | |
|---|---|
| **CS1 Denmark** | • Forming coherent arguments<br>• Working collaboratively<br>• Scientific reasoning (argumentation) |
| **CS2 United Kingdom** | • Forming coherent arguments<br>• Working collaboratively (communication)<br>• Scientific reasoning (argumentation<br>• Scientific literacy (analysis and interpretation of data) |
| **CS3 United Kingdom** | • Forming coherent arguments<br>• Working collaboratively<br>• Scientific reasoning (argumentation)<br>• Scientific literacy (analysis and interpretation of data) |
| **CS4 Belgium** | • Forming coherent arguments<br>• Working collaboratively<br>• Scientific reasoning (argumentation, making comparisons)<br>• Scientific literacy (analysis and interpretation of data) |

In **CS1 Denmark**, three assessment methods were used – classroom dialogue, assessment of student devised materials and self-assessment. The students asked the teacher questions throughout the lesson, and at the end of the lesson the teacher provided a small oral follow-up to provide formative feedback. In addition, the students handed in their written work, and the teacher commented on their work. The students engaged in self-assessment, as outlined in the unit, but the teacher noted that they had some difficulties with this, as they wording was not student-friendly. Nonetheless, using the rubrics students evaluated their arguments, and modified their work to improve their performance level.

In **CS2 United Kingdom**, the students prepared poster presentations, and peer-assessment using Post-It notes was carried out at the end of the session. The teacher gave students time at the end of the lesson (10 minutes) to give feedback and to improve some of their answers. Initially some students provided only a grade, and did not include feedback or reasoning for their decisions. The teacher prompted them to provide formative feedback by reminding them to include "what worked well" (WWW) and "even better if" (EBI) comments, an approach that they are familiar with from their previous experiences.

In **CS3 United Kingdom**, the teacher observed the students as they worked within their groups and kept mental notes, which influenced the teacher's judgment about how well students achieved in development of inquiry skills. The teacher provided formative feedback during the class discussions (verbal feedback, which the students responded to), allowing students to identify the elements of their attainment and how they could improve their work. The teacher also drew on the student's responses to questions asked during the activity and plenary to further inform his judgment along with an analysis of the written reports produced by individual students.

In **CS4 Belgium**, students assessed their own arguments and those of their peers, by using the two rubrics provided in the unit. Performance levels assigned by self-, peer- and teacher-assessments were analysed and the results shared with the students. The degree of variation between peer- and self-assessment and the grade assigned by the teacher was highlighted. The teacher provided feedback in each class, highlighting the need to be critical in examining the work of others' and to distinguish opinion from fact.