The Creative School

Open Educational Resources

Critical Thinking on climate change

Topic: STEAM

Age Group: 14-18 years old

Erasmus+

Authors

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Images

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Disclaimer

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The Creative School open educational resources include the following learning modules, here listed according to subject matters and age of the target students:

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Art History		Let Them Live Again	Let Them Live Again
Citizenship and Philosophy	Ethical Dilemmas	Ethical Dilemmas	Ethical Dilemmas
Environment, Natural Sciences	Biodiversity and Visual Arts	Biodiversity and Visual Arts	
Facilitation	Online learning through object based learning	Online learning through object based learning	Online learning through object based learning
Geography	Urban walks	Urban walks	
History			How did young people live?
	Photos as memories of the past	Photos as memories of the past	Photos as memories of the past
STEAM			Critical thinking on climate change
	#Empowering YouthVoices	#Empowering YouthVoices	#Empowering YouthVoices
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Teachers Training	Europeana as a learning tool	Europeana as a learning tool	Europeana as a learning tool
	Practical approaches to teaching with objects	Practical approaches to teaching with objects	Practical approaches to teaching with objects

The Creative School project develops learning modules for children and schoolteachers, promoting self-directed learning, critical and visual thinking skills by using cultural heritage content made available by the partner organisations. The present output has developed a set of training materials focusing on the development of thinking skills through engagement with cultural heritage.

More and more children and young people need to develop higher level thinking skills in order to find solutions to social, emotional and economic problems, both personally and in the context of the wider world. They are encouraged to be creative, innovative, enterprising and adaptable, with the motivation, confidence and skills to use creative and critical thinking purposefully.

The main beneficiaries of the project include primary and secondary school teachers, who, through engaging with the project will become equipped with the skills necessary to facilitate pedagogical strategies for creativity and critical thinking. Children and young people involved as participants in the Creative School project will develop the skills required to respond to the challenges offered by the Creative School curriculum.

We hope this material will bring a new dimension to your work and inspire you to use it for fostering creative and critical thinking among young people. The selected topics have been chosen together with teachers and educators coming from Austria, Croatia, Finland, France, Ireland, Italy and the United Kingdom through focus groups and surveys.

Each material is accompanied by key learning points as well as several interesting facts or pieces of information, which are intended to be used to provoke further discussion. The most appropriate age group is also indicated.

Wherever possible we have included a short interactive activity that can be carried out with students or a series of suggested questions to ask, in order to introduce the topics of each learning module. Should you wish to explore certain topics or themes further, each material includes a link to other related ones. When available, a general list of additional educational resources related to the topics is also provided.

The material and accompanying text are designed as standalone educational aids. In this respect, the resource is intended to provide an overall framework from which you can pick and choose the issues most relevant to your activities. The module can be used within any country any context as it deals with issues, which are cross-border and universal.

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For more information about *The Creative School* project, please visit:

https://www.creative-school.eu/

Critical Thinking about climate change

Topic:	STEAM
Age range:	14-18
Time:	30-45 minutes
Materials and tools:	Presentation of the investigation.
Learning objectives:	Encourage children to: • challenge preconceived ideas; • learn how to evaluate the value of information; • distinguish between knowledge and opinion; • discover the approach of different scientists; • understand the importance of comparing measurements to interpret results and thus to understand how scientific knowledge is elaborated.

Climate change investigation module

14-18

Start the workshop by telling the students that they are going to investigate climate change. The teacher/educator is the expert scientist and the students are climate investigators. They have to carry out the investigation and discover if the 2 suspects of climate change, sun and greenhouse effect, are guilty or not.

Description of the workshop

As the topic of Climate is a major sciences topic of science programs in secondary schools, this workshop aims to awaken critical thinking of the students on this topic. This module would contribute to make the students understand how the scientific culture is indispensable nowadays to perceive the societies evolution - like that of the environment- and to control it and allow them to develop their critical thinking and capacity to argue.

3 different parts compose the workshop

- Starting the investigation
- The suspects
- Conclusion

The teacher will use the presentation in order to lead the investigation.

Instructions for teachers – how to lead an investigation on climate change?

The workshop takes the form of an enquiry in which students are put in the position of investigators. They must use their critical thinking skills to analyse a series of media and documents from very different sources: public opinion polls, results of observations (by successive scientists across several generations or using the latest tools), graphs. The workshop is designed to be done by a high school science teacher in a face-to-face workshop with students. The teacher plays the role of a scientific expert while the students are the investigators.

The framed grey parts in the document are specification for the teacher.

Part 1: Starting the investigation

Slide 2

Part 1: Starting the investigation

Educational objective

To discover the importance of reference measurements to interpret a measurement or an observation.

Slide 3

The investigation begins with the observation of the progressive melting sea ice (pack ice) in the North Pole.

Comment: "Let's observe the progressive melting sea ice (pack ice) in the North Pole. This is a NASA video showing the evolution of the sea ice surface over the last 40 years."

Question: "This melting also concerns the glaciers. We have many fears about melting glaciers. And among our fears, there is the fear of losing part of our archives… which archive do you think is being referred to?"

Answer: "The climate archive".

Slide 4

Comment: "Cycles of natural variability are known to play a role in the extent of the Arctic sea ice, but the sharp decline cannot be explained by natural variability alone. Natural variability and rising global temperatures have contributed to the melting of larger amounts of Arctic sea ice. Some specialists predict an ice-free Arctic for at least part of the year by the end of the 21st century."

Slide 5

Comment: "This is the picture of the Subglacior project, undertaken by glaciologists from the Laboratory of Glaciology and Geophysics of the Environment (LGGE) and the Grenoble Observatory for the Science of the Universe (OSUG), whose ambition is to go back 1.5 million years!"

Slide 6

Figure: Variations in temperature and concentration recorded in Vostok ice core in Antarctica.

Question: "What do you notice?"

Answer: "Temperatures have varied over time, due in particular to the natural Milankovitch cycle. There are so-called glacial and interglacial periods. We are currently in an interglacial period."

Milankovitch cycles describe the collective effects of changes in the Earth's movements on its climate over thousands of years. ... Now, materials on Earth that have been unchanged for millennia (obtained via ice, rock, and deep ocean cores) are being studied to indicate the history of Earth's climate.

Explanation of Figure

Glacial-interglacial variations are characterized by large variations in temperature, in ice sheet extent, and in sea level, which can be observed in various paleoclimate records ([Masson-Delmotte and Chapellaz, 2002, Masson-Delmotte et al., 2015]). 21,000 years ago, the Earth underwent the last glacial maximum. The overall temperature was 5°C colder, a polar cap covered all of Northern Europe, and the sea level was 130 m lower. For 10,000 years, we have been in an interglacial period. There is an inter-glacial period every 100,000 years.

Slide 7

Focus on the temperatures of recent years.

Comment: “Let's take a closer look at the trend in recent years: There is an increasing positive deviation from the average. This results in a sudden increase in temperature.”

Slide 8

Focus on the temperatures on recent years

Comment: “Ice archives are therefore essential witnesses to the fact that there is currently rapid warming! Moreover, the composition of each air bubble informs us about past atmospheric compositions: this is essential for understanding the mechanisms of the current climate. So we need to preserve them and find out what is causing this sudden warming. This is the subject of our investigation and I need your help to make rapid progress on this matter. It is urgent!“

Part 2: The suspects

Slide 9

Part 2: The suspects

- Critical thinking objective: Distinguish between knowledge, belief and opinion
- Educational objective: Gather students' initial conceptions.

Slide 10

Question: “What do you think is the cause of global warming?”

Answer: “Human-made pollution…”

Slide 11

Question: “Is it the only cause?”

Slide 12

Figure of the results of a survey carried out on a sample of 798 French people.

Slide 13

Question: Regarding the results of the survey “What do you think of these results?

If I ask you again: Who thinks that global warming is caused by human activities?

Who thinks that it is only a natural phenomenon that has always existed?

Who thinks it is both?...

Who doesn't know?

What do you think about when we talk about human activities and when we talk about natural factors?”

Slide 14

Part of answer: “In this high-profile global warming affair, it is indeed sometimes difficult to distinguish between what is true and what is false, to sort out the information... Moreover, my colleagues have collected a large amount of data on several suspects, and it is up to us to classify and then analyse it in order to evaluate, if possible, the potential involvement of these factors in global warming.”

Slide 15

Suspect number one: the sun

Educational objective

To become aware that the sun is responsible for 99.99% of the energy that reaches the Earth.

Critical thinking objective

- To talk about a suspect often mentioned by climate scientists. What do we know, how do we know it? Talk about observation tools.

Critical thinking objective on the nature of scientific knowledge and the importance of the scientific community: the observation of solar activity is one of the most famous observation series in science

- Scientific knowledge is based on collective research of past or present scientists.

Slide 16

Suspect sheet designed in the manner of an investigation

Slide 17

Question: “The Sun alone provides 99.99% of the energy that enters our environment on Earth. This abundant energy reaches us mainly in the form of radiation, including visible light, infrared and ultraviolet radiation. « Who thinks that the sun may be responsible for the current global warming? Why or why not? Do you think global warming is a natural or human-made phenomenon?”

Slide 18

Comment: “The flow of solar energy received on the Earth's surface and the insolation varies essentially because of the rotational movement of our planet around its axis of rotation, which is the origin of the alternation between day and night. And it also varies with the movement of revolution in its orbit around the Sun, which is the origin of the alternation of seasons.”

Slide 19

Comment: “Cycles are perceptible in the climatic archives of ice cores. The flow of energy radiated by the Sun, the irradiance (expressed in W/m^2), was for a long time considered to be constant, hence its name of "solar constant". It was not until the extremely precise measurements obtained by satellites since the 1960s that it was shown that this 'constant' is in fact variable, but only very slightly on a human scale.”

Slide 20

Question: “he sun has been observed and studied for a very long time, but systematically since the beginning of the 16th century, thanks in particular to the diffusion of the astronomical telescope. Here is what can be observed… What difference do you see between these two images? What hypothesis could we make?”

Slide 21

Comment: “The main indicator of the Sun's activity are sunspots, episodic dark spots on the surface of the star. Since the 16th century these spots have been counted continuously. This is the most famous time related series. Today, specialised satellites such as Ulisse, Soho (study of the solar corona with an artificial eclipse), Cluster and recently Solar orbiter study the sun more closely.”

Slide 22

Comment: The solar cycle is an approximately 11-year cycle experienced by the Sun. During the solar cycle, the Sun's stormy behaviour builds to a maximum, and its magnetic field reverses. Then, the Sun settles back down to a minimum before another cycle begins. “What are the results of your observations.”

Question: Here are the results of all the counts in different parts of the world since the 16th century. You can measure and count. There is inevitably information to recover. “What are the results of your observations?”

Answer “All the counts in different parts of the world have progressively revealed the existence of a solar cycle of 11 to 13 years as well as other variations on the scale of centuries (secular) and millennia.”

Explanation. The Solar Cycle:

Sunspots increase and decrease through an average cycle of 11 years. Dating back to 1749, we have experienced 23 full solar cycles where the number of sunspots have gone from a minimum, to a maximum and back to the next minimum, through approximate 11 year cycles.

Slide 23

Comment: “And where are we today? -Although we do not know exactly when the current minimum cycle will end, we have nearly three centuries of studies to predict it. On 9th of December 2019, the Space Weather Prediction Center (SWPC) announced that it would occur in April 2020, give or take six months. We are therefore at the very beginning of the 25th cycle in a secular period with rather low activity. Now we need to know whether this activity has an impact on solar radiation.”

Question: “Here is a second graph. What can we learn from it?”

Explanation of the figure

The red squares on the graph represent the sunspot cycle lengths. One point is the cycle length from the time of the maximum number of sunspots to the time of the maximum number of sunspots of the next cycle, and the following point is the cycle length from the time of the minimum number of sunspots to the time of the minimum number of sunspots of the next cycle. The sunspot cycles are back filtered using weighting 1,2,3,4 applied to each cycle point, both min to min and max to max. This assumes that the current cycle has the most effect on temperature (weight 4), and previous

half cycles affect current temperatures in declining amounts, but future cycles have no effect on the current temperature. The temperature curve in blue used the HadCRUT3 land and sea data to 1978, the MSU satellite data from 1984 to 2006, and the average of the datasets for 1979 to 1983. This eliminates much of the urban heat island effects. The temperatures are unfiltered annual. The CO2 concentrations (ppmv) from 1958 to 2007 are derived from air samples collected at the Mauna Loa Observatory, Hawaii. CO_2 concentrations prior to 1958 are uncertain. Note that there is a correspondence between sunspot cycle length and temperature. Both the temperature and the cycle length curves begin to rise at 1910, and temperatures fall after 1945 to 1975 when the cycle length curve falls, and both curves rise again after 1975. Temperatures have been increasing since 1980 faster than can be explained by the sunspot cycle length, indicating a possible human CO_2 contribution. The recent increase of the cycle lengths explains why there has been no warming since 2002. Temperature changes are expected to follow Sun activity changes due to a time lag resulting from the large heat capacity of the oceans.

Slide 24

Answer: “There is a correlation between the number of sunspots and the solar irradiance. But the variation in irradiance remains very small. Today we are at the very beginning of a new 'decadal' cycle and in a period of low global activity (secular cycle). Therefore, we are in a period of low irradiance. However, the temperature is rising independently of this activity.”

Definition. Minimum cycle

Solar minimum is the period of least solar activity in the 11-year solar cycle of the Sun. During this time, sunspot and solar flare activity diminishes, and often does not occur for days at a time. The date of the minimum is described by a smoothed average over 12 months of sunspot activity, so identifying the date of the solar minimum usually can only happen 6 months after the minimum takes place. Solar minimum is contrasted with the solar maximum, when hundreds of sunspots may occur.

Slide 25

Question: “Where does the sun fit in: suspect or natural phenomenon?”

Answer a cause of natural phenomenon.

Slide 26

Comment: “However, scientists consider that this activity can have an impact on regional temperatures. The most striking feature of the evolution of solar activity over the last few centuries is the absence of sunspots during a large part of the 17th century (the Maunder Minimum: MM). This was at the beginning of the Little Ice Age (there were only about 50 sunspots (instead of the usual 40-50,000)) and there is a general consensus* that the corresponding cooling is due to this phenomenon.”

Definition. Maunder minimum definition

Also known as the "prolonged sunspot minimum", is the name used for the period around 1645 to 1715 during which sunspots became exceedingly rare, as was then noted by solar observers. The term was introduced after John A. Eddy published a landmark 1976 paper in Science. Astronomers before Eddy had also named the period after the solar astronomers Edward Walter Maunder (1851–1928), and his wife Annie Russell Maunder (1868–1947), who studied how sunspot latitudes

changed with time.[The period which the Maunders examined included the second half of the 17th century.

Definition. Little Ice Age definition

The Little Ice Age (LIA) was a period of regional cooling that occurred after the Medieval Warm Period. It was not a true ice age of global extent. The term was introduced into scientific literature by François E. Matthes in 1939. The time period has been conventionally defined as extending from the 16th to the 19th centuries, but some experts prefer an alternative timespan from about 1300 to about 1850.

The NASA Earth Observatory notes three particularly cold intervals: one beginning about 1650, another about 1770, and the last in 1850, all separated by intervals of slight warming. The Intergovernmental Panel on Climate Change Third Assessment Report considered that the timing and areas affected by the Little Ice Age suggested largely independent regional climate changes rather than a globally synchronous increased glaciation. At most, there was modest cooling of the Northern Hemisphere during the period.

Slide 27

Suspect number two: the greenhouse effect

As a reminder: Educational objective: To discover the history of science and how scientists have progressively worked together.

Critical thinking objective : To be better equipped to refute a central argument of climate sceptics, which is that the atmosphere already absorbs all infra-red radiation and therefore that more or less CO_2 makes no difference.

Slide 28

Comment: “The greenhouse effect, a warming of Earth's surface and troposphere (the lowest layer of the atmosphere) caused by the presence of water vapour, carbon dioxide, methane, and certain other gases in the air.”

Slide 29

Comment: “Two thirds of the energy from the sun is absorbed by the atmosphere, soil and ocean. The remaining third is reflected directly back to space by clouds, aerosols, the atmosphere and the earth's surface... It is in the atmosphere that the greenhouse effect, often cited when talking about global warming, occurs.”

Slide 30

Question: “Do you think that the greenhouse effect could be a suspect?”

Answer: “yes.”

Slide 31

Question: “If so, do you think the greenhouse effect is a recent phenomenon? If not, when do you think the greenhouse effect was discovered?”

“Let me introduce you 3 scientific experiments.”

Slide 32

First experiment by Joseph Fourier: “In the early 19th century, scientists had a suspicion that the earth’s atmosphere had the ability to keep the planet warm by transmitting visible light but absorbing infrared light (or heat), and that human activity could change the atmosphere’s temperature. One such scientists was Joseph Fourier who in his 1827 paper mentioned “the progress of human societies” having the potential to – in the course of many centuries – change the “average degree of heat Based on the heliothermometer invented by Saussure a few years earlier, Fourier gives the first description of what we call today the greenhouse effect: "the temperature is increased by the interposition of the atmosphere, because the heat finds less obstacle to penetrate the air, being in the state of light, than it finds to pass back into the air when it is converted into obscure heat. “

Slide 33

Second experiment performed by Eunice Foote in the mid-19th century. E. Foote is one of the first American women scientists.

Comment: “Tyndall experiments were inspired by experiments made by Pouillet and he didn’t know about Foote’s experiments.”

Slide 34

Comment: “In 1856 Foote conducted a series of experiments that demonstrated the interactions of the sun's rays on different gases. She used an air pump, four mercury thermometers, and two glass cylinders. First, she placed two thermometers in each cylinder, then by using the air pump, she evacuated the air from one cylinder and compressed it in the other. Allowing both cylinders to reach the same temperature, she placed the cylinders in the sunlight to measure temperature variance once heated and under different moisture conditions. She performed this experiment on CO_2, common air, and hydrogen.”

Slide 35

Comment: Of the gases she tested, Foote concluded that carbon dioxide (CO_2) trapped the most heat, reaching a temperature of 125 °F (52 °C). From this experiment, she stated “The receiver containing this gas became itself much heated - very sensibly more so than the other - and on being removed [from the Sun], it was many times as long in cooling.” Looking to the history of the Earth, Foote theorized that “An atmosphere of that gas would give to our earth a high temperature; and if, as some suppose, at one period of its history, the air had mixed with it a larger proportion than at present, an increased temperature from its own action, as well as from increased weight, must have necessarily resulted.”

Slide 36

Third by John Tyndall “In 1859, Fourier’s theoretical musings were turned into experiments, when John Tydall, an Irish physicist, published his study investigating the absorption of infrared in different gases. This was the first experiment showing how heat absorption by the atmosphere could lead to temperature rises, and that certain gasses such as water vapor, methane, and CO_2 absorb more heat than others.”

Slide 37

Picture of John Tyndall's setup for measuring radiant heat absorption by gases.

Slide 38

Table of the characteristics of the 3 closest telluric planets to the sun

Comment: Following these experiments, here are the characteristics of the 3 closest telluric planets to the sun - the range of surface temperatures show the importance of the presence of the atmosphere and its composition.

Slide 39

Question: “To conclude, do you think the greenhouse effect is responsible for the current global warming?”

Slide 40

Answer: “Indeed, the greenhouse effect is an "effect" and therefore, by definition, cannot be responsible. We cannot therefore classify it as a suspect. We must now study the suspects behind the increase in greenhouse gases effect.”

Part 3: Conclusions

Slide 41

Comment: “It would seem that each of these 2 suspects has its share of responsibility, but that humans are responsible for unprecedented levels of greenhouse gases emissions…”

Slide 42

Comment: “Moreover, the CCXG (Climate Change Expert Group) has been working on this issue : carbon dioxide accounts for by far the largest share of radiative forcing since 1990, and its contribution continues to grow at a steady rate. Carbon dioxide alone would account for a 36-percent increase in radiative forcing since 1990. Here below the results they obtained.”

Slide 43

Table of the global mean radiative forcing of the climate system for the year 2000 relative to 1750.

Explanation of the table:

“Many external factors force climate change. This radiative forcing arises from changes in the atmospheric composition, alteration of surface reflectance by land use, and variation in the output of the sun. Except for solar variation, some form of human activity is linked to each. The rectangular bars represent estimates of the contributions of this forcing - some of which yield warming, and some cooling. Forcing due to episodic volcanic events, which lead to a negative forcing lasting only for a few years, is not shown. The indirect effect of aerosols shown is their effect on the size and number of cloud droplets. A second indirect effect of aerosols on clouds, namely their effect on cloud lifetime, which would also lead to a negative forcing, is not shown. Effects of aviation on greenhouse gases are included in the individual bars.

The vertical line about the rectangular bars indicates a range of estimates, guided by the spread in the published values of the forcing and physical understanding. Some of the forcing possess a much greater degree of certainty than others. A vertical line without a rectangular bar denotes a forcing for which no best estimate can be given owing to large uncertainties. The overall level of scientific understanding for each forcing varies considerably, as noted.

Some of the radiative forcing agents are well mixed over the globe, such as CO_2, thereby perturbing the global heat balance. Others represent perturbations with stronger regional signatures because of their spatial distribution, such as aerosols. For this and other reasons, a simple sum of the positive and negative bars cannot be expected to yield the net effect on the climate system."

Slide 44

Comment: "Great work! Your results are in line with those of the scientists!"