Lesson 4
The Greenhouse Effect and Climate Change

Teaching Scenario

MAIN IDEA

The greenhouse effect plays a central role in the creation and sustainability of life on Earth. But humanity has disturbed the balance of Nature. As a result, the greenhouse effect threatens the sustainability of life on our planet, and also provokes an extensive change on Earth's climate. The greenhouse effect is not a unique characteristic of Earth, since it appears also on other planets and natural satellites of our Solar system.

GENERAL AIM OF THE SCENARIO

The general aim of the teaching scenario is for the students to describe the greenhouse effect on Earth, its consequences (positive and negative), and to get acquainted with the use of new technologies and scientific procedures.

SCIENTIFIC CONTENT

The greenhouse effect is a natural process and one of the main causes for the creation and sustainability of life on Earth.

The atmosphere and the surface of Earth are heated from the solar rays. Solar radiation enters the Earth's atmosphere. Almost half of it is absorbed by the ground, whereas a smaller part is absorbed by the atmosphere. The remaining part is reflected back from the ground to the atmosphere, directed towards the outer space. In the atmosphere, gases, such as carbon dioxide, but also water vapor absorb and re-emit the reflected radiation to all directions, leaving but a small part to be eventually directed to outer space. This mechanism resembles the process that takes place in a greenhouse and this is why this phenomenon is called the "greenhouse effect".

The gases that absorb and re-emit the reflected radiation, with most important being the carbon dioxide (CO_2), the nitrous oxide (N_2O) and the methane (CH_4), are called "greenhouse gases". When these are found in increased concentrations in the atmosphere, they prohibit even more the escape of the reflected radiation to outer space, thus increasing even more the temperature of Earth.

Greenhouse gases, as well as the greenhouse effect itself, contribute to climate change (the term "climate change" refers to the global climate change and to the long-term alterations of the meteorological conditions) through global warming.

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Consequences of global warming are the desertification of the lowest part of the temperate zone, the frequent occurrence of extreme weather phenomena (such as fires, floods, landslides), the raising of the sea level etc.
The greenhouse effect exists in other celestial bodies of our solar system as well: On Mars, Venus, and Titan (a natural satellite of Saturn).

IDEAS OF THE STUDENTS

- Students believe that the solar energy is reflected from the surface of the Earth. Science shows that the incoming ultraviolet radiation (UV radiation) is absorbed from the surface of the Earth and is converted into the outgoing infrared radiation (McCaffrey, 2010).
- The greenhouse effect has only negative consequences.

A) INSTRUCTIONAL OBJECTIVES

Knowledge:

The students, after completing the lesson, will be able to:

- Describe the function of the farmer's greenhouse
- Describe how the greenhouse effect is generated on Earth
- Formulate the definition of the global warming on our planet
- Report the consequences of global warming the greenhouse effect and of the greenhouse effect (positive-negative)
- Report the gases responsible for the greenhouse effect
- Report the scientific procedures used for answering questions
- Report that the greenhouse effect also appears elsewhere in the Solar system

Skills:
The students, after completing the lesson, will be able to:

- Perform the construction of a simple greenhouse
- Get acquainted with new technologies by developing experimental settings, with sensors and the relevant software.
- Interpret scientific diagrams
- Process scientific information
- Make calculations and classify the results
- Derive conclusions from data (images, experiment, texts)

Attitudes:
The students, after completing the lesson, will be able to:

- Raise their awareness of the greenhouse effect and the global warming of our planet
- Cooperate in groups

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- Attain a positive attitude towards science
- Attain a positive attitude towards the STEM specialties

B) TEACHING TOOLS AND MATERIALS

- Video projector
- PC
- Internet connection
- Storytelling video
- Data table
- Power point presentation
- Materials for the experimental arrangement
- Temperature sensors
- Worksheet of the student
- Evaluation sheet of the student

C) TEACHING METHODOLOGY

We suggest the specific teaching proposal (Inquiry-based learning) based on the following theoretical assumptions:

A. The new knowledge is constructed by the student and is not transmitted by the teacher. The already existing knowledge plays a significant role for the learning of the students. Based on the social dimension of knowledge, learning is conducted through social interaction.

B. The teaching is structured from the specific to the abstract, or from the partial to the general.

C. The use of analogies in teaching connects the already existing knowledge of the student with the new knowledge.

D. The cooperation between the students in small groups facilitates their social interaction and their learning, especially in what concerns difficult cognitive goals.

E. The teaching of aims relevant to science is preferably to be conducted in a direct manner, where each stage of the scientific methodology is presented and evaluated distinctly.

As it has been pointed out (Egger, 2009a, Egger 2009b), the teaching about the scientific procedures can be based on the following ideas:

a. To make the scientific procedures explicit instead of implicit to the students.
b. To use storytelling.
c. To use real data

In the present teaching scenario, the scientific procedures are explicit. In our teaching approach we use simulations and images and also real data. Also, activities of constructivist teaching are included, such as the promotion of the ideas of the students by asserting their own hypotheses, and the meta-cognitive

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activity of the comparison between the hypotheses and the conclusions of the students. The teaching scenario also includes an activity which aims to connect the object of astronomy, and more general, science and engineering, with the labour market.

F. The instructional procedure followed is in accordance with the inquiry-based learning method that includes the following steps:

- The phenomena
- Questions by the students
- Questions of the lesson
- Answers/Hypotheses
- Experimentation (data from simulations and images)
- Conclusion
- Comparison between the initial hypotheses and the final conclusions of the students.
- Generalization
- Extension/Application.

Open-Structured Inquiry

The inquiry-based method of learning-teaching may be determined either as a non-structured or open inquiry, or as a structured inquiry. The subject (teacher or student), who determines the procedure and the activities, also determines the type of the inquiry method. According to the open inquiry method the student is the one who determines the phenomena of study, the questions, the procedure, the conclusions. According to the structured inquiry the teacher is the one who determines the majority of the teaching variables, whilst the students participate in the procedure and reach conclusions, which are then used in order to answer the questions (Bunterm et al., 2014).

The proposed method of teaching is a combination of open inquiry and structured inquiry. The activities up to the point of the questions posed by the students are the beginning of an open inquiry procedure, while the rest of the teaching course follows the lines of structured inquiry.

D) CREATION OF THE EVALUATION TEST

The evaluation (knowledge) test has been constructed based on the following principles:

- The questions correspond to the teaching aims

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- There were used questions of many forms (of objective and open type) (Kassotakis, 2010)
- For the attitude questions the students answer with a "yes" or "no"[1].

E) SCENARIO DURATION

Two teaching hours, about 90 minutes

F) STAGES OF THE TEACHING APPROACH

Introduction-Frame of the lesson (2 minutes)

The aims and the course of the lesson are announced. The students are divided into working groups of 4-5 persons. The worksheet is handed to each group.

Activity 1: Story telling (6 minutes)

The teacher handles the story telling presentation.

<u>Storytelling</u>

Back in ancient years, when men and gods lived together in this world, in Ancient Greece, in a place called Thessaly, ruled Erysichthon. His palace was near to a forest full with many kinds of trees: apple trees, pine trees, pear trees, elms...But, this was a sacred forest, because the inhabitants had dedicated it to the goddess Demeter. One day the king decided to enlarge the hall where he gave his symposia. He needed wood. He took his slaves, axes, and they entered the sacred forest. They started to cut uncontrollably... What if the goddess warned him, what if she told him that the trees were sacred. He cut and cut without ending. The goddess raged against him; she threw a heavy curse on him. To feel eternal hunger, without being able to satisfy it. From this moment on the torment of Erysichthon begun. He ate without stopping but never satisfied his hunger. So, the more he ate, the thinner he got. He ate all his flocks, he even ate the cats and the mules. And, on his desperation he devoured his own flesh. One message, one warning which comes from this ancient myth about the devastating consequences which may come from the imprudent exploitation of the natural resources by humans?

Since the epoch of the industrial revolution humans ceased to see themselves as an integral part of the natural environment. They looked at Nature all around them and thought that it exists only for dominating it, believing that the Sun will always send his life-giving rays to Earth. That the seas will have fish for their meals, that the forests shall be endless, for cutting as many wood as they want. They believed that the sole reason of the existence of Nature was for dominating

[1] The analysis of the attitude questions can be performed either by the classic Item Response Theory (Türk, 2015) or the modern corresponding theory (Tang, 2016). The teachers can find many more similar questions in the paper of Chapman, Catala, Mauduit, Govender και Louw-Potgieter (2015) "Monitoring and evaluating astronomy outreach programmes".

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it, without ever thinking that this violent behavior against her would provoke a violent response from her, in her attempt to seek for her lost balance.
Nowadays, there is a lot of talk about the greenhouse effect, a vital natural process. One of the elements which determine the climate conditions on Earth is the constant flow of energy from the Sun. Earth is heated by the Sun and as it is being heated, the ground sends thermal radiation to the atmosphere; a large part of it travels to space. But, there, in the atmosphere, gases, most important of them being carbon dioxide, form a protective layer which traps a part of this radiation. In consequence, the atmosphere is being heated even more. Then, something marvelous happens. Earth is being kept warm, and thus the conditions for the appearance and sustainability of life on it are created. But human activities, such as deforestation, uncontrolled livestock farming, huge industrial zones, release enormous quantities of carbon dioxide, and as a result the sensible balance of Nature is disturbed. The gases which are emitted prevent the escape of the reflected radiation from the ground, and the temperature of Earth has increased little by little, but steadily over the past 130 years. This leads to climate change, with devastating consequences. Extreme weather phenomena do happen, the ices are melted, disastrous typhoons, floods, huge land areas are desertified. During the last years there is an attempt to redefine the disrupted relation between humanity and its natural environment. Can, perhaps, humanity regain its sense of moderation and harmony before it is too late...? Many things bear awe, man bears the greatest awe of all.

Activity 2: Questions of the students (2 minutes)
The students are guided to formulate their questions related to the story telling and write them on the worksheet.

Activity 3: Questions of the lesson-teacher (2 minutes)

1. How can I construct a greenhouse with simple materials?
2. Which is the effect of the greenhouse on the temperature in the interior of the greenhouse? (experiment)
3. How is the greenhouse effect created on Earth?
4. Which gases cause the greenhouse effect?
5. What does the global warming mean?
6. Which are the consequences of the greenhouse effect and the global warming?
7. Which scientific procedures do scientists follow?
8. The greenhouse effect is something positive or negative for the planet Earth and Man?
9. Does the greenhouse effect exist on other planets?

Activity 4: Answers-hypotheses of the students (5 minutes)
The students write their answers to the above questions without aid on the worksheet.

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Activity 5: Construction of the greenhouse with simple materials (20 minutes)

Materials-Procedure

The students are handed with straws, cellophane and plasteline, in order to construct greenhouses, such as the one depicted in Image 1, presented to the students with the power point presentation. Then, the students are asked to construct greenhouses of several types.

Image 1: Proposal for the construction of the greenhouse with simple materials

Activity 6: The effect of the greenhouse on the temperature in its interior (20 minutes)

Two temperature sensors are placed in the interior and the exterior of the greenhouse, after they have been placed in water, in order to acquire the same temperature.

The experiment is performed by the teacher and the students write down the maximal temperatures inside and outside of the greenhouse, which is lighted by a powerful lamp. Based on these temperature values and the graphic plots the students conclude that the temperature within the interior of the greenhouse is greater than the temperature outside the greenhouse.

Note: There are two ways by which the experiment may be performed. In the first we use two temperature sensors that come with their own software and in the second we attach two temperature sensors to an arduino device and download from the internet the free software. According to the version that s/he prefers to perform the teacher may choose to use version 1 or 2 of the presentation file respectively.

1st Version

Materials:

For the experimental arrangement the following materials are needed:

- A construction resembling a greenhouse. A plastic or glass box, or bottle, may be also used. It is proposed to choose one of the constructions of the students.
- Two temperature sensors
- PC and software for displaying and processing data

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- One halogen light bulb of 100 Watt
- Desk lamp
- Transparent membrane
- Adhesive tape
- Scissors
- Glass
- Water

Steps of the performance of the experiment:

Step 1: The teacher puts the halogen bulb in desk table lamp,

Step 2: The teacher connects the temperature sensors with the PC and loads the relevant software. For obtaining the same temperature quickly, the sensors are placed initially in a glass of water. Usually, the software offers the option for adjusting the temperature of the two temperature sensor systems.

Step 3: Then, the teacher secures with adhesive tape one of the sensors on one of the external faces of the greenhouse and the other sensor within the interior of the greenhouse. S/he covers the possibly existing openings of the greenhouse with transparent membrane and lightens the arrangement with the lamp, placed at a distance of about 5 cm to 10 cm away.

The relevant software offers the possibility of the simultaneous display of the measurements of both temperature sensors. It is determined which sensor corresponds to which display (inside and outside of the greenhouse). The students process the data on the worksheet[2].

2nd version

Materials

- A construction resembling a greenhouse. A plastic or glass box, or bottle, may be also used. It is suggested to use one of the constructions of the students.
- An Arduino device with two temperature sensors
- PC and software for displaying and processing data
- One halogen light bulb of 100 Watt
- Electric cable (recommended to be one with grounding), or desk lamp
- Transparent membrane
- Adhesive tape
- Scissors

[2] In the case we use the Vernier sensors: We open the file "The greenhouse Effect" located in the file "Middle School Science with Vernier". We adjust the rate of the measurements, so that 100 measurements of temperature are taken in every minute (100 samples/minute), for 15 minutes, and then we click on "Collect" to begin the recording of the temperature measurements, for both temperature sensors.

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- Glass
- Water

Step 1: The teacher puts the halogen bulb in desk table lamp,

Step 2: The teacher connects the Arduino with the temperature sensors with the PC and loads the relevant software. For obtaining the same temperature quickly, the sensors are placed initially in a glass of water.

Step 3: Then, the teacher secures with adhesive tape one of the sensors on one of the external faces of the greenhouse and the other sensor within the interior of the greenhouse. S/he covers the possibly existing openings of the greenhouse with transparent membrane and lightens the arrangement with the lamp, placed at a distance of about 5 cm to 10 cm away.

<u>Instructions for the use of the Arduino device</u>

- Connect the arduino to the computer.
- open the program 'cool term' (there is a wide variety of free software applications that may be used – Cool term is one among them)
- click 'connection' from the menu and then 'capture to textfile' and 'start'
- click 'connection', 'option' and from the menu 'receive' and tick the box 'add timestamps to received data' and click 'OK'
- click 'connect' and the data will start appearing on the screen and they will be saved to the textfile
- click 'disconnect' to stop recording the data
- to import data to excel open excel and click 'data' and then 'data import from text", choose the textfile you saved the data and import it to the excel sheet.

Activity 7: The greenhouse effect (7 minutes)

Based on the images and the simulation[3] the students write down their conclusions on the worksheet:

- The solar energy enters the atmosphere of Earth and is reflected on its surface. One part of it ……………….. outside ………………… Another part of it, after its reflection from Earth ……………………….. to the atmosphere of Earth.
- The temperature of Earth ……………………..
- This phenomenon is called ……………………….

[3] https://phet.colorado.edu/en/simulation/greenhouse
Note: The simulation has to be already installed in the PC or the Java platform.

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Activity 8: Gases in the greenhouse effect (5 minutes)
Based on the images and the graphs, the students write on the worksheet their conclusions about the greenhouse gases and the rate of their concentration as a function of time.

Activity 9: The global warming of our planet (5 minutes)
Based on the images and the graphs, the students write on the worksheet their conclusions about the change of the atmospheric temperature, because of the greenhouse effect and as a function of time.

Activity 10: Consequences of the global warming of our planet (5 minutes)
Based on the images and the graphs, the students write on the worksheet their conclusions about the consequences caused by the greenhouse effect and the global warming of the planet.

Activity 11: Scientific procedures (3 minutes)
The students, based on the material they watched, fill out on the worksheet the table below, referring to the scientific procedures.
Based on the lesson, the scientists:

- derive conclusions ( )
- explain phenomena ( )
- predict phenomena ( )
- draw diagrams ( )
- make hypotheses ( )
- pose questions ( )
- change the existing scientific theories ( )
- do not perform measurements ( )

Activity 12: The positive consequences of the greenhouse effect (5 minutes)

The students read the text[4] and answer to the following question: "Does the greenhouse effect have only negative consequences?".

A rather misunderstood natural phenomenon is the famous greenhouse effect, which has already attracted members of the scientific community, and also elsewhere. The phenomenon is physical and so old, just as our planet is. We should be thankful for its existence! Life would have become extinct without its presence, since the temperatures would be extremely low on a global and a yearly basis (-18 degrees Celsius, instead of the +15 degrees Celsius, which is the present temperature), therefore prohibitive for life, as we know it. Venus is too hot (+450 degrees Celsius), Mars is too cold (-53 degrees Celsius), Earth is in the habitable

[4] http://users.sch.gr/xtsamis/OkosmosMas/FainThermoKip.htm

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zone. But, many curse this phenomenon, which is so vital for sustaining life on our planet.

Activity 13: The greenhouse effect in other celestial bodies (5 minutes)

In the specific activity the students fill out the following table and answer to questions relevant with the existence of the greenhouse effect on other celestial bodies[5].

Planet	***Dominating gases in the atmopshere***	***Shall we observe the greenhouse effect?***
Venus	*97% carbon dioxide*[6]	
Titan	*98% nitrogen and 1,4% methane*[7]	

Questions

- Question 1: In which other planets, except from Earth, do we encounter a strong greenhouse effect?
- Question 2: Which planet exhibits the most intense greenhouse effect?

Activity 14: Comparison between the conclusions and the answers of the students (4 minutes)

In this activity the students compare their initial answers-hypotheses with the conclusions.

Activity 15: Application of the conclusions (4 minutes)

The students answer to questions related to the application of the conclusions.

Activity 16: Connection of the lesson with vocational guidance (10 minutes)

In the specific activity the students are asked to propose a solution to a problem related to the STEM specialties[8]. Then, each group presents its proposals to the rest of the class.

Activity 17: Evaluation sheet (10 minutes)

The evaluation sheet is handed for being filled out by the students.

[5] *In the solar system we also encounter the greenhouse effect on **Venus and Titan**, the largest satellite of Saturn. The greenhouse effecct on Venus is especially intence due to its thick atmopshere, which is constiituted mainly by carbon dioxide.*

[6] Chaisson & McMillan (1999)

[7] Coustenis & Taylor (2008)

[8] STEM specialties: Astronomer, astrophysicist, physicist, electric engineer, aeronautics engineer, mechanics engineer, telecommunications engineer, computer engineer, technologist, metereologist, geologist, mathematician, technician, chemist, biologist.

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a. http://users.sch.gr/xtsamis/OkosmosMas/FainThermoKip.htm
b. https://en.wikipedia.org/wiki/greenhouse_effect

14. Simulation: https://phet.colorado.edu/en/simulation/greenhouse

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