Journal of Modern Education Review, ISSN 2155-7993, USA
September 2020, Volume 10, No. 9, pp. 676–687
Doi: 10.15341/jmer(2155-7993)/09.10.2020/004

http://www.academicstar.us

Studying Climate Inside the High School Classroom

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Abstract: This article describes how high school students can study into the classroom the phenomenon of climate change. Specifically, the article refers to a project which includes three activities. The first activity shows how teachers and students can use real temperature and rain data from their region to investigate if these climate parameters have changed there, by using simple ICT tools and basic statistics. The second activity describes an experiment the project team can perform for producing, collecting and studying carbon dioxide, one of the most important greenhouse gases which affects climate. The third activity measures the project team's ecological footprint and emphasizes the role individual citizens can play to decelerate the deterioration of our direct natural environment.

The author has conducted this project once with students ranging from of 15–18 years of age. After the description of the steps a school team has to follow to accomplish the three activities, the outcomes of that effort are presented as examples.

We end up highlighting how this project meets some of the 21st Century Skills according to the framework of UNESCO.

Key words: climate change, greenhouse carbon dioxide, ecological footprint, 21st Century Skills

1. Introduction: What Our Project Is

The economy of our region on the southwestern side of Greece is mainly based on agriculture. Very often, local people say that the air temperature increases continuously thus destroying the crops and allowing a huge increase in the population of weeds and harmful insects, and that the amount of rain increases rapidly causing a lot of violent floods and destructions of the fields. These phenomena are attributed to climate change.

Climate change is an everyday social, scientific and financial issue all over the world. In this article we aim to show that high school students have the ability to investigate it for their region by using real atmospheric data, simple ICT tools and basic statistics. Furthermore, we propose a simple experiment for them to become acquainted with carbon dioxide CO2, one of the most important factors which influences climate. Moreover, they learn to evaluate their daily contribution on the quality of their natural environment.

The project we propose is based on the pedagogical framework of UNESCO for the students' 21st Century Skills. During the last decades a lot of new didactic and pedagogical approaches about Education have been proposed. These proposals impose the modification of the objectives of Students' School Learning (Kivunja, 2015) in order for students to cultivate new specific skills to prepare themselves for their future demands (Delafosse, 2012). According to the framework of UNESCO, these 21st Century Skills are: Self Regulation, Collaboration, Knowledge

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Construction, Communication, Use of ICT, and Real World problem solving. These skills aim to practice the "4Cs" competences: Critical thinking, Collaboration, Creativity and Communication (Common Sense Education, 2016).

Students have to accomplish some basic learning objectives during this project. So, they should:

i) study the climate change phenomenon and some of the factors which affect it,

ii) relate climate change to everyday life,

iii) discover the role of carbon dioxide (CO_2) in the Earth's atmosphere,

iv) recognize the importance of each individual person in the effort of reducing the deterioration of ecosystems,

v) learn to provoke ecologically and promote social awakening to their family/peers/local community through the adoption of ecological ways of life,

vi) use ICT educational tools,

vii) become familiar with chemical symbols and chemical equations,

viii) practice on designing and performing scientific experiments,

ix) acquaint themselves with scientific graphs,

x) learn how to make graphs of experimental data by using the Microsoft Excel program,

xi) evaluate the behavior of their graphs by statistically elaborating them.

The project involves 15–18 year old students and its topics are Physics, Chemistry, ICT and Art. It requires 14 hours to be completed, so it could be expanded during the whole school year. The author has conducted it once with her students, so Units 2, 3, and 4 of this article firstly contain instructions to other teachers of how to perform the proposed steps, and then those students' outcomes as examples. The final two Units refer to the impact this project had on the author's students.

2. Temperature and Rainfall Graphs

2.1 Preparation (3 Hours Required)

Before starting the activity, students should have the following classroom knowledge and skills:

- Understanding what the difference between weather and climate is (NASA Climate Change, 2018; Darron Gedge's Geography Channel, 2013), and identifying air temperature and rainfall as two basic parameters of climate (one hour needed).
- Ability to plot graphs using Microsoft Excel as with this program we can easily extract data from tables, represent this graphically and apply statistical analysis to this (two hours needed, suggest cooperation with the ICT teacher).
- Need to contact a weather organization to acquire suitable data: temperature-per-month and rain-per-month of a long period, 30 years and more, because climate is the average situation of the atmospheric conditions for a very long period.

2.2 Procedure (5 Hours Required)

2.2.1 Instructions for Teachers

- Divide students into two groups so that the 1st one can work on the temperature data and the 2nd one on the rain data.
- Provide the groups with their data and instruct them to create the corresponding graphs (Igines, 2012). The 1st group has to plot monthly temperatures to years (so 1 plot-per-month, totally 12 plots), and the 2nd group has to plot monthly rainfall against years (so 1 plot-per-month, totally 12 plots).

Notion: it is recommended for the 1st group to plot and elaborate on the same graph the maximum value, the mean value and the minimum value of monthly temperatures (Office Mystic, 2015) because most times the mean values alone don't reveal the real behavior of the variable we study.

- Ask students to perform a basic statistical check at their plots:

i) firstly add the Trendline and its equation for each graph. If the slope of this line is positive, the physical variable (temperature or rainfall) seems to increase with time, while when the slope is negative the variable seems to decrease with time.

ii) If the physical variable increases/decreases with time, it should mean that the microclimate of the region really changes. However, an increasing/decreasing trend of the physical variable doesn't mean that the variable indeed increases/decreases with time because this variation may not be statistically important but would be due to the inherent variability of the climate system. So, students have to find the 95% Confidence Interval (CI) of the slope of the trendline (Top Tip Bio, 2019) in order to statistically study this trend.

The 95% CI of a value means that there is a 95% possibility for this value to be inside this interval. So:

(A) Let the slope of the trendline be positive.

When we find positive both its Upper Confidence Interval value (UCI) and its Lower Confidence Interval value (LCI), it means that indeed there is a 95% possibility for the slope to be positive so the physical variable really increases. So, as this increase is not random but statistically important, we conclude that this parameter of the microclimate changes and there must be a cause for this behavior.

On the other hand, if we find the UCI value positive and the LCI value negative, it means that there is a 95% possibility this increase is not statistically significant but may be due to the inherent variability of the climate system. So, we can't conclude that the variable really increases although its trend is incremental, so we can't say that the microclimate changes.

(B) Let the slope of the trendline be negative.

If both the UCI and LCI values are negative, there is a 95% possibility for the slope to be negative so the physical variable really decreases. As this decrease is statistically important, we conclude that indeed this parameter of the microclimate changes.

If we estimate the UCI value positive and the LCI value negative, it means that there is a 95% possibility this decrease is not statistically significant but may be due to the inherent variability of the climate system. So, we can't conclude that the variable really decreases although its trend is diminishing, so we can't say that the microclimate changes.

2.2.2 Our Example

In this paragraph we demonstrate, as an example of the aforementioned activity, the work we did at our school, with a team of 20 students ranging in age of 15–18 years old.

Taking data from nearby meteorological stations, we investigated the following climate parameters of our region:

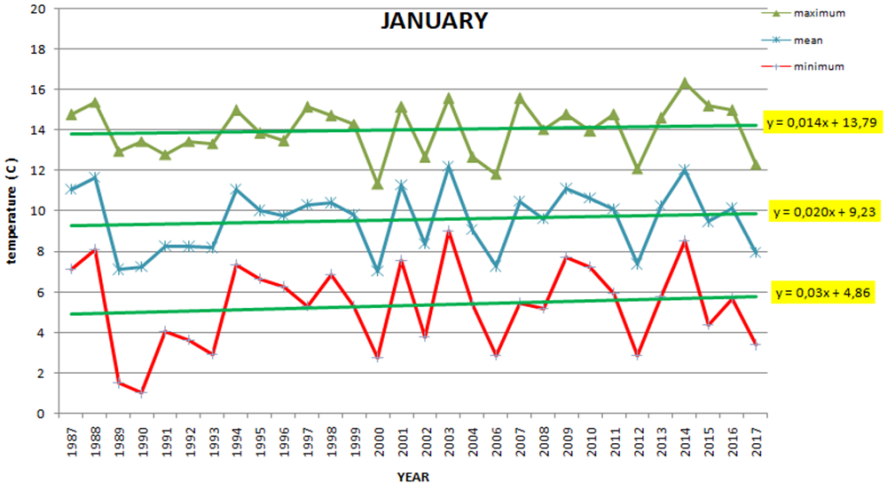
1) The monthly temperatures for the last 30 years, provided by the Hellenic National Meteorological Service.

2) The monthly amount of rainfall over the last 12 years, provided by the National Observatory of Athens (NOA). More specifically, the NOA gave us 10-minute rain data of the last 12 years, so we summed this data to acquire the monthly amounts of precipitation.

Our results are summarized below:

temperatures:

Let see our findings for the temperatures of January:



The 95% Confidence Interval of each slope:

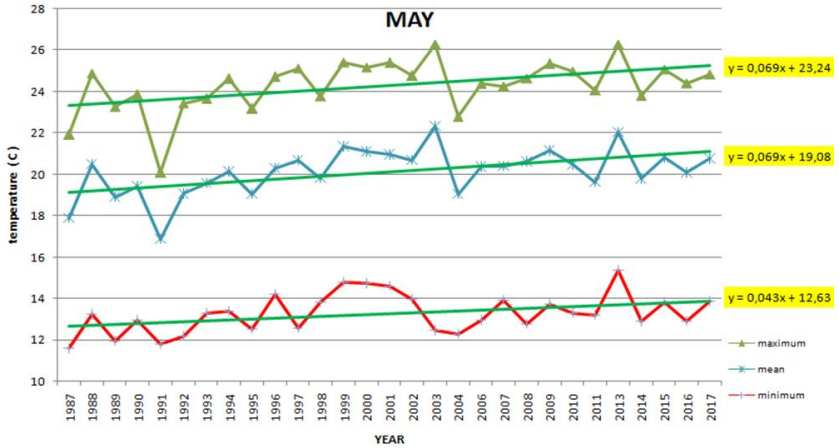
	maximum	mean	minimum
Lower Confidence Interval 95%	-0,039	-0,0456	-0,0598
Upper Confidence Interval 95%	0,0669	0,0834	0,1154

Figure 1 Temperatures of January

The temperatures of this month present an increasing trend line, so one could conclude that this month becomes warmer as time passes, so the microclimate of the region is changing. Nevertheless, if we calculate the 95% CIs of the slopes (recorded in the above table), we find the UCIs positive and the LCIs negative, so apparently there is a 95% probability that this increase is not statistically significant but this may be due to the inherent variability of the climate system. So, we can't tell for sure that the microclimate is changing but that it is exhibiting its normal, natural variations.

We found similar behavior for February, March, September, October, November, December as well.

Now, let study the month of May:



The 95% Confidence Interval of each slope:

	maximum	mean	minimum
Lower Confidence Interval 95%	0,0145	0,0203	0,002
Upper Confidence Interval 95%	0,1115	0,1052	0,0771

Figure 2 Temperatures of May

The temperatures of this month also present an increasing trend line, so a possibility of warmer Mays is revealed. In this case, both the LCIs and the UCIs are positive, so there is a 95% probability this increase is statistically significant, probably meaning that indeed the microclimate is changing and is becoming warmer.

April, June, July and August behaved in the same manner as May, while we found that the most stable month was October.

Rainfall:

NOA's stations have been operating only for 12 years, so the trends we derived can't give us statistically reliable conclusions as it is pointless to perform the 95% CI check for such a small time interval.

Nevertheless, we plotted each month separately and found that April, October and December (Figure 3) become less rainy through the years, in contrast to the other months. Moreover, January and November (Figure 4) present the largest tendency of increasing precipitation of rain.

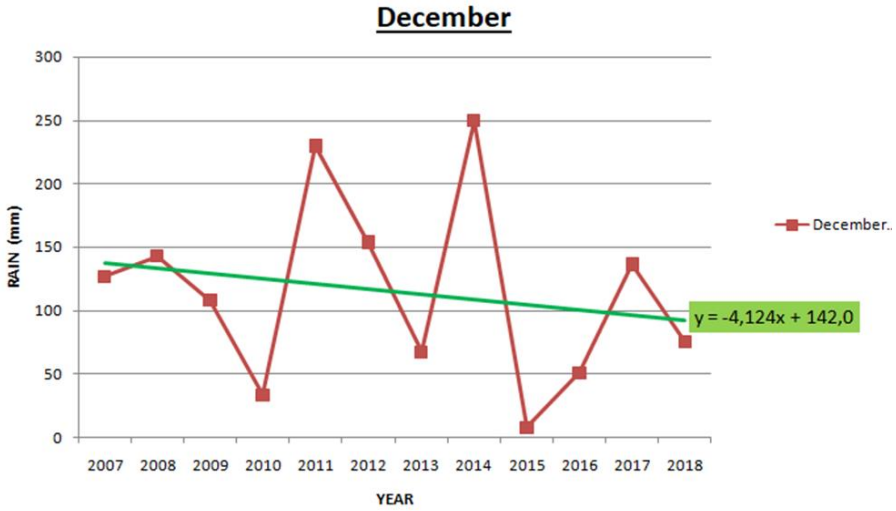


Figure 3 Rain in December. We Calculated A Decreasing Trend in the Amount of Rainfall.

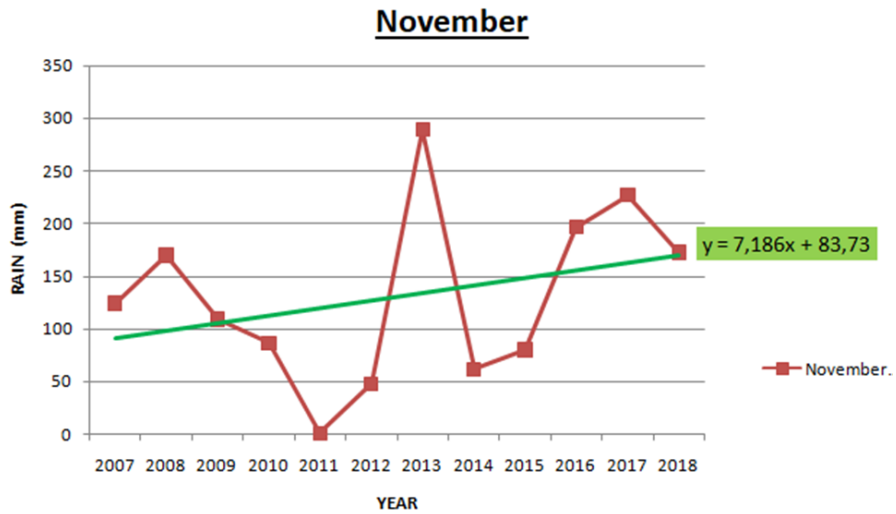


Figure 4 Rain in November, With An Impressive Increase in the Amount of Rainfall

When we finished this part of the project, our students realized that although they found indications of some change of the microclimate of our region, they had to study and analyze more thoroughly the given meteorological data and not to superficially conclude that climate change really happens just because it is widely said that it occurs.

Besides, it was mentioned to them that they have to be very careful with their conclusions about the climate behavior as climate has always been continuously changing. Nowadays we are aware that both natural phenomena and human activities affect this change, but the percentage of contribution is under research. So, even if we find indications of change, we can't attribute it directly to human activities and become alarmed.

3. Experimenting With the Impact of CO_2 on Air Temperature

3.1 Preparation (2 Hours Required)

One of the most important factors that influences climate is the greenhouse effect (Ahrens, 2013). For this reason, the teacher should study this phenomenon with the students (1 hour needed).

The next step for the students is to conduct research (bibliography, internet) about how we can produce and measure the quantity of one of the most important greenhouse gases: carbon dioxide (CO_2). In this way, the students should practice on how to plan a scientific experiment (1 hour needed).

3.2 Procedure (2 Hours Required)

3.2.1 Instructions for Teachers

- Divide students into two groups so that the 1st one can conduct the experiment and the 2nd one can plot and comment on the derived graph.
- Ask them to perform the following steps:

1st step: production of CO_2 and recording of the gases' temperatures (1 hour needed)

- Use grated marble ($CaCO_3$) and HCl 31–33% w/w for the following chemical reaction:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

- Collect the produced gas CO_2 by channelizing it into an empty bottle.
- Take a second similar bottle which contains atmospheric air.
- Tap both bottles and put thermometers into them.
- Put the bottles into a tank which is filled with water.
- Heat the water of the tank up to 500°C, so that the gases inside the bottles are heated, too.
- Measure the temperature of each gas every 3 min and record the values on a table.

2nd step: plotting the graphs (1 hour needed)

- Open a Microsoft Excel file.
- Create a table and write the above values of the temperatures of the two gases, and the corresponding time you measured them.
- Create on the same plot the graphs of these temperatures (0°C) against time (min).
- Compare the two graphs and write down your conclusions.

3.2.2 Our Example

We conducted the above experiment, under the instructions of the director of the Laboratory Center of Physical Sciences of Ileia prefecture.

Figure 5 Left Photo: We Put Grated Marble Into the Conic Flask and Then Poured HCl Into It. The Produced CO_2 Was Collected Inside the Bottle on the Right. Right Photo: One Bottle Contained CO_2 and the Other One Atmospheric Air. We Put Thermometers Inside Both of Them.

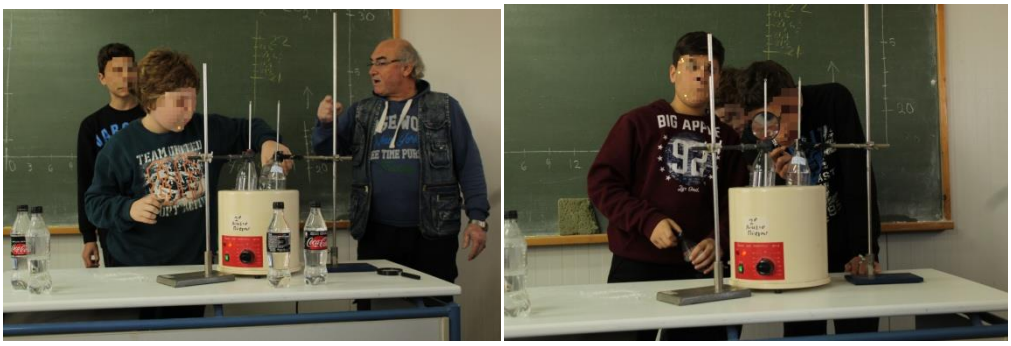
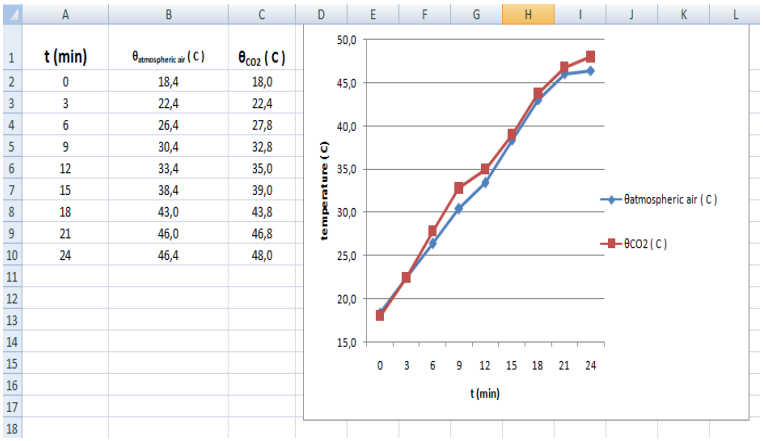


Figure 6 Left Photo: We Put the Bottles in the Beige Tank and Filled It With Water. Right Photo: As We Were Heating the Water of the Tank, So Were We Heating the Gases in the Bottles as Well, We Measured the Temperature of Each Gas Every 3 min.

In Figure 7, we can see the temperatures of the two gases taken every 3 minutes, and the graphs we created from this data.



t (min)	$\theta_{atmospheric\ air}$ (C)	θ_{CO2} (C)
0	18,4	18,0
3	22,4	22,4
6	26,4	27,8
9	30,4	32,8
12	33,4	35,0
15	38,4	39,0
18	43,0	43,8
21	46,0	46,8
24	46,4	48,0

Figure 7 Our Results

We can observe that in the end of the experiment CO_2 became 1.6°C warmer than the atmospheric air, suffering 2°C more increase than that of the atmospheric air, although we offered the same amount of heat to both gases!!

The dry atmospheric air contains only 0.04% CO_2 so one could say that this gas is unable to influence the temperature of the atmosphere, and climate by extension. Nevertheless, if we consider the huge amounts of CO_2 (290 ppm during the year 2015) humans release into the atmosphere per year, we can conclude that carbon dioxide from anthropogenic sources may contribute to the warming of the atmosphere, so to climate change.

Another important point is that although these induced temperature increases seem small, because of the presence of CO_2, we have to remember that during the last glacier period the mean temperature of the Earth's surface was only 4°C less than its current value!!!! So, even these small changes in atmospheric temperature, can cause huge changes to the climate.

4. Inquiry of the Students' Ecological Profile — Poster (2 Hours Required)

At the last stage of the project, the students should calculate their ecological footprint in order to realize how their everyday habits and way of life affect their ecosystem, consequently the climate. With the term "ecological footprint" we mean how many planets we need in order to fulfill all our needs, if everybody lives like us.

This calculation can be done by using the following software: https://www.footprintcalculator.org.

In the beginning students should answer some questions about their daily habits, then the software calculates their ecological footprints, and in the end offers proposals for a more "green" way of life.

In Figure 8 we can see a part of this software:

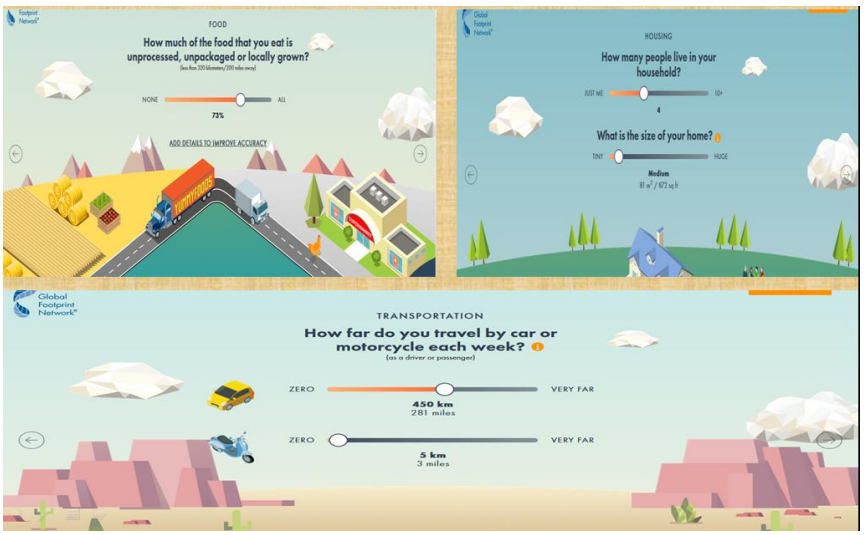


Figure 8 Some Questions of the Software

Unfortunately, the way of life in developed countries leads to huge ecological footprints!! For example, our students' mean ecological footprint was that each one of them would need the resources of 4.5 Earths to fulfill all his/her needs!!!!! One can imagine how much carbon dioxide is emitted, how much energy is wasted, how many resources are needed, on each one of them!!!

The software itself suggests simple and applicable solutions-proposals to change this undesired and dangerous situation, emphasizing the fact that each and every single citizen can attribute to the effort of improving the damaged situation of our natural environment. Some of these proposals are: reduction of food waste, reduction of the amount of meat we eat, integration of more vegetarian recipes during the week, proposal to the local authorities to adopt sustainable policies for our city, regulating the size of our family to affect our long-term footprint, increased use of

renewable sources of energy, cycling, walking or carpooling at least once a week instead of driving solo etc. These habits could reduce the anthropogenic intervention on climate and the deterioration of our ecosystems,

Concluding the project, our students designed posters inspired by the above proposed "green" habits and voted the best one of them. The "winner" is Figure 9. We offered it to a few other schools in order to promote awareness on how important it is for each and every one of us to make an effort for a better environment, and consequently for a healthier life.

Figure 9 Stairs of Attitude

5. Accomplishment of the 21st Century Skills

By conducting the proposed project, our students fulfilled a lot of the parameters of the 21st Century Skills. More specifically:

5.1 Communication

1) *Validation*: the project was based on real data (data from our CO_2 experiment, temperature data from the Hellenic National Meteorological Service, rainfall data from the National Observatory of Athens).

2) *Planning for a specific audience*: the results of the activities were addressed both to the local schools and authorities, and the scientific community. So, taking into account the specific characteristics of each audience, we used informal vocabulary for the first ones as we tried to promote to them new "green" everyday habits, and formal vocabulary for the second ones when we referred to our scientific conclusions. Moreover, our outcomes, the poster and the Excel files, are very easily accessible and comprehensible by everybody.

5.2 Collaboration

1) *Team working*: at a first stage, team working was held among the students of the same school. The nature of the project permits, as a second future stage, team working with students of other schools and scientists, at real time or/and asynchronously.

2) *Co-responsibility and interdependent work*: although the students were divided into smaller groups to realize a specific task (one group performed the CO_2 experiment, another one constructed the graphs of temperature, another the graphs of rain, another one drew the poster etc.), the whole team cooperated on making decisions and processing the topics, and was responsible for the accuracy of the results and the products.

5.3 Knowledge Construction

1) *Knowledge construction*: critical thought was required in order for the students to analyze, evaluate and interpret the real scientific data.

2) *Interdisciplinarity*: the project combined Science (climate change, statistics, experiment), ICT (Excel) and Art (drawing a poster).

5.4 Real World Problem Solving

1) *Problem solving*: The students solved the following problems: where to find real temperature and rainfall data, search ways of reducing the CO_2 emissions into the atmosphere, design a suitable experiment of measuring the emitted CO_2.

Then, they designed products — the poster and the Excel files — and disseminated them.

2) *A real world problem*: most of the people of our region are influenced by possible climate change financially and psychologically.

3) *Innovation*: the proposed solutions can be implemented (by adopting ecological behavior). Moreover, this project can help people (by starting the deceleration of the deterioration of their natural environment).

5.5 Self Regulation

1) The objectives and the criteria used to evaluate the quality of the activities were given to the students at the beginning of the project, so they themselves could easily check their own progress.

2) The project had a long duration so the students had the time to evaluate their work step by step and correct any imperfect points.

3) The students themselves had the possibility to plan their work as they were those who decided which member of the group would investigate every aspect of the project.

5.6 Use of ICT

1) The use of ICT supported the knowledge construction, without being the main objective of the project but a useful tool of solving real problems.

2) The use of ICT was necessary for the project because without Microsoft Excel for representation and processing of the data, too much time would be required without any learning benefit.

3) The students became ICT product constructors/designers as other schools and/or scientific organizations can use their Excel files for further statistic processing and data analysis.

6. Summarizing

During the aforementioned procedure the students practiced their Science and Art skills on the very serious issue of climate change. In this way they were proud of participating in a very interesting project as it was inspired by a local problem, which also intended to implement the UNESCO's 21th Century Skills.

As for the major question "if our microclimate has changed" they found indications of some change, but by now they learned to be very careful with their conclusions as climate, in any case, has been changing continuously.

The ICT skills which were cultivated by the project team are: Microsoft Excel for the elaboration of the data, Power Point for presenting the project at school, and Microsoft Photos for making a descriptive video of their work in order to share this work with a large and diverse group of people.

They also practiced on performing the chemical experiment of the CO_2 production, and studied the greenhouse effect.

Moreover, they became aware of the solutions/proposals the "ecological footprint" software suggests in order to change their way of life and stop deteriorating their natural environment and therefore, influencing climate. They also proposed more solutions and made a "pact" as citizens where they gave a promise to fulfill as many more proposals as they can, recognizing how important each individual person is in the effort of improving the quality of their lives. They tried to diffuse to their family/peers/local community their outcomes in order to provoke their ecological and social awakening.

In addition, one of the benefits of the project was that the project team had the opportunity to cooperate with respectable organizations such as the Ionian University of Greece, the Hellenic National Meteorological Service, the National Observatory of Athens, the Laboratory Center of Physical Sciences of our prefecture, and the Environmental Education Center Pertouliou-Trikkeon are.

As for future steps, the project team should seek constructive feedback about their research so when they or other teams repeat the project, it will be improved and more fruitful. This article belongs to this framework.

They also may find potential partners for future cooperation.

Moreover, they may try to repeat the project by using data from meteorological stations of other regions in order to investigate the climate behavior of those regions, too. And even more important is that they should find data of larger time intervals in order to be led to more reliable conclusions.

7. Acknowledgements

The author would like to thank Stratis Vougioukas of the National Observatory of Athens and Sotiris Arsenis of the Hellenic National Meteorological Service who willingly gave us the meteorological data, Anastasios Kalimeris, professor of the Ionian University of Greece, who helped to a great degree with the statistical elaboration of the graphs, Elias Kalogirou, director of the Physics Laboratory Center of our prefecture, who helped us to carry out the CO_2 experiment, and Maria Tsoukala, English literature teacher and school owner, for assisting in the correction of the texts. The author also would like to thank the Environmental Education Center Pertouliou-Trikkeon (Central Greece) for allowing us to participate in their program "Facing the global climatic change" which included both the calculation of ecological footprints and awareness of some renewable energy resources and "green" daily ways of living. In the end, the author would immensely like to thank the European Space Agency (ESA) for its thrilling project "Climate Detectives" (ESA, 2019) which gave us the opportunity to deal with the huge issue of climate change. We participated in it as "Music Climatologists" during the school year 2018–2019 and our work was highly commended at ESA's relevant competition.

References

Ahrens C. D. (2013). *Meteorology today, an introduction to Weather, Climate, and the Environment* (10th ed.), Belmont Canada: Cengage Learning.

Common Sense Education (2016). "What are the 4Cs?", available online at: https://www.youtube.com/watch?time_continue=9&v=QrEEVZa3f98.

Darron Gedge's Geography Channel (2013). "Why does climate vary in different parts of the Earth?", available online at: https://www.youtube.com/watch?v=RdySewpDvAQ.

Delafosse S. (2012). "Teaching in the 21st century", available online at: https://www.youtube.com/watch?v=075aWDdZUlM.

ESA (2019). Available online at: https://www.esa.int/Education/Climate_detectives.

Igines (2012). “How to make a line graph in excel — Scientific data”, available online at: https://www.youtube.com/watch?v=Xn7Sd5Uu42A&t=42s.

Kivunja C. (2015). “Teaching Students to learn and to work well with 21st century skills: Unpacking the career and life skills domain of the new learning paradigm”, *International Journal of Higher Education*, Vol. 4, No. 1, pp. 1–11.

NASA Climate Change (2018). “What’s the difference between weather and climate?”, available online at: https://www.youtube.com/watch?v=vH298zSCQzY.

Office Mystic (2015). “Excel multi-line chart”, available online at: https://www.youtube.com/watch?v=b0EB7i8gJ4g.

Top Tip Bio (2019). “How to calculate confidence intervals in excel”, available online at: https://www.youtube.com/watch?v=laCIJa7m4ao.