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INTEGRATION OF ICT IN ENVIRONMENTAL EDUCATION – CASE STUDY ON THE GREENHOUSE EFFECT AMONG SECONDARY SCHOOL STUDENTS

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ABSTRACT

This article deals with methods for teaching secondary school students about the greenhouse effect. The research question is addressed in a didactic context using ICT. Our experiment used a pre-test and post-test methodology, in which we compared the learning outcomes of two groups of students: experimental group (EG) and control group (CG). Both groups followed the same teaching on the greenhouse effect during a Life and Earth Sciences (LES) class. Our study involved introduction of the following differentiation for the two groups of students: CG received explanations, accompanied by a theoretical presentation of the experiment to demonstrate the greenhouse effect. The students were then presented with the theoretical results. EG used a computer simulation of the same experiment on the greenhouse effect and interpreted the results. At post-test, the experimental group (EG) demonstrated a better understanding of the mechanisms of the greenhouse effect than the control group (CG), and scored better on questions related to infrared radiation as a result of global warming. This has been confirmed by a statistical test of homogeneity. However, on the other questions about the nature and consequences of the greenhouse effect, including on behavior advocated for the protection of the environment, we found no significant differences. Moreover, the students in both groups only proposed actions in response to the consequences of human activity and did not propose actions to respond to the consequences of natural origin. We therefore conclude that computer simulation of the greenhouse effect experiment, accompanied by further scientific interpretation, constitutes a "good didactic situation" to instill a more global understanding of the greenhouse effect.

Keywords:-Environmental education - Greenhouse effect - Secondary education - ICT - Experiment simulation - Representations and behaviors.

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Academic Discipline and sub-disciplines

Education, Didactics of life and earth Sciences

SUBJECT CLASSIFICATION

Innovation in education

INTRODUCTION

The global conferences on climate change held in Stockholm in 1972, Rio de Janeiro in 1992, Kyoto in 1997 and Copenhagen in 2009 testify to a growing awareness of the environmental issues facing our planet, and in particular the worldwide ecological crisis and the issue of global warming (Catherine and Franck-Dominique, 2006).

Following the Congress of Tbilisi (Giolitto and Clary, 1994), institutional bodies in Morocco (SLASI, 2010), in line with several other countries (Giordan and Souchon, 1991; Sauvé, 1995), recognized this global challenge in education and in 1999 introduced environmental education in the new curriculum of fundamental scientific education (COSEF Morocco, 1999). Environmental issues have been incorporated into the life and earth sciences programs and chemistry teaching (HAMOUCHI, 2010), with a focus on reducing greenhouse gas emissions. The aim of teaching young learners (16–18 years old) about the issues is to sensitize future generations from an early age about the value of human resources and thus promote sustainable and equitable development.

Information and communication technologies (ICT) can play a useful role as a didactical aid in environmental education. When used as an educational resource, ICT, which includes video, simulations of experiments, database interpretation through spreadsheets, or indeed any digital resource used for an educational purpose, provides flexibility that promotes better understanding among learners of issues relating to environmental education.

In this research project we investigate environmental education in a didactic situation using ICT, in our case teaching about the greenhouse effect. We are specifically interested in assessing the impact of ICT on the learning of high school students in this kind of didactic situation through a study that analyzes the conceptual development of the learners.

1.Research question and theoretical framework

Posner, Strike, Hewson, and Herzog (1982) showed that learners can only build a correct representation of a scientific concept if it is transmitted in a clear and relevant mode of expression, through presentations in different registers (experiments, diagrams, symbols, etc.). DiSessa (1988) finds the use of visual and manipulable models effective, especially in the experimental sciences, and indicates that computer-based microworlds are a good tool that allow learners to conduct experiment on models of worlds firstly with characteristics that the students expect, and secondly on models with idealized characteristics, allowing them to improve the structuring of their initial models. There are many works that have tried to show that the use of computers in classroom can make a beneficial contribution to learning (Kulik and Cohen, 1980). However, in more general situations where ICT is integrated, the benefits yielded by the use of these technologies in the classroom are not always easy to demonstrate. Russell (2001) has reviewed more than 300 studies, in which he analyzed the effects of technology without being able to conclude with any certainty that they consistently produce positive effects. Lebrun (2002) reviews the research and stresses the need for caution in that the observed effects are often minor and are generally not controlled. Taking into account all these findings and recommendations on the integration of ICT in education, we wanted to conduct a study on a specific issue within teaching about the environment in an educational situation using computers.

The issue of climate change, through its constant media coverage, is a vector of knowledge and factor of learning (Chailley, 2004) in consequence of the debates it generates in society and among groups of experts from different disciplines, meaning it is one of the major socio-scientific issues today (Legardez and Alpe, 2001). The greenhouse effect is a highly complex concept that it is hard for students to understand easily. In light of this problem, we deem it important to find a didactical solution that can overcome the difficulties encountered by students in this context. We therefore opted for the integration of computer simulations in educational sessions, starting from the assumption that this kind of computer-based learning environment, accompanied by adequate teaching, will provide the students with better input, and therefore a better understanding of an experiment to demonstrate the greenhouse effect.

Thus, we will try through this research to answer the following questions: Does the simulation allow students to better understand an experiment on the greenhouse effect? What didactic impact does it have on the students' input in this kind of environmental experiment? And finally, what effect would this understanding have for the behavior and attitudes of students in respect of protection of the environment?

1.Research methodology

Our experimental study was conducted in the El Amal secondary school in Fez, Morocco, on a sample of 225 students with an average age of 16, studying in the first year of high school. Furthermore, in order to study the impact of the simulation on the students, we had to adopt an experimental pre-test and post-test methodology. Through random distribution we constituted an experimental group (EG) of 110 students and a control group (CG) of 115 students.

The two groups of students, who are all at the same level of education, all received the same traditional lecture on the greenhouse effect. In the control group, the teacher provided only a theoretical presentation with an explanation of how the experiment is conducted, following which the first theoretical results were presented. This is a classical approach to

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education, as recommended by the official instructions. By contrast, the experimental group received a presentation of the same experiment in the form of a computer simulation, which generated two sets of data, allowing interpretation.

The computer simulation showed how the experiment was set up with two containers, one containing dry cotton wool, and the other containing wet cotton wool, which emits steam. Lamps are then lit outside the two containers, which are the sources of heat. After 15 minutes data acquisition is started: the temperature inside the two containers is measured over time. This results in two curves, where the one relating to the temperature inside the container with wet cotton wool is consistently higher than the control container.

At the end of the teaching session, the teacher invites each group of students to perform the experiment, providing them with the necessary equipment, but without providing any other input. These experimental sessions were recorded on video, to enable qualitative assessment of the students' attitudes and behaviors during the experiment. The following table provides a summary of the concepts studied in connection with the greenhouse effect by the control group and the experimental group:

Table 1 : Concepts studied in connection with the greenhouse effect

	Control Group (CG)	**Experimental Group (EG)**
Concepts studied	- Natural imbalance	- Natural imbalance
	- Greenhouse effect	- Greenhouse effect
	- Greenhouse gas	- Greenhouse gas
	- Effect of greenhouse gases	- Effect of greenhouse gases
	- Consequences of the greenhouse effect	- Consequences of the greenhouse effect
	- Theoretical presentation of the greenhouse effect experiment.	- Greenhouse effect experiment using a GLX interface and temperature sensors that are used in computer-assisted experiments (EXAO)
Length of session	1 hour	1 hour

1.Analysis of the pre-test results

Through the pre-test questions (see Appendix 1), we sought initially to identify the initial, subjective knowledge of all the students (in both the control group and the experimental group) on the greenhouse effect.

Almost all students (98% in the control group (CG) and 100% in the experimental group (EG)) already have some knowledge of the greenhouse effect. The origin of this knowledge is primarily from school (65% in CG and 57% in EG) and to a lesser extent, the media (32% in CG and 26% in EG). This is explained by the fact that half of the Moroccan school program Life and Earth Sciences in science studies in the first year in high school is devoted to ecology. Furthermore, the media, especially television, represents a significant source of information and culture today, including on environmental issues. The media have a particularly strong influence on students' opinions about the causes of the greenhouse effect, probably far more significant than knowledge acquired institutionally in the classroom. Thus, a large majority of the students (70% in CG and 74% in EG) a priori link the concept of global warming to "human activity". By contrast, only 27% of CG and 26% of EG know that the greenhouse effect is a natural phenomenon.

The conceptions of the students about the origin and causes of the greenhouse effect have a strong influence on the correct answers to questions concerning the consequences of the greenhouse effect for the environment (see Fig. 1).

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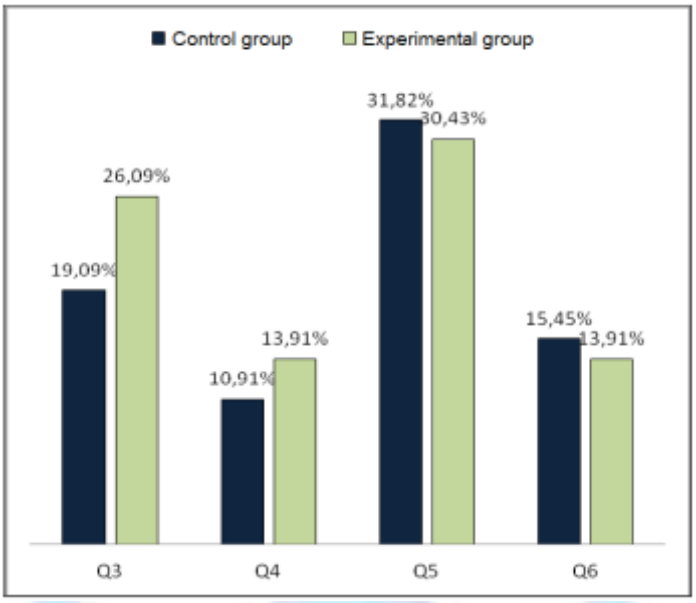

Fig. 1 : Percentages of correct answers in CG and EG groups to pre-test questions related to the consequences of the greenhouse effect for the environment.

Indeed, in our detailed analysis of the students' answers we noticed that 78% of CG and 75% of EG think that an absence of gases in the atmosphere would cause a rise in temperature, while 14% of CG and 14 % of EG declare that it would cause a drop in temperature. Furthermore, 74% of CG and 83% of EG think that the main greenhouse gas produced by human activities is carbon dioxide (CO_2). Neither group demonstrates widespread awareness of the other greenhouse gases, such as ozone (O_3) (11% in CG and 18% in EG), methane (CH_4) (9% in CG and 8% in EG) and chlorofluorocarbon (5% in CG and 21% in EG) to a significant extent. Nevertheless, it should be noted that a considerable share of students (24% in CG, 17% in EG) believe that oxygen (O_2) is given off by human activities and causes greenhouse effect. Finally, the majority of students (72% in CG and 79% in EG) believe that greenhouse gases prevent the return of ultraviolet rays to the universe.

The distribution of correct answers to the pre-test in the two groups of students, control and experimental (see Figure 1), seems to indicate that the correct initial conceptions about the consequences of the greenhouse effect on the environment are comparable. To verify this, we conducted a bilateral homogeneity test. We tested the answers to each of the questions 3, 4, 5 and 6 of the pre-test (see Appendix 1) relating to the nature and consequences of the greenhouse effect on the environment using the null hypothesis H0 : p1 = p2 = p, where p1 and p2 indicate, respectively, the theoretical proportions of success to a question, for the control group (CG) and experimental group (EG).

$$U = \frac{F_1 - F_2}{\sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

This test uses the formula , where F1 and F2 indicate the random variables corresponding to the frequencies of the samples CG and EG respectively, and n1 and n2 are the respective sizes of these two samples. The respective sizes n1=115 $\geq$ 30 and n2=110 $\geq$ 30 of CG and EG, as well as the frequencies observed f1 and f2 of these two groups in each of the questions 3, 4, 5 and 6, check the conditions n1f1 $\geq$ 5, n1(1 – f1) $\geq$ 5, n2f2 $\geq$ 5 and n2(1 – f2) $\geq$ 5; therefore, under the null hypothesis H0, the statistic U follows a normal distribution centered and reduced N (0.1). By fixing the standard threshold at 5% (risk of the first kind), we obtained a region of rejection of the null hypothesis H0 by P($|U| \geq$ 1.96) = 0.05.

The calculation of all the observed values[1] $u = \dfrac{f_1 - f_2}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$ of the statistic U show that the homogeneity test was not significant for all the questions 3, 4, 5 and 6 (see Table 2). In other words, the null hypothesis H_0 is not rejected,

[1] In the calculation of u, $\hat{p}$ is an unbiased estimate of theoretical proportion p of the null hypothesis H_0, where $\hat{P} = \dfrac{n_1 f_1 + n_2 f_2}{n_1 + n_2}$

and consequently, the control and experimental groups present a priori the initial conceptions comparable to the questions relating to the nature and consequences of the greenhouse effect on the environment. This result reinforces our findings from a methodological point of view, because any observation at post-test of better performance by the experimental group (EG) compared to the control group (CG) will a priori be mainly due only to effect of the simulation of the greenhouse effect experiment in the experimental group (EG), described in the research methodology in section 3.

Table 2: Results of the bilateral homogeneity test on the frequencies of successes observed with EG and CG groups on questions 3, 4, 5 and 6 of the pre-test

	Q3	Q4	Q5	Q6
f_1 of control group CG (110)	0.1909	0.1091	0.3182	0.1545
f_2 of experimental group EG (115)	0.2609	0.1391	0.3043	0.1391
Calculating the observed value *u*	-1.2529	-0.6824	0.2241	0.3267
Signification of the homogeneity test	Not significant	Not significant	Not significant	Not significant

1.Analysis of the post-test results

The post-test consisted of an experiment based on the greenhouse effect experiment that all students in EG and CG were asked to perform (see questions 1 and 2 post-test in Appendix 2). In addition, we sought to evaluate the change in the students' understanding of the nature and the consequences of the greenhouse effect by repeating the pre-test questions (see questions 3, 4, 5 and 6 in Appendix 2), as well as identify the behaviors and attitudes acquired by students in respect of protection of their environment (see question 7 in Appendix 2).

1.1.Impact of the computer simulation on the students' qualitative interpretation of the greenhouse effect

The experimental group did significantly better than the control group at interpreting the effect of CO_2 emissions on the rise in the temperature inside the container containing wet cotton wool (see questions 1-1 of Appendix 2): 58.28% in EG, compared with 22.11% in CG. Furthermore, 45.63% in EG gave a correct explanation of variations in temperature in both containers (See item 1-2 of Appendix 2), while only 17.89% in CG provide the correct explanation.

In question 2 of the post-test (see Appendix 2), where the students had to relate the different elements in the greenhouse effect experiment to their real-life correspondents, we found that globally the two groups had virtually identical correct answers (see Fig. 2), except for the question 2-1 (see Appendix 2), where the students in the experimental group (EG) performed significantly better (67.97%) in respect of correctly correlating the sulfuric paper in the experiment with the atmosphere in reality than their peers in the control group (52.63%).

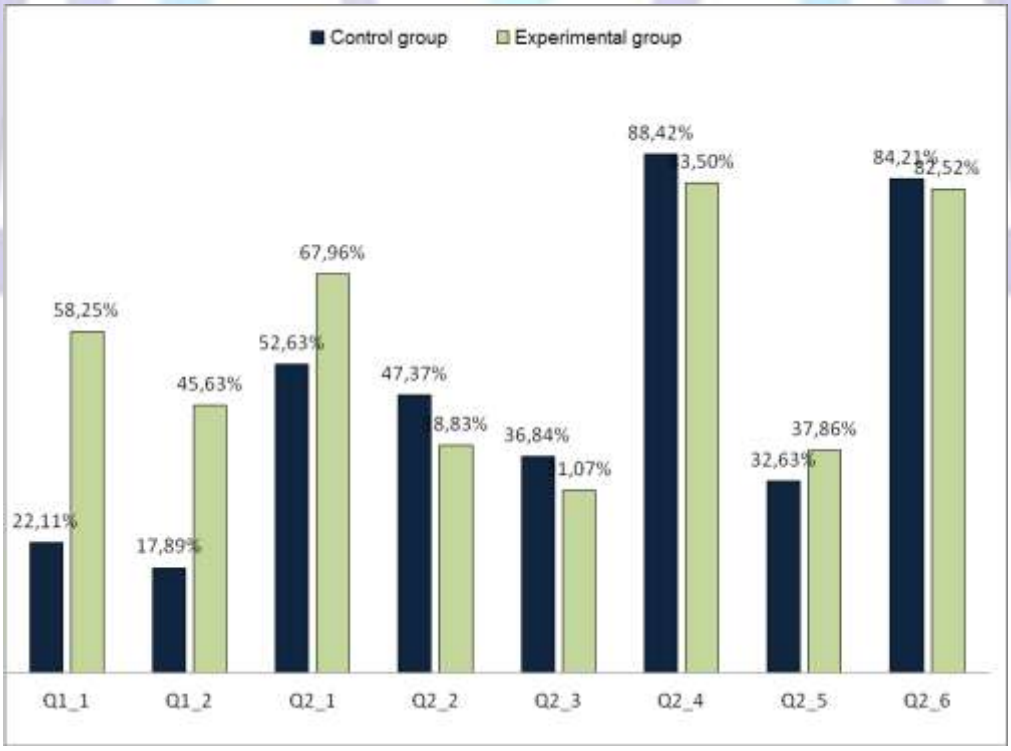

Fig. 2: Percentages of correct answers to questions 1 and 2 at post-test in control group (CG) and experimental group (EG)

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The gap analysis of the difference between the correct answers in the control group (CG) and the experimental group (EG) confirms the previous descriptive analysis. Indeed, the bilateral homogeneity test applied (at the threshold of 5%) on the various elements in questions 1 and 2 of the post-test (see Table 3) confirms that only the correct answers to questions Q1-1, Q1-2 and Q2-1 are significant in terms of better performance by the experimental group (EG) than the control group (CG); or, to put it another way, the H_0 hypothesis that the theoretical proportion of correct answers in EG and CG is equal is only rejected for these three questions.

Table 3: Results of bilateral homogeneity[2] test on the frequencies of successes observed in CG and EG groups on questions 1 and 2 of the post-test

	Q1_1	Q1_2	Q2_1	Q2_2	Q2_3	Q2_4	Q2_5	Q2_6
f_1 of control group CG (95)	0.2211	0.1789	0.5263	0.4737	0.3684	0.8842	0.3263	0.8421
f_2 of experimental group CG (103)	0.5825	0.4563	0.6796	0.3883	0.3107	0.8350	0.3786	0.8252
Calculating the observed value *u*	-5.1683*	-4.1689*	-2.2055*	1.2120*	0.8579*	0.9938*	-0.7694*	0.3181*
Signification of the homogeneity test	Significant	Significant	Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant

Following the previous analysis of the answers to questions 1 and 2, we can confidently conclude that the experimental group (EG) demonstrates better understanding of the subject matter than the control group (CG) in respect of the fact that the CO_2-rich air warms more than the CO_2-poor air, and it would be much easier for the EG group (unlike CG) to give an interpretation of the type *"The more carbon dioxide the atmosphere contains, the more it warms: carbon dioxide is a greenhouse gas".*

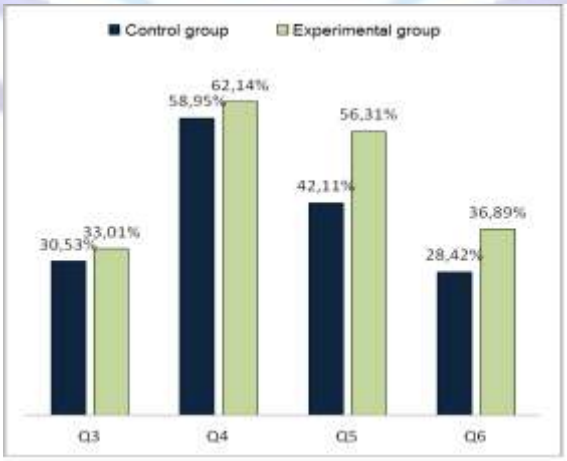
1.1.The students' attitudes towards the greenhouse effect

The majority of students responded to question 3 that the greenhouse effect is caused by human physical activities (45% CG, 57% EG), and only 27% of CG and 25% of EG think that this phenomenon is caused by the presence of certain gases in the atmosphere.

In response to question 4, the majority of students (66% in CG and 79% in EG) remembered that CO_2 is the main gas resulting from human activities and that it amplifies the greenhouse effect, followed by chlorofluorocarbon (CFC) in second place (28% in CG and 26% in EG), and sulfur dioxide (SO_2) (24% in CG) and methane (CH_4) (25% in EG). None of the students retained the fact that oxygen (O_2) is a greenhouse gas.

Furthermore, 49% of CG and 45% of EG think that the greenhouse gases are gaseous components that absorb infrared radiation emitted by the earth's surface, thus contributing to the greenhouse effect (see question 5 in Appendix 2).

As regards the consequences of global warming (see question 6 in Appendix 2), the majority of students responded (74.73% in CG and 75.45% in EG) "melting of the icecaps" followed by "eradication of animal and plant species" (46.31% in CG and 67.27% in EG).



[2] Note that the observed frequencies f1 and f2 of these two groups for each of the elements of questions 1 and 2 satisfy conditions $n_1f_1 \geq 5$, $n_1(1 - f_1) \geq 5$, $n_2f_2 \geq 5$ and $n_2(1 - f_2) \geq 5$.

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Fig. 3: Frequency distribution of correct answers to questions 3, 4, 5 and 6 at post-test in control group (CG) and experimental group (EG)

In order to supplement the descriptive analysis (see Fig. 3) of the students' attitudes as measured in the post-test questions on the greenhouse effect, we wanted to refine this analysis to identify potential significant differences between correct answers in both groups. To this end, we performed another (bilateral) homogeneity test on the frequencies of observed correct answers (see Table 4).

Table 4: Results of the bilateral homogeneity[3] test on the frequencies of observed correct answers in EG and CG groups to post-test questions 3, 4, 5 and 6.

	Q3	Q4	Q5	Q6
f_1 of control group CG (95)	0.3053	0.5895	0.4211	0.2842
f_2 of experimental group EG (103)	0.3301	0.6214	0.5631	0.3689
Calculating the observed value *u*	-0.3748*	-0.4587*	-1.9973*	-1.2683*
Significance of the homogeneity test	Not Significant	Not Significant	Significant	Not Significant

The descriptive analysis shows a priori greater success on all questions (3, 4, 5 and 6) by all the students in EG and CG compared with the results of the pre-test (see Table 2), and slightly better results in the post-test in EG compared with CG (see Table 4). However, the homogeneity test on the post-test results indicates that this difference is not significant for questions 3, 4 and 6, i.e. it is only significant for question 5.The students in EG demonstrate a better conceptual understanding than those in CG of the issue of reflection of UV, X-rays and infrared radiation in connection with global warming. We can explain this difference in performance by the fact that, compared with CG, EG showed in its answers to the post-test questions Q1-1, Q1-2 and Q2-1 (see section 5.1.) a better understanding of the mechanisms of the greenhouse effect, especially in respect of the causes and consequences of climate change. However, we note that almost one out of two students (42% of CG and 45% of EG) continues to think that "greenhouse gases prevent transmission of UV from the universe to the earth". The difficulty the students have grasping this concept reflects very clearly the complex nature of the concept of the greenhouse effect.

Finally, we would like to point out that the students' answers reflect a significant impact of their "social environment" and "information conveyed by the media", which prevents them from integrating into their conceptions the fact that the greenhouse effect is a natural phenomenon.

1.1.Behaviors advocated by the students for the protection of their environment

Table 5 below provides an exhaustive summary of the behaviors recommended by the students in both groups to protect their environment (see question 7 in Appendix 2).

Table 5: Analysis of behaviors recommended by the students in EG and CG for the protection of their environment

	Control Group		Experimental Group	
Behavior I : **Actions that benefit the environment**	Protection of the environment and natural resources	18%	Protection of the environment and natural resources	14%
	Use of renewable energy	11%	Use of renewable energy	20%
	Exploitation of forest resources	8%	Exploitation of forest resources	4%
Behavior II : **Individual responsibility of big polluters**	Install filters on the chimneys of industrial plants to absorb the fumes emitted	9%	Construction of factories using natural products	1%
	Use modern "green" transportation such as electric cars	7%	Decrease in means of transport that amplify the greenhouse effect	6%
	Decreased activities that cause air pollution and water	11%	Burning of waste in specialized factories	2%
	Locate factories away from populated areas	4%	Reduced use of chemicals	10%
			Limit polluting human activity	15%

[3] Note here also that the frequencies observed f_1 and f_2 of these two groups to each of questions 3,4,5 and 6, confirm the conditions $n_1f_1 \geq 5$, $n_1(1-f_1) \geq 5$, $n_2f_2 \geq 5$ et $n_2(1-f_2) \geq 5$

Behavior III :	Acting responsibly and changing our behavior towards our environment to	13%	Raising awareness of the greenhouse effect	7%
Recommended actions to resolve environmental problems	Do not burn forests, materials and tires	6%	Do not burn forests	8%
	Do not throw garbage anywhere	13%	Do not throw garbage anywhere	11%
			Waste recycling	2%

The analysis of the results described in Table 4 shows that the students put forward three main types of behaviors to promote environmental protection, which overall appear to have roughly equal importance to all students. Statistically, there is an equal distribution (proportion 1/3) among the three behaviors (see Table 6).

Table 6: Distribution of the three types of behaviors advocated by students (CG and EG) for the protection of the environment

	Control Group	Experimental Group
Behavior I :		
Actions that benefit the environment	37%	38%
Behavior II :		
Individual responsibility of big polluters	31%	34%
Behavior III :		
Individual civic actions for environmental protection	32%	28%

These three behaviors each represent a specific type of action in response to the consequences of various harmful factors to the environment:

- The protection of the environment, in particular through the use of renewable energy and the exploitation of forest resources, as principal actions in favor of the environment to ensure a healthy life on earth.
- Implementation of efficient measures against pollution of the air and water through the limitation and control of pollutants and gases emitted by factories, locating factories far away from urban areas, forest protection, using less polluting means of transport; these actions highlight the responsibility of individuals as the main action against the main sources of pollution.
- Responsible civic behavior by individuals with regard to the environment, such as not disposing of waste in inappropriate places, recycling waste, not burning forests, in order best to preserve the environment for ourselves and for future generations.

  Together, the behavioral actions recommended by the students testify to their strong sensitization to environmental issues, and the specific proposals formulated by the pupils reflect a successful environmental education.

CONCLUSION

The analysis of the pre-test responses showed that students associate the cause of the greenhouse effect much more with human activities than with natural phenomena. This can largely be explained by the considerable influence of the media, as a source of information, and thus knowledge, by the students, particularly about the causes of the greenhouse effect and its consequences for the environment. Furthermore, the pre-test results showed that the initial knowledge about the greenhouse effect in the two groups, experimental (EG) and control (CG), were comparable, and this was confirmed by the statistical homogeneity test, which validated the non-significance of the variations in the results between the two groups on all the pre-test questions. This finding in itself constitutes a validation of our experimental model based on a pre-test–post-test methodology. Indeed, the observation of possible variations in the correct results in favor of the experimental group (EG) at post-test can at this moment only be explained by a positive effect of the simulation of the greenhouse effect experiment carried out by the experimental group (EG). After our study we found that the experimental group (EG) had a better understanding of the mechanisms of the greenhouse effect in terms of the causes and consequences of global warming compared to the control group (CG) (cf. Q1-1, Q1-2 and Q2-1 of the post-test). This better learning exhibited by the experimental group resulted in better scores on the question regarding reflection of the infrared rays during the warming of the ground: the simulation of the greenhouse effect thus had a significant positive impact on the students' understanding of the mechanisms at play. We can thus deduce using ICT in well-developed didactic situations can contribute to better learning outcomes about concepts related to environmental education.

Finally, we observed that in response to questions about environmental protection, all the students questioned (EG and CG) recommend behaviors that can be classed into three types of actions: protection of the environment by man, individual responsibility toward major sources of pollution and responsible civic behavior with respect to the environment. The students' responses ascribe equal importance to all three types of behaviors, in both the experimental group (EG) and the control group (CG); nevertheless, it should be noted that all these actions are a priori suggested solutions to causes

related to human activity, and not to natural effects. We thus ask the question, within the framework of our study, if the simulation of the greenhouse effect could not be used as a "relevant didactical opportunity" to further improve the students' understanding of the natural causes of the greenhouse effect.

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APPENDIX 1: Pre-test

1- Do you know what the "greenhouse effect" is?
   - ☐ YES ☐ NO

2- If so; where have you heard of it?
   - ☐ At school
   - ☐ From the media
   - ☐ On the internet

3- The greenhouse effect is:
   - ☐ A natural phenomenon
   - ☐ A biological phenomenon
   - ☐ A geological phenomenon
   - ☐ A phenomenon produced by human activities

4- The Earth's atmosphere is composed of several gases, what do you think would happen if these gases ceased to exist?
   - ☐ It would get too hot
   - ☐ It would get too cold
   - ☐ The temperature would remain the same

5- Which are the main greenhouse gases emitted by human activity? (Several answers are possible)
   - ☐ Oxygen (O_2)
   - ☐ Carbon dioxide (CO_2)
   - ☐ Steam
   - ☐ Ozone (O_3)

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- Methane (CH_4)
- Chlorofluorocarbon (CFC)

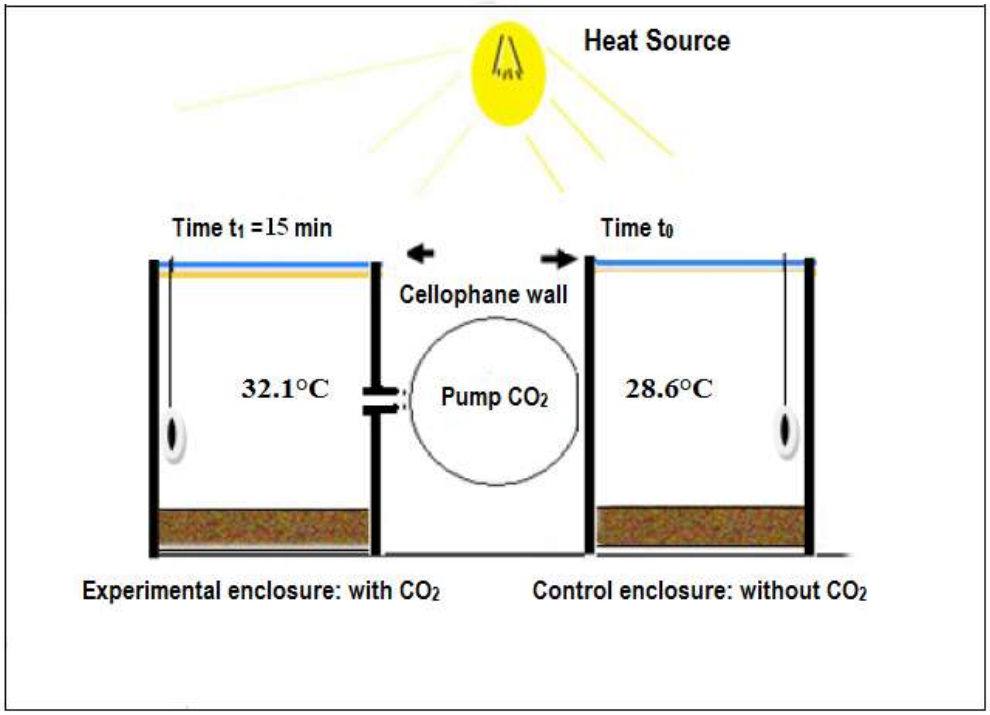
6- What type of radiation does the ground emit when heated by the sun?

- Ultraviolet rays
- X-Rays
- Infrared rays

APPENDIX 2: Post-test

1- To demonstrate the greenhouse effect, we carried out the following experiment:

- Two containers were set up closed with sulfuric paper:
  - The first container contains the ground + air inside the enclosure.
  - The second container contains the ground + air of inside the enclosure + CO_2.
- Light has been projected light on the two enclosures, after 15 minutes CO_2 and temperature were measured. The results of the experiment are shown in the following figure:



a. According to the above experiment, what difference can be observed?

b. How can we explain the observed variation in temperature inside the two enclosures?

2- If we translate this experiment to a model of the greenhouse effect, what is the equivalent of each part of the actual experiment?

2-1 - Sulfuric papers	Greenhouse gases
2-2 - The gases in enclosure 1	Domestic and industrial human activities
2-3 - The gases in enclosure 2	The atmosphere
2-4 - Source of light	The earth
2-5 - CO_2 Pump	Gases that amplify the greenhouse effect
2-6 -The ground	The sun

3 The greenhouse effect is a natural phenomenon – it results from:

- Human physical activities.
- Chemical and biological reactions between the constituents of the atmosphere.

- Some constituent gases of the atmosphere.

4 Cite three gases emitted into the atmosphere resulting from human activity and that cause amplification of the greenhouse effect:

5 The greenhouse gases, do not allow:

- The return of the infrared rays to the universe.
- The return of ultraviolet rays to the universe.
- The return of X-rays to the universe.

6 What are the consequences of global warming?

- Decrease in the amount of oil
- Use of GMOs
- Melting of the icecaps
- Eradication of animal and plant species

7 Our current lifestyle causes considerable changes in the atmosphere. In your opinion what behaviors and attitudes must be adopted to decrease the amplification of the greenhouse effect and to protect the environment?