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Inquiry Based Learning for Addressing Misconceptions on the Greenhouse Effect

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Abstract

Studies have shown that students commonly have misconceptions about the 'greenhouse effect'. Many times they associate it with ozone depletion, or do not know to distinguish between natural and man-made atmospheric effects. One of the reasons for such misconceptions is that traditional teaching approaches often impart facts without a sufficient focus on context. In contrast, Inquiry-Based Learning (IBL) promotes the acquisition of independent inquiry skills and deep conceptual understanding. Utilizing this approach to help students develop a fuller understanding of the greenhouse effect, IBIMET-CNR developed an IBL unit within the MISStoHIT project (Erasmus+, 2015-2017). The unit is interdisciplinary (involving science, chemistry and math) and was tested by 70 Italian students, whose attitudes toward the pilot testing were subsequently assessed.

In the lab, students received materials: thermometers, lamps, and jars with different gas compositions (dry and moist air, carbon dioxide and helium, as well as a vacuum), and were asked to set up an experiment explaining the connection between gas, radiation and the greenhouse effect.

Organised in work groups, students arranged the materials and made decisions together about the methodology, which mainly focused on recording the temperature change of the gas mixtures with and without exposure to light.

Discussion both within and between groups identified the external variables affecting the success of the experiment (e.g. distance from and type of lamp), improving their critical thinking, problem solving capacity and decision-making skills. They produced graphs, compared the different groups' results and explained their observations, showing how greenhouse gases (GHGs) trap heat compared to mixtures with little or no GHG content. Reflecting on the results, they better understood that while GHGs at natural levels are needed, higher concentrations resulting from human activity are responsible for global warming and disruptive climate change.

The survey examining students' engagement showed that they felt a significant challenge in carrying out the experiment, were engaged in the activity, and had no difficulty concentrating on the task at hand. In addition, they affirmed that the activities ran smoothly, that they understood the requirements and that they were confident in their abilities.

Keywords**:** *Attitude in science activities, GHGs, inquiry based learning, problem solving, survey*

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1. Introduction

Over the last decades, society has been facing global environmental challenges, which are continuously addressed by developing smart innovative solutions. Also in the future, the coming generations will be asked to contribute with new means and keys to development – and scientific disciplines will be crucial for understanding and managing the issues.
Scientifically informed citizens can better understand the positive and negative impacts of environmental change, and they may raise their own awareness and make choices that can be more sustainable. Therefore, science education is fundamental for present and future generations to address the "grand challenges" such as climate change, food and water security, sustainable cities etc.
Nevertheless, in the last decade there has been an increase in students leaving formal education that could provide scientific qualifications, together with a reduction in students undertaking a scientific career [1,2]. This has been attributed to a lack of interest among students toward the traditional teaching of science [3].
In order to make the understanding of concepts more efficient and keep the students' interest, science in the classroom should be more connected to the world around and everyday life experiences [4,5,6]. Students' learning is improved when they think like scientists, applying methodologies that foster critical thinking and investigation [7]. Moreover, students often hold misconceptions or use scientific concepts incorrectly. For instance, the common misconception that "*heavier objects fall quicker than the light objects*" is frequently noticed.
Research findings suggest that traditional approaches like the repetitive reading of texts and performing of exercises often do not succeed in deep conceptual understanding. However alternative approaches like Inquiry Based Learning (IBL) can promote active learning by putting the student at the centre of the activities [8,9,10].
In IBL students are involved in authentic problem-based learning activities in which students find an answer to an initial question by 'experimenting'. Experimenting means adopting a procedure, running an experiment or a hands-on activity, and discussing the results and the significance of findings with peers.
These steps increase the students' capacity for questioning, exploring and confronting their initial misconceptions with the observations made.
In order to address some common scientific misconceptions, the "MissToHit" project co-funded by the Erasmus+ Programme in 2015-2017 (http://misstohit.deusto.es/) developed ten didactic modules based on IBL in playful activities.
Experience and studies [11,12] demonstrate that students have common misconceptions about the greenhouse effect and global warming, associating it with ozone depletion, or not distinguishing between natural and man-made atmospheric effects.
Utilizing the above-mentioned approach, IBIMET-CNR developed a module to help students develop a fuller understanding of the greenhouse effect, focusing on the properties of different gases and their propensity to trap heat.

2. Methodology

A didactic module for secondary school students was developed to address a misconception that has developed among many students that the greenhouse effect is an exclusively "bad" phenomenon, without any distinction between the Earth's natural functioning and man-made global warming. The idea was to address this issue by investigating some of the gases that comprise Earth's atmosphere, in terms of their heat-absorbing properties which cause Earth's temperature to be raised.
The module (http://misstohit.deusto.es/activity-3/) is interdisciplinary, involving science, chemistry and math – allowing students to use scientific tools and methods, apply chemistry, and make calculations in worksheets. It was tested in two Italian high schools (both scientific *Lyceum*) in the 2016-2017 school year, involving a total of 70 students aged 16-17. The duration of the module was approximately three hours, with some homework for students.

Their attitude in piloting a scientific methodology was assessed by submitting at the end of the module a "flow and worry" questionnaire adapted from a previously-developed approach [13,14,15] and by asking the teacher to methodically observe their behavior during the implementation. The questionnaire was submitted at the end of the module (in the science laboratory for the paper version, and in the informatics laboratory for filling in the online version). The gathered data collected were elaborated by calculating the frequencies of responses for each answer.

3. Results

Three classes from the two Italian secondary schools piloted the module. In preparation for the activity, students were asked to bring to school electric lamps (one per group). In the science lab, students received materials: thermometers and jars with different gas compositions (dry and moist air, carbon dioxide and helium, as well as a vacuum). They were asked to set up an experiment explaining the connection between gas, radiation and the greenhouse effect.

Organized in work groups, students had to answer the question *"Do you think that the greenhouse effect is bad for the Earth?",* and then to hypothesize what kind of relationship there is between gas concentration and temperature.

To test their hypothesis, they arranged the materials in the science laboratory and made decisions about the methodology by discussing both within their group and between different groups. This mainly focused on recording the temperature change of the gas mixtures with and without exposure to light.

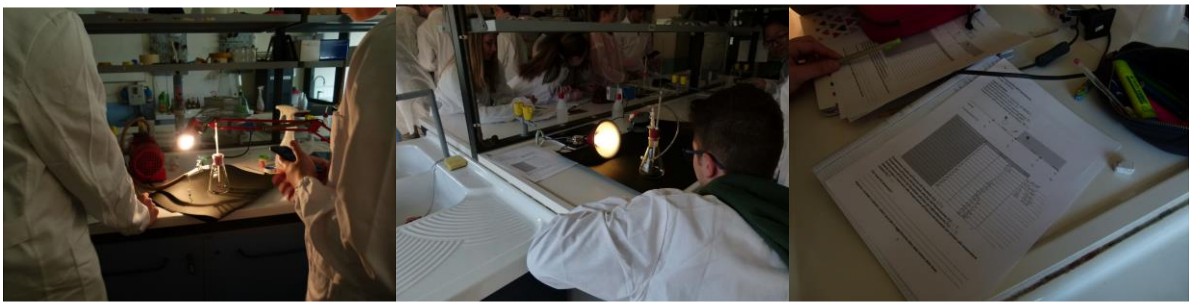

Fig.1. Students piloting the module.

Students tracked the temperature change every minute over a 10-minute period, both with the light on and with the light off, and finally they compared the results for the five different gases.

Discussion both within and between groups identified the external variables affecting the success of the experiment (e.g. distance from and type of lamp). In certain cases students had to repeat the experiment, taking more care to maintain accurate settings in order to compare the different situations.

They produced graphs, compared the different groups' results and explained their observations, showing how greenhouse gases (GHGs) trap heat compared to mixtures with little or no GHG content.

Reflecting on the results helped the students to understand how the relationship between radiation and gas concentration is dependent on the type of gas, and the discussion indicated how air traps more heat when it is moist than when it is dry, though still not as much as when it has a high concentration of GHGs. In addition, they identified human activities that cause GHG concentrations in the atmosphere to rise, and discussed the consequences for the Earth's temperature.

The survey examining students' engagement (Table 1) showed that they felt a significant challenge in carrying out the experiment, were engaged in the activity, and had no difficulty concentrating on the task at hand. They affirmed that the activities ran smoothly without their noticing the time passing, and that they understood the requirements and were confident in their abilities.

The observations made by the teachers mainly concerned student behavior. In general, students looked engaged in the laboratory activities, and the groups which encountered problems were willing to repeat the experiment.

Question	Average	St. Dev.	Strongly Agree & Agree
1. I felt just the right amount of challenge during the activity. (F)	3.64	0.96	69%
2. The activities I had to perform run fluidly and smoothly. (F)	3.73	0.88	70%
3. I did not notice time passing. (F)	3.86	0.90	74%
4. I had no difficulty concentrating. (F)	3.91	0.89	80%
5. My mind was completely clear during the task.	3.83	0.80	74%

(F)			
6. I was totally absorbed in what I was doing. (F)	3.71	0.85	69%
7. I knew what I had to do each step of the way. (F)	3.66	0.84	66%
8. I felt that I have everything under control. (F)	3.57	0.90	56%
9. I was completely lost in thought. (F)	1.80	1.04	9%
10. I was sure that I would not make any mistake during the task. (W)	3.16	1.01	34%
11. I was worried about failing during the activities I had to perform. (W)	2.59	1.14	21%

Table 1. Responses of students to the questionnaire about “flows (F) and worries (W) ” performing the activities. The questionnaire responses were according a 5-point Likert scale: Strongly Agree (5), Agree (4), Nor agree nor disagree (3), Disagree (2), Strongly Disagree (1).

4. Discussion

This activity described above was designed to address, in simple and intuitive way, the misconception that many students and the general public have about the greenhouse effect. The module focused specifically on the propensity of certain gases to trap heat. In fact, we thought that focusing the attention on the gas composition of the atmosphere would be the best way to understand the effect of different gases (or gas mixtures) on the temperature, which has also been reported previously [11]. Alternative options include air with limited presence of GHGs (by removing CO_2 with soda-lime) or using nitrogen.

Student understanding was self-assessed by using worksheets included in the module. From the final discussion, it emerged that while GHGs at natural levels are needed, higher concentrations resulting from human activity are responsible for global warming and disruptive climate change.

In this experience of teaching and assessing students' behaviour, we noticed that during the experiment students’ attitude was in general positive. They were able to follow the instructions and in fact set up the experiment on their own, though some asked for the teacher’s *approval* when designing and carrying out the experiment. Though each student started without a particular individual mental model, the experience of Inquiry-Based Learning allowed curiosity and experimentation to take over.

At the same time, certain problems were encountered (e.g. making a vacuum, sealing the jars, maintaining correct radiation intensity, and establishing the precise distance between jar and lamp) that improved their critical thinking, problem solving capacity and decision-making skills either by working within the group or between the groups. The results from the “flow and worry evaluation” demonstrate their positive attitude toward the activity’s organization.

The main constraint connected to this kind of learning experience is the curricular time limitation. The experiments take time and repetitions are often needed for a deeper understanding, so as not to foster additional misconceptions.

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