

Literacy of students of the Physics Department regarding the greenhouse effect and the ozone hole

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Abstract

In this research, we study the literacy of students of the Physics Department regarding the greenhouse effect and the ozone hole. Misconceptions of the students in these topics were also identified. The progression of the perceptions that students have from year to year of their study was also studied. The results of the research led to the conclusion that students have misconceptions, some of which have been published in other papers and some are being identified for the first time. The research on how students' misunderstandings change within their study, has shown that they remain unchanged throughout their studies. This result means that their studies do not change any misconceptions on these topics. This finding leads also to the conclusion that the students of a physics department should connect their knowledge of their courses with everyday problems of the modern life.

Key words: Science literacy, misconceptions, natural sciences, greenhouse effect, ozone hole, University students.

Introduction

The greenhouse effect and the ozone hole are issues that had, have and will continue to have an important influence on the environment and ergo the everyday life of humans. The two phenomena have contributed, each in their own way, to the changes in the environmental equilibrium that have been documented in the last decades, with such repercussions as the increase in extreme weather events (Easterling, 2000) and the negative effect on the oceanic ecosystem (Harvell et al., 2008).

The greenhouse effect has preoccupied the scientific community for several decades. For this reason, studies have been conducted to record its history (Jones & Henderson-Sellers, 1990), the misconceptions and myths that people have gained about it (Royal, Society, & Geographers, 2014), as well as to find solutions about the increase in carbon dioxide levels on the atmosphere (Sakakura, Choi, & Yasuda, 2007). Furthermore, researches have been conducted to record the knowledge and perceptions that children (Boyes & Stanisstreet, 1993), pre-service teachers and teachers (Groves & Pugh, 1999) have about the phenomenon.

The ozone hole is a phenomenon that has been observed more recently, compared to the greenhouse effect, but scientists have already studied its history (Susan, 1999) and the more noticeable ozone depletion above the South Pole (Solomon, 1990). In recent years, researches have been conducted to identify gases, besides chlorofluorocarbons, responsible for the phenomenon (Ravishankara, Daniel, & Portmann, 2009), as well as possible ways to repair the problem in the ozone layer (Data & With, 2009). In addition, the effects that can be caused to humans by UV radiation have been studied (Cadet, Sage, & Douki, 2005; Matsumura & Ananthaswamy, 2004).

All the above show that it is necessary to have some basic knowledge on environmental issues, with these two issues being amongst the most important, and all the levels of education should play a key role in educating and informing people about them. There are

many studies concerning the perceptions, knowledge, misconceptions and alternative ideas that students and teachers have about various environmental issues and most of them are showing the existence of common misconceptions between the two groups, with the two issues that were studied, the greenhouse effect and the ozone hole phenomenon, being no exception to that rule. Generally, these alternative ideas and misconceptions stem from the lack of coverage of the above two environmental issues in the curriculum on all education levels and the misinformation from various news, media and internet outlets. It is also important to note that people tend not to have enough interest in finding proper sources for their information regarding these environmental issues and have a carefree attitude about the effect these issues have in their everyday life, which furthers their lack of knowledge.

Greenhouse effect

In general, students and teachers have a lack of knowledge about the definition and nature of the greenhouse effect (Wallin, 2000; Pruneau, 2001). They think that it is not a natural phenomenon, human activities were the primary cause of the it (Khalid, 2001) and the effect is considered an environmental problem that we need to stop (Koulaidis & Christidou, 1999). The false perception, that the greenhouse effect is a manmade phenomenon, is quite prevalent in most studies.

Furthermore, there is a wide confusion between the greenhouse effect and the phenomenon of ozone hole (Wallin, 2000; Pruneau, 2001), mixing up their nature and usually correlate them in various ways, with people going as far as saying that the greenhouse effect is causing holes in the ozone layer or that ozone depletion is causing the greenhouse effect or the increased greenhouse effect is depleting the ozone.

As far as identifying gases that cause the effect, air pollutants are mistakenly considered as greenhouse gases (Boyes & Stanisstreet, 1997; Koulaidis & Christidou, 1999), while there is the belief that carbon dioxide (CO₂) is not a greenhouse gas (Boyes & Stanisstreet, 1993; Pruneau et al., 2001). Besides all the above, most people state that they don't really think about the greenhouse effect, the impact it has on the environment and in general it does not really worry them.

Ozone hole

As stated before, studies show a universal confusion between the greenhouse effect and the phenomenon of the ozone hole, which leads some to contradictory misconceptions. For example, a common thought is that the greenhouse gases cause the depletion of the ozone layer (Boyes & Stanisstreet, 1994), meanwhile many people think that the thinning of the ozone layer increases the greenhouse effect (Kalipci, Yener & Özkadif, 2009).

In addition, most people think there are actual holes on the ozone layer (Boyes & Stanisstreet, 1994; Koulaidis & Christidou, 1999; Wallin, 2000; Österlind, 2005; Pekel, 2005; Arslan, Cigdemoglu, & Moseley, 2012) and there is the belief that the layer consists of various gases (Gungordu, Yalcin-Celik, & Kilic, 2017), instead of simply consisting of ozone (O₃). As far as the reasons that the layer is depleting, the common misconception is the role of two greenhouse gases, carbon dioxide (CO₂) and methane (CH₄) (Pekel, 2005; Arslan, Cigdemoglu, & Moseley, 2012), which further confirms the confusion between the two phenomena.

Meanwhile, chlorofluorocarbons are correctly identified as an important cause, but most people do not know what they actually are (Khalid, 2001) and how they affect the ozone layer. Also, there is a lack of distinction between ultraviolet and infrared radiation (Boyes & Stanisstreet, 1997; Koulaidis & Christidou, 1999; Österlind, 2005) and the belief that ultraviolet radiation is both a cause and effect of ozone depletion (Pekel, 2005; Arslan, Cigdemoglu, & Moseley, 2012).

Research

The main purpose of this study is to record and examine the perceptions of students of the Physics Department about the greenhouse effect and the ozone hole and to determine their literacy in this field. A second objective was to determine whether there was a change in their misconceptions from year to year of their studies.

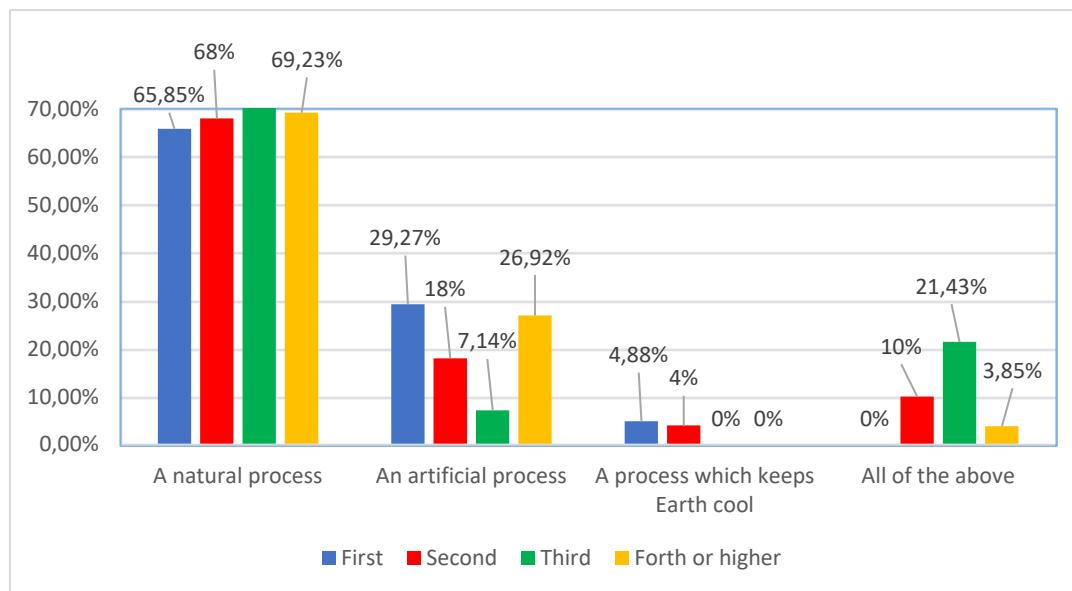
145 students took part in the research, with 79 (54,48%) of them being male and 66 (45,52%) being female. From the 145 participants, 41 (28,28%) of them were in their first year of study, 50 (34,48) were in their second year of study, 28 (19,31%) were in their third year of study and 26 (17,93%) were in their fourth year of study or higher.

The questionnaire was consisted of three parts. The first part of the questionnaire included four demographic questions. The second part of the questionnaire included seven questions and the third part included five questions about the greenhouse effect and the ozone hole, respectively. These questions pertained to the nature and the effects of the phenomena. The twelve questions regarding the two issues were multiple choice with only one correct answer.

The data of the research were processed using IBM SPSS Statistics 22, with the questions acting as categorical variables. Independent samples t tests (chi-square) were conducted between the variables. The variables were transformed into right-wrong questions, so that the independent samples t tests were done correctly.

Results

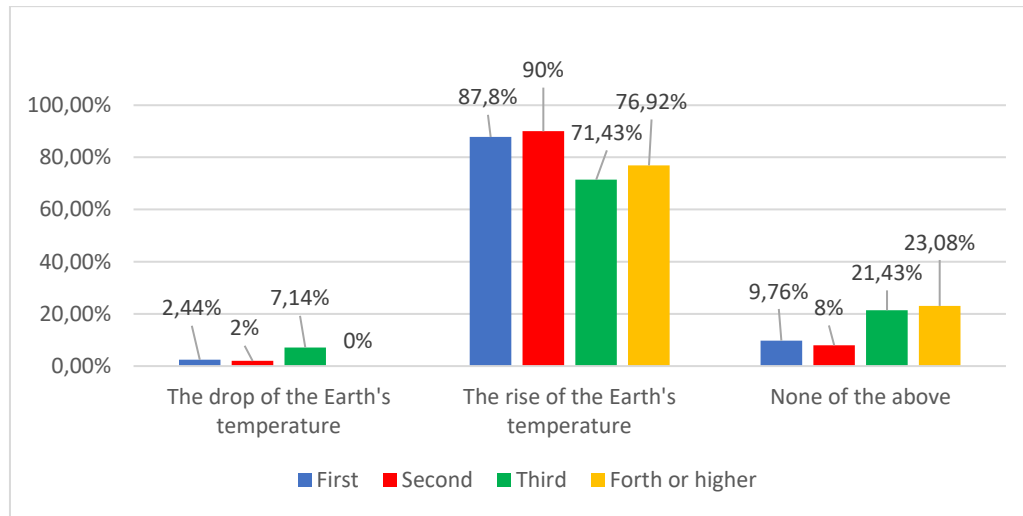
Graph 1 shows the distribution of students' answers in relation to the year of study regarding question 1 "The greenhouse effect is:". 27 (65,85%) of the 41 first-year students, 34 (68%) of the 50 second-year students, 20 (71,43%) of the 28 third-year students and 18 (69,23%) of the 26 fourth-year or higher students answered correctly that the greenhouse effect is a natural process. The application of the independent t-test ($\chi^2=0,252$, $df=3$, $p=0,969$) showed that the variables are independent, and that the year of study is not a statistically significant factor.



Graph 1. The bar graph of students' answers, in relation to the year of study, for question 1: "The greenhouse effect is:"

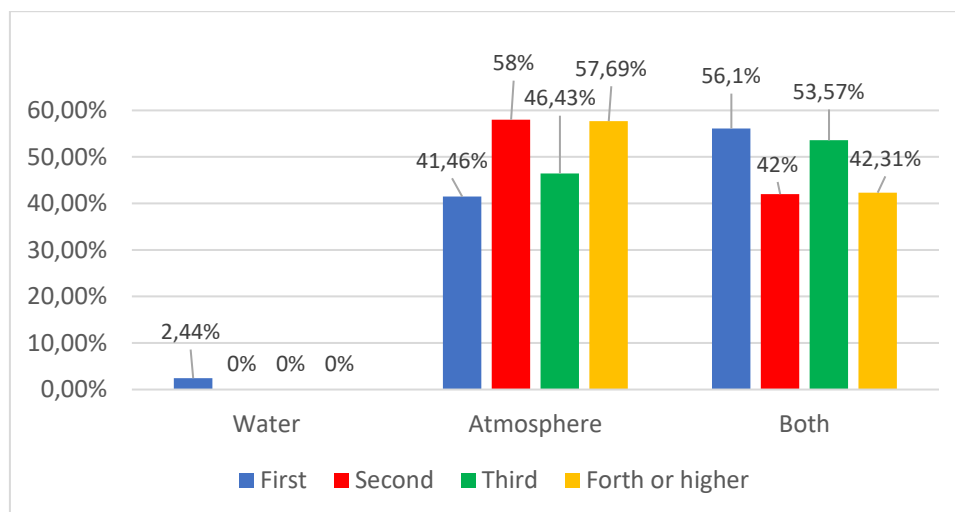
Graph 2 shows the distribution of students' answers in relation to the year of study regarding question 2 "The greenhouse effect causes:". 36 (87,8%) of the 41 first-year students, 45 (90%) of the 50 second-year students, 20 (71,43%) of the 28 third-year students and 20

(76,92%) of the 26 fourth-year or higher students answered correctly that the greenhouse effect increases the average surface temperature of the Earth. The application of the independent t-test ($\chi^2=5,848$, $df=3$, $p=0,119$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 2. The bar graph of students' answers, in relation to the year of study, for question 2: "The greenhouse effect causes:"

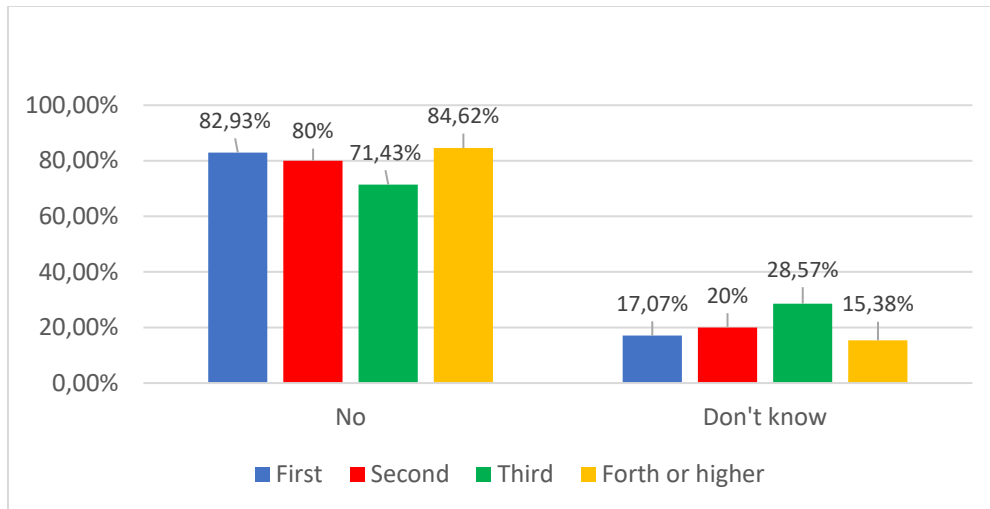
Graph 3 shows the distribution of students' answers in relation to the year of study regarding question 3 "The greenhouse effect occurs to planets that have:". 17 (41,46%) of the 41 first-year students, 29 (58%) of the 50 second-year students, 13 (46,43%) of the 28 third-year students and 15 (57,69%) of the 26 fourth-year or higher students answered correctly that planets must have an atmosphere for the greenhouse effect to occur. The application of the independent t-test ($\chi^2=3,173$, $df=3$, $p=0,366$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 3. The bar graph of students' answers, in relation to the year of study, for question 3: "The greenhouse effect occurs to planets that have:"

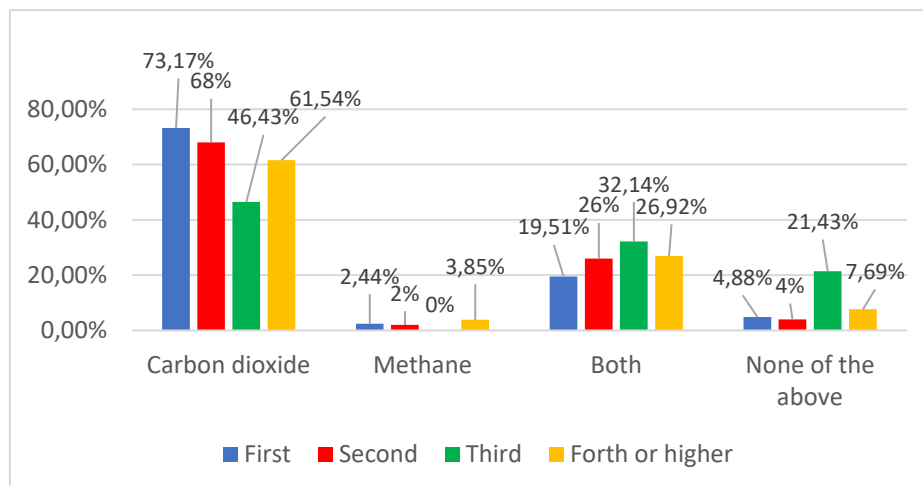
Graph 4 shows the distribution of students' answers in relation to the year of study regarding question 4 "Does the greenhouse effect occur on the Moon?". 34 (82,93%) of the

41 first-year students, 40 (80%) of the 50 second-year students, 20 (71,43%) of the 28 third-year students and 22 (84,62%) of the 26 fourth-year or higher students answered correctly that the greenhouse effect does not occur on the Moon. The application of the independent t-test ($\chi^2=1,851$, $df=3$, $p=0,604$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 4. The bar graph of students' answers, in relation to the year of study, for question 4: "Does the greenhouse effect occur on the Moon?"

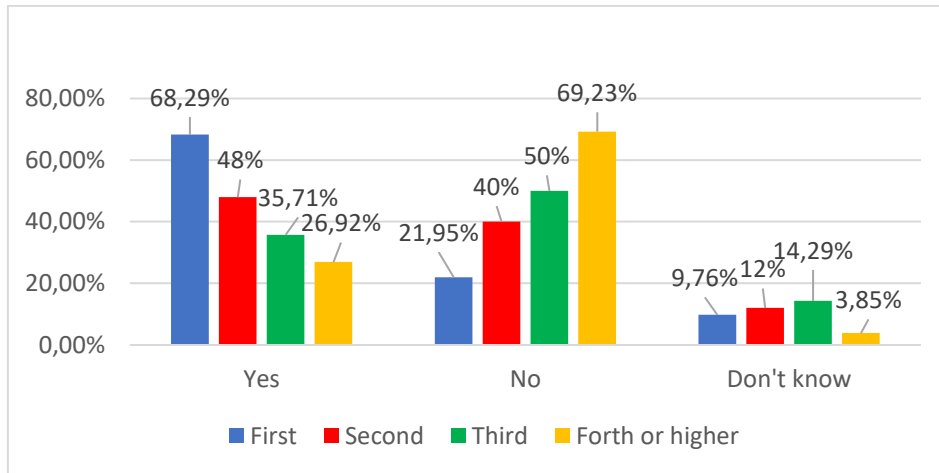
Graph 5 shows the distribution of students' answers in relation to the year of study regarding question 5 "Which gases are responsible for the greenhouse effect?". 8 (19,51%) of the 41 first-year students, 13 (26%) of the 50 second-year students, 9 (32,14%) of the 28 third-year students and 7 (26,92%) of the 26 fourth-year or higher students answered correctly that both gases are responsible for the greenhouse effect. The application of the independent t-test ($\chi^2=1,458$, $df=3$, $p=0,692$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 5. The bar graph of students' answers, in relation to the year of study, for question 5: "Which gases are responsible for the greenhouse effect?"

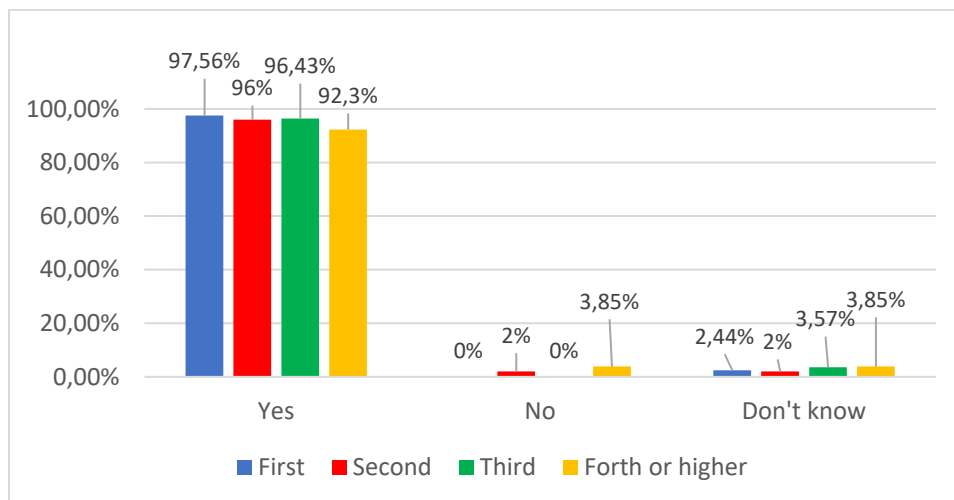
Graph 6 shows the distribution of students' answers in relation to the year of study regarding question 6 "Did the greenhouse effect occurred to Earth after the appearance of

humankind?". 9 (21,95%) of the 41 first-year students, 20 (40%) of the 50 second-year students, 14 (50%) of the 28 third-year students and 18 (69,23%) of the 26 fourth-year or higher students answered correctly that the greenhouse effect did not begin to occur on Earth after the appearance of humankind. The application of the independent t-test ($\chi^2=15,490$, $df=3$, $p=0,001$) showed that the variables are not independent and that the year of study is a statistically significant factor.



Graph 6. The bar graph of students' answers, in relation to the year of study, for question 6: "Did the greenhouse effect occurred to Earth after the appearance of humankind?"

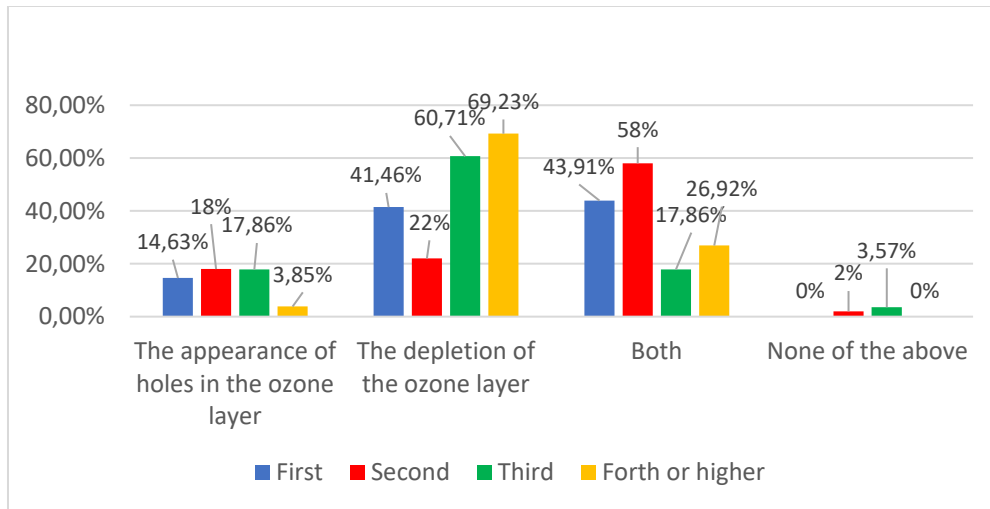
Graph 7 shows the distribution of students' answers in relation to the year of study regarding question 7 "Is the greenhouse effect contributing to the melting of polar ice caps?". 40 (97,56%) of the 41 first-year students, 48 (96%) of the 50 second-year students, 27 (96,43%) of the 28 third-year students and 24 (92,3%) of the 26 fourth-year or higher students answered correctly that the greenhouse effect contributes to the melting of the polar ice caps. The application of the independent t-test ($\chi^2=1,184$, $df=3$, $p=0,859$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 7. The bar graph of students' answers, in relation to the year of study, for question 7: "Is the greenhouse effect contributing to the melting of polar ice caps?"

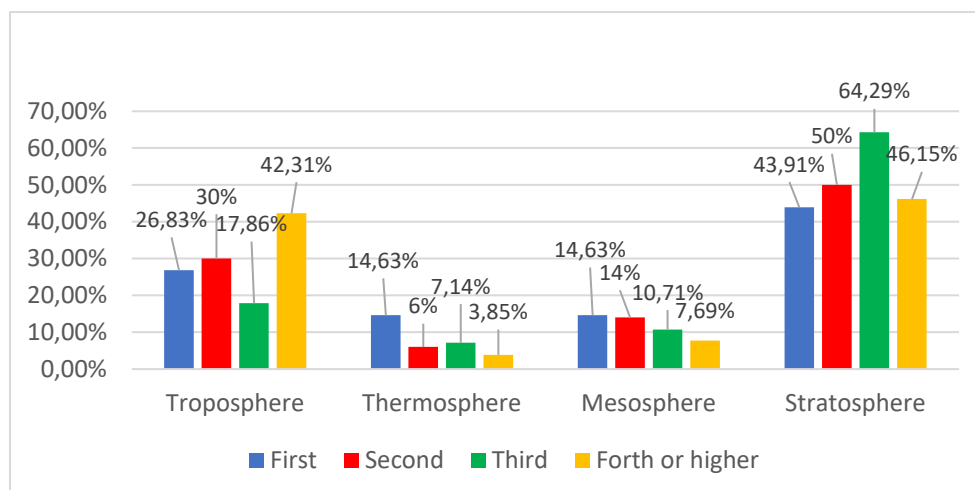
Graph 8 shows the distribution of students' answers in relation to the year of study regarding question 8 "The phenomenon of ozone hole is:". 17 (41,46%) of the 41 first-year

students, 11 (22%) of the 50 second-year students, 17 (60,71%) of the 28 third-year students and 18 (69,23%) of the 26 fourth-year or higher students answered correctly that the phenomenon of the ozone hole is the depletion of the ozone layer. The application of the independent t-test ($\chi^2=19,858$, $df=3$, $p=0,000$) showed that the variables are not independent and that the year of study is a statistically significant factor.



Graph 8. The bar graph of students' answers, in relation to the year of study, for question 8: "The phenomenon of ozone hole is:"

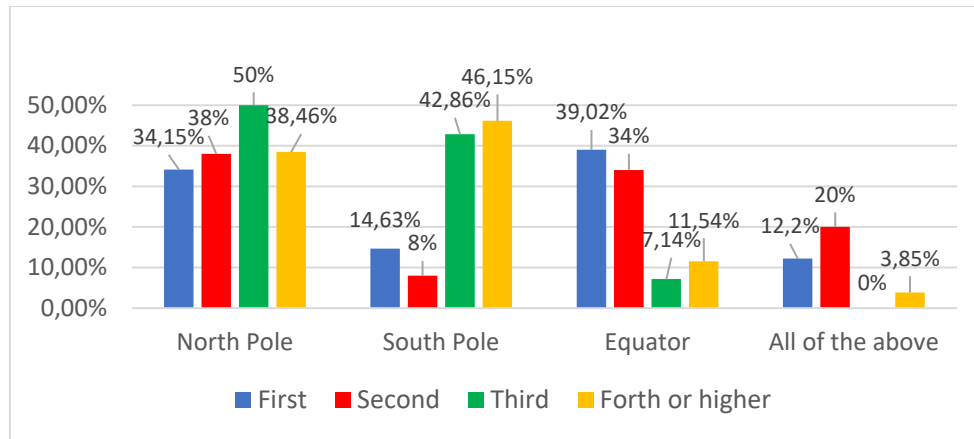
Graph 9 shows the distribution of students' answers in relation to the year of study regarding question 9 "At which layer of the atmosphere is the phenomenon of ozone hole observed?". 18 (43,91%) of the 41 first-year students, 25 (50%) of the 50 second-year students, 18 (64,29%) of the 28 third-year students and 12 (46,15%) of the 26 fourth-year or higher students answered correctly that the phenomenon is observed in the stratosphere. The application of the independent t-test ($\chi^2=3,043$, $df=3$, $p=0,385$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 9. The bar graph of students' answers, in relation to the year of study, for question 9: "At which layer of the atmosphere is the phenomenon of ozone hole observed?"

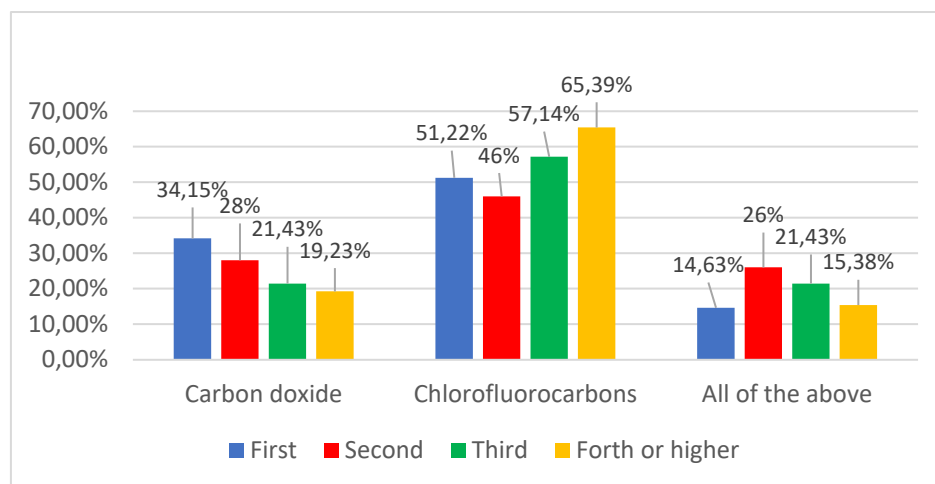
Graph 10 shows the distribution of students' answers in relation to the year of study regarding question 10 "The phenomenon of ozone hole is most intense at the:". 6 (14,63%) of

the 41 first-year students, 4 (8%) of the 50 second-year students, 12 (42,86%) of the 28 third-year students and 12 (46,15%) of the 26 fourth-year or higher students answered correctly that the phenomenon is most strongly observed at the South Pole. The application of the independent t-test ($\chi^2=21,766$, $df=3$, $p=0,000$) showed that the variables are not independent and that the year of study is a statistically significant factor.



Graph 10. The bar graph of students' answers, in relation to the year of study, for question 10: "The phenomenon of ozone hole is most intense at the:"

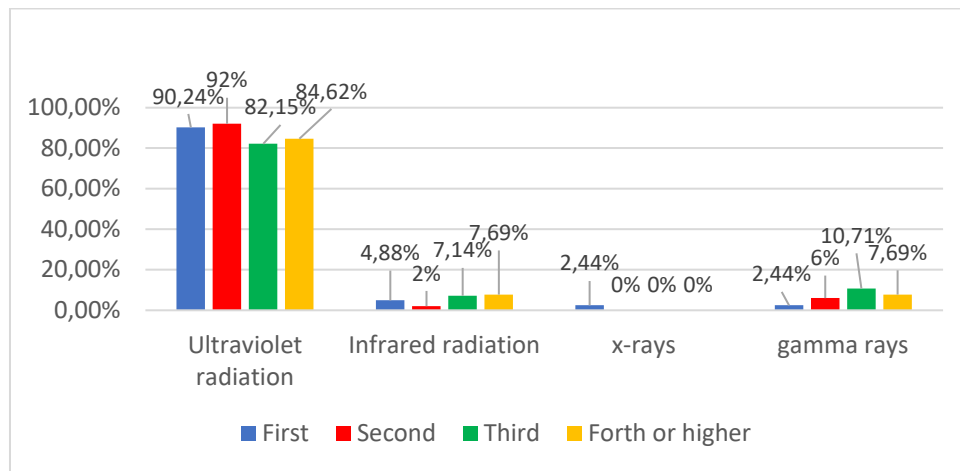
Graph 11 shows the distribution of students' answers in relation to the year of study regarding question 11 "The phenomenon of ozone hole is caused by:". 21 (51,22%) of the 41 first-year students, 23 (46%) of the 50 second-year students, 16 (57,14%) of the 28 third-year students and 17 (65,39%) of the 26 fourth-year or higher students answered correctly that the phenomenon is caused by chlorofluorocarbons. The application of the independent t-test ($\chi^2=2,830$, $df=3$, $p=0,419$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 11. The bar graph of students' answers, in relation to the year of study, for question 11: "The phenomenon of ozone hole is caused by:"

Graph 12 shows the distribution of students' answers in relation to the year of study regarding question 12 "Ozone protects us from:". 37 (90,24%) of the 41 first-year students, 46 (92%) of the 50 second-year students, 23 (82,15%) of the 28 third-year students and 22 (84,62%) of the 26 fourth-year or higher students answered correctly that ozone protects us

from ultraviolet radiation. The application of the independent t-test ($\chi^2=2,178$, $df=3$, $p=0,536$) showed that the variables are independent and that the year of study is not a statistically significant factor.



Graph 12. The bar graph of students' answers, in relation to the year of study, for question 12: "Ozone protects us from:"

Table 1 shows the results of the independent t-tests between the twelve questions and the year of study. The tests show that the year of study is not a statistically significant factor for the nine of the twelve questions answered by the students.

Table 1. Correlation table of students' answers and the year of study

| Question | χ^2 | p | Difference |
|----------|----------|-------|-------------------------|
| 1 | 0,252 | 0,969 | Random distribution |
| 2 | 5,848 | 0,119 | Random distribution |
| 3 | 3,173 | 0,366 | Random distribution |
| 4 | 1,851 | 0,604 | Random distribution |
| 5 | 1,458 | 0,692 | Random distribution |
| 6 | 15,490 | 0,001 | Statistical significant |
| 7 | 1,184 | 0,859 | Random distribution |
| 8 | 19,858 | 0,000 | Statistical significant |
| 9 | 3,043 | 0,385 | Random distribution |
| 10 | 21,766 | 0,000 | Statistical significant |
| 11 | 2,830 | 0,419 | Random distribution |
| 12 | 2,178 | 0,536 | Random distribution |

Furthermore, the score of the students' correct answers to each question and per year of their studies was determined. The data are presented in Table 2, which shows the percentages of students who gave correct answers to the twelve questions according to their year of study, as well as the average of the correct answers to the twelve questions in total.

Table 2. The percentages of correct answers of students per question and per year of study

| Question | First-year | Second-year | Third-year | Fourth-year or higher |
|----------|------------|-------------|------------|-----------------------|
| 1 | 65,85% | 68% | 71,43% | 69,23% |
| 2 | 87,8% | 90% | 71,43% | 76,92% |

| | | | | |
|----------------|---------------------|---------------------|---------------------|---------------------|
| 3 | 41,46% | 58% | 46,43% | 57,69% |
| 4 | 82,93% | 80% | 71,43% | 84,62% |
| 5 | 19,51% | 26% | 32,14% | 26,92% |
| 6 | 21,95% | 40% | 50,00% | 69,23% |
| 7 | 97,56% | 96% | 96,43% | 92,30% |
| 8 | 41,46% | 22% | 60,71% | 69,23% |
| 9 | 43,91% | 50% | 64,29% | 46,15% |
| 10 | 14,63% | 8% | 42,86% | 46,15% |
| 11 | 51,22% | 46% | 57,14% | 65,39% |
| 12 | 90,24% | 92% | 82,15% | 84,62% |
| Average | 54,88 ± 8,49 | 56,33 ± 8,50 | 62,20 ± 5,17 | 65,70 ± 5,45 |

The data from Table 2 show that a first-year student answers correctly on average 6,6 questions out of 12, a second-year student answers correctly on average 6,8 questions out of 12, a third-year student answers correctly on average 7,5 questions out of 12 and a fourth-year or higher student answers correctly on average 7,9 questions out of 12. This analysis also shows that the students change very slightly their perceptions with their year of study and they tend to keep their perceptions.

Conclusions

Some misconceptions were identified by this study, which examined the literacy of students of the Physics Department regarding the greenhouse effect and the ozone hole. These are:

- The greenhouse effect is an artificial process.
- The greenhouse effect appears only to planets that have both water and an atmosphere.
- Carbon dioxide is the only greenhouse gas.
- The greenhouse effect occurred to Earth after the appearance of humankind.
- The phenomenon of the ozone hole is the appearance of holes in the ozone layer.
- The phenomenon of the ozone hole is observed at the troposphere.
- The phenomenon of the ozone hole is most intense at the North Pole.
- The phenomenon of the ozone hole is caused by carbon dioxide.

The independent t-tests showed that the year of study is not a significant factor and does not affect students' responses. The year of study is a statistically significant factor for only three of the twelve questions. All the above show that the misconceptions of the participants usually do not change during their studies at the university and they essentially keep their misconceptions. Of course, the results of this research cannot generalize due to the limitations of the sample, especially for the students of the 3rd and the 4th year. On the other hand, it's clear that the literacy of students is independent from the time-progress of their studies. That means that the students of a physics department must connect their knowledge of their courses with everyday problems of the modern life and especially with environmental problems.

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