Assessing climate knowledge and perceptions among adolescents: a case study in Portugal

Antonio García-Vinuesa

Science Education Faculty, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

a.garcia.vinuesa@usc.es

ORCID: 0000-0003-3969-4647

Sara Carvalho

Biology Department, University of Aveiro, Aveiro, Portugal

ORCID: 0000-0002-0954-8449

Pablo Ángel Meira Cartea

Science Education Faculty, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

ORCID: 0000-0003-0194-7477

Ulisses M. Azeiteiro

Biology Department, University of Aveiro, Aveiro, Portugal

ORCID: 0000-0002-5252-1700.

Assessing climate knowledge and perceptions among adolescents: a case study in Portugal

The purpose of this study is to assess climate change knowledge among high school students and their beliefs and perceptions about the climate crisis. A questionnaire composed of 43 closed-ended questions was applied to 219 students aged 15–18 in three schools located in the north of Portugal. The results show that participants declared having limited knowledge about the issue. Similarly, the research confirms the conclusions of other studies that identified generalized alternative representations of climate change. Our findings aim to offer data geared toward supporting and promoting a new way of conceptualizing and understanding climate change education (CCE) in formal education contexts in the Portuguese education system.

Keywords: climate change education; climate literacy; environmental education; high school; students

Introduction

Climate change (CC) is one of the main challenges that humankind has to face. Given this challenge, the United Nations (Intergovernmental Panel on Climate Change [IPCC], 2014; UN, 2015) consider education as one of the fundamental social pillars for tackling CC. However, to reach the established mitigation and adaptation goals, Climate Change Education cannot be reduced solely to the teaching and learning of the physical–chemical dimensions of CC. This reductionist approach has proved to be inefficient in countries such as the United States, Brazil, and Mozambique among others (Barros & Pinheiro, 2013; Bodzin et al., 2014; García-Vinuesa et al., 2020). Moreover, this approach excludes from its curriculum other perspectives such as those offered by the social sciences and the humanities (Henderson et al., 2017).

The inclusion of the social, environmental, and economic contexts of the climate crisis in education through integration in both the educational curriculum and extracurricular activities has been approached from three main paradigms: positivism/post-positivism, constructivism, and critical/transformative (Busch et al., 2018). The first of these approaches has been the dominant view since climate literacy became an educational approach for tackling CC 20 years ago as part of science literacy (Dupigny-Giroux, 2010; National Oceanic and Atmospheric Administration [NOAA], 2009). Thus, efforts in education have focused on positivist/post-positivist paradigms to foster scientific knowledge in schools in the view that this knowledge could change behaviors and encourage pro-environmental attitudes.

A considerable number of papers have been published between 1993 and 2017 on the understanding of CC among students between the ages of 12 and 18 (García-Vinuesa & Meira-Cartea, 2019). These studies examine different dimensions of the knowledge and understanding of CC among sample groups of students from 27 countries. This relative abundance of such studies is essential considering the influence that context,

culture, and beliefs (e.g., educational policies, worldviews, ideologies, socio-demographic and geographical characteristics, languages etc.) might have on promoting actions to mitigate CC (González-Gaudiano, 2012; Hornsey et al., 2016; Komatsu et al., 2019). However, the sheer number of such studies does not seem excessive considering that our global society, characterized by multicultural complexity and diversity, is in need of contextualized and meaningful educational responses (Adams et al., 2008; Reid, 2019). Analyzing and understanding the knowledge and perceptions of different groups within the same population facilitates the educational interventions needed within a situated educational context in order to confront the local–global and individual–collective threats posed by the climate crisis.

Our study aims to respond to the need for supporting and promoting a new way of conceptualizing and understanding climate change education (CCE), and thereby lay the foundation for more effective CCE in Portugal. As opposed to previous approaches, which were exclusively grounded in scientific knowledge and based on the information deficit model (Cantell et al., 2019; González-Gaudiano & Meira-Cartea, 2020), CCE needs to integrate findings and knowledge from other disciplines, such as social sciences, health sciences, and politics, with ethical and humanistic perspectives in order to tackle the climate crisis (Lundholm, 2019; Reid, 2019).

Moreover, research in education should focus on the knowledge, perceptions, and behaviors of students as one of the four main dimensions inherent to all formal educational praxis along with teachers' knowledge and attitudes, the way the subject is taught, and the broader purpose of education (Chang & Pascua, 2017). Hence, this study aims to explore the first of these dimensions by focusing on Portuguese students. Among its motivations is the lack of research on this population given that only one such prior study exists (Azeiteiro et al., 2018). Furthermore, our research aims to offer data that

Portuguese educational stakeholders, teachers, and the whole educational community in Portugal might find useful to address CC in their national educational policy, syllabus, and daily practice.

To this end, a case study was carried out with a group of Portuguese high school students aged between 15 and 18, and enrolled in public schools in three towns located in the north of Portugal.

Climate change: a challenging topic for education

With the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988, CC became one of the most discussed subjects in the scientific community. In education, positivist and post-positivist paradigms based on science literacy became the main approach in official educational curricula around the world (Roberts, 2007). Thus, 20 years ago, climate literacy became the educational approach favored to tackle CC as part of science literacy (Dupigny-Giroux, 2010; NOAA, 2009). Nevertheless, the complexity of the climatic phenomenon, together with the fact that its causes are grounded in the global economic system and the way of life of wealthy countries, make it difficult to address solely from the perspective of scientific knowledge (Lundholm, 2019; Reid, 2019; González Gaudiano, 2012). This approach has been proven to have limited success as Bodzin and colleagues suggested when they concluded that

> many climate change knowledge deficits found in this study were similar to those reported in recent studies with other U.S. high school learners […] and college students […], indicating that climate change science learning may not be advancing in the U.S. education system. (Bodzin et al., 2014, p. 423)

Moreover, focusing the curriculum related to climate change on strictly technical and scientific disciplines, such as chemistry, physics, and biology, discourages many secondary education students enrolled in social sciences or humanities programs. As an

educational topic, the climate emergency requires a holistic and humanistic vision that is based on dialogue between different disciplines in order to tackle a problem that has already exceeded its biophysical dimension and will determine the social, economic, and environmental future of all societies (Siegner & Stapert, 2019).

As an educational topic, CC presents several challenges that make it difficult to address in a classroom. Shepardson et al. (2014) identified difficulties in student understanding due to the predominance of a linear and unidirectional vision as opposed to systemic vision to understand the climate system. This systemic thought is difficult to integrate into a curriculum comprising subjects that compartmentalize content and prevent addressing complex and multidimensional visions of the climate crisis. This epistemological limitation generates a series of misconceptions that are perpetuated through textbooks containing biased information or that prioritize an approach to climate change exclusively from its biophysical dimension (Reinfried et al., 2012; Serantes-Pazos & Liotti, 2020).

In some countries, such as the United States, the presence of a strong denialist movement creates further obstacles (Klein, 2015). Thus, both personal beliefs and perceived public disagreement on climate change condition educators' practice in classrooms and other non-formal educational contexts (Busch et al., 2018; Kunkle & Monroe, 2018). In other countries, obstacles come in the form of positivist orientations implanted by Western views of the curriculum, which tend to exclude local epistemologies, beliefs, and discourses (Adams et al., 2008). At the same time in these countries, the official discourse tries to question the science that warns of the climate emergency. Such curricular frameworks question the evidence of the anthropogenic origin of climate change and hinder advances toward educational paradigms that integrate the

climate emergency as a relevant problem according to different socio-economic, cultural, and geographical contexts (Adams et al., 2008; Artur & Hilhorst, 2012).

A new conceptualization of Climate Change Education

Against this background, the last decade has seen the emergence of a new approach to CCE that aims to go beyond the usual positivist paradigms. Broadly speaking, efforts are being made to foster CCE that can achieve the following (Cantell et al., 2019; González-Gaudiano & Meira-Cartea, 2020; Reid, 2019):

- raise awareness about the climate crisis;
- address CC from an interdisciplinary and multidisciplinary framework;
- include the ethical imperative of global climate justice;
- seek to integrate local and global manifestations;
- aspire to develop social learning processes; and
- promote the urgent need for educators and educational policies to incorporate the treatment of a highly invisible and uncertain phenomenon into the main curricular axes.

Those who argue in favor of this approach defend the need for a holistic view of the phenomenon, which considers not only the perspective of the natural sciences, but also integrates the broad knowledge and resources offered by research findings in the social sciences and humanities (Henderson et al., 2017; Kunkle & Monroe, 2018; Siegner & Stapert, 2019). Such findings are particularly relevant in the classroom context in order to address the socio-psychological, cultural, and ethical dimensions as well as the processes inherent to socially controversial environmental issues (Kelly, 1986). Such approaches allow the development of actions and proposals that "identify in each specific social context—both regionally and locally—the existing connections between individual

and community daily practices, and the causes and consequences of CC" (González-Gaudiano & Meira-Cartea, 2019, p. 28). This is in addition to planning activities geared toward action and transformation rather than the mere transmission of scientific knowledge (Vaughter, 2016). In this respect, Siegner and Stapert (2019) stated that "the action/solutions focus can be strengthened by better incorporating authentic and meaningful student climate action projects in the local community" (p. 13). Similarly, Monroe et al. (2017) highlighted this type of practice, among others, as particularly effective for CCE because community projects implemented in schools reinforce the relevance of actions through the participation of students together with their families and community.

At the same time, this approach should help combat climate change helplessness caused by the magnitude and complexity of the problem, and thereby disinhibit possible mitigation and adaptation responses, both individual and collective (Salomon et al., 2017). Cantell and colleagues included many of the elements and dimensions described so far in a proposal for CCE based on what they called the *bicycle model*, where scientific knowledge is an important part of the pedagogical model proposed but is not the core on which an adequate pedagogical proposal geared toward the climate emergency can be built (Cantell et al., 2019). This situation necessarily implies proactive social agents armed with the necessary tools to navigate through times characterized by uncertainty and risk.

By way of conclusion, Reid (2019) offered an accurate synthesis of this new paradigm by indicating that CCE

> might well mean: not just knowing the facts about climate change or how people feel in the face of it […] but rather, ensuring climate change education addresses people's rights to be free of oppressions created by climate injustices, including being able to live lives they have good reason

> to imagine and choose, i.e., that will foster rather than inhibit sustainability, equity, and authenticity in their lives as well as those in their communities. (p. 778)

Background

A significant number of studies on how high school students are approaching CC have been published in scientific reviews (García-Vinuesa & Meira-Cartea, 2019). The findings that have been discussed and interpreted allow identifying common elements of CC knowledge and perceptions despite the cultural differences between the societies to which the participating students belong.

In general, studies showed that secondary school students have superficial knowledge about CC (Barros & Pinheiro, 2013; Bodzin et al., 2014; Harker-Schuch & Bugge-Henriksen, 2013; Yazdanparast et al., 2013), indicating a simplistic view dominated by a linear and unidirectional vision of the causes and effects of this phenomenon. Moreover, this view ignores the feedback processes and complex relationships established between the biophysical and human dimensions of the problem (Shepardson et al., 2014). Students' understanding of the phenomenon is based exclusively on the atmospheric component, without taking into account other biophysical processes that influence climate and its alteration, and focusing only on the immediate effects, mainly with respect to emblematic species and exotic places (e.g., polar bears or the melting glaciers). Chang and Pascua (2016) identified two main deficits in students' mental models regarding CC. The first is a correction deficit, consisting of superfluous elements that comprise a repertoire of concepts and beliefs about CC. Such elements can produce an incomplete or distorted understanding of the phenomenon and displace and/or replace scientifically established representations. The second is a coherence deficit: although the arguments behind the students' answers pertain to certain "commonsensical"

logic, they are grounded in erroneous initial premises such as, for example, that the sun overheats the Earth through the hole in the ozone layer.

Given these facts, another recurrent issue in climate change education research is naïve knowledge (Chi & Roscoe, 2002), which causes a person to relate different environmental processes and phenomena to CC despite the fact that such a connection is non-existent or very insignificant (IPCC, 2013). The most frequent of these confusions are as follows: (i) associating CC with tectonic activity and its manifestations, such as earthquakes and tsunamis (Chang & Pascua, 2016; Espejel & Flores, 2015; Yazdanparast et al., 2013); (ii) indiscriminately relating CC to different types of pollution, mainly atmospheric, for example, CC as cause and/or consequence of acid rain (Pruneaud et al., 2002); (iii) not connecting CC with daily habits such as diet or solid waste recycling (Almeida et al., 2016; De Boer et al., 2013; Malandrakis et al., 2011); (iv) confusing the natural greenhouse effect and its anthropogenic alteration (Chang & Pascua, 2014; Espejel & Flores, 2015; Shepardson et al., 2011); and (v) misconceptions regarding the depletion of the ozone layer and its protective function (Sellmann et al., 2015; Yazdanparast et al., 2013).

Gender socialization is another variable to consider in the educational treatment of CC (Dijkstra & Goedhart, 2011; Finucane et al., 2000; Fisher et al., 2020). McCright (2010) pointed out how the literature on environmental education and science teaching tends to highlight that men show a higher degree of knowledge than women, whereas women show a greater degree of concern and responsibility for environmental problems. The author analyzed data from different surveys on knowledge about CC that in fact contradict such claims: it is women who show the greatest degree of knowledge about CC. Such findings are in contrast with those obtained in other studies on knowledge about CC (Harker-Schuch & Bugge-Henriksen, 2013; Yazdanparast et al., 2013). However, in

the area of environmental attitudes and concerns, McCright (2010) obtained similar results to other studies, thus confirming that women tend to be more concerned and responsible for climate change issues (Stevenson et al., 2018).

On the other hand, there is evidence that gender socialization encourages women to enroll in studies related to health sciences, social sciences, and humanities to the detriment of learning natural and technological sciences. The latter block remains, thus, a male-dominated academic and professional area, which tends to appeal less to women and in which important gender barriers can still be found (Finucane et al., 2000; Fisher et al., 2020).

Aims of the Study and Research Questions

This study builds on the assumption that the integration of CC in the education system has been made through approaches based on the information deficit model, which states that an adequate level of scientific knowledge in the general population will foster behavior that might serve as a rational and coherent response to the challenges identified by CC science. Thus, this study aims to assess whether levels of scientific knowledge about CC might predict beliefs and perceptions about the phenomenon. Considering that "scientific [climate] literacy is primarily a concept about curriculum goals" (Roberts, 2007, p. 9), it would be reasonable to think that students enrolled in science and technology specialization classes would have a higher level of climate literacy than students enrolled in social sciences and humanities specialization classes and, as a result, the former category would have a more accurate perception of the climate crisis than the latter. Specifically, this study addressed the following research questions:

(1) Do science and technology students have higher levels of climate change knowledge than social sciences and humanities students?

(2) Do higher levels of climate change knowledge predict more appropriate perceptions of climate change?

Materials and methods

The methodological design of this research is quantitative and descriptive. It applies a closed-ended questionnaire. The respondents of the study were 219 students from public schools in the towns of Esguira (21.50%), Leça da Palmeira (35.20%), and Gondomar (43.40%) in the north of Portugal.

Instrument development

The instrument, which comprises 43 closed-ended questions, is a questionnaire used in previous studies carried out by the Resclima project with Mozambican students (García-Vinuesa et al., 2020). Content validation was performed by high school teachers who collaborated with the project and later a piloting phase was carried out with students to check their understanding of the questionnaire items. The instrument (see Appendix) consists of three sections:

1. The first section aims to gather personal information regarding gender, age, specialization, and academic year.

2. The second section, comprising 32 items, aims to assess the correctness of students' appraisal through a series of declarative statements on climate change knowledge. The reliability test for Portuguese high school students offered a Cronbach's alpha of 0.620. Even though the alpha level for climate change knowledge scale is lower than 0.7, it falls within the acceptable range for educational assessment (Qaqish, 2006). The items are presented as declarative statements on various aspects related to CC, with participants having to indicate the degree of agreement they attribute to each statement on a scale of 1 to 4, with a maximum total score of 128. According to Linn and Gronlund

(2000), the difficulty indexes indicated that 5 out of 32 items were very easy, 16 were easy, 2 had a medium difficulty, and 9 had a high difficulty.

3. The third section consists of 11 questions aimed at exploring personal appraisals and beliefs about CC (see Appendix). We focus our analysis on 10 items: (i) the anthropogenic origin of CC, three categorical items; (ii) perception of responsibility and risk, four items on a 10-point Likert scale ($\alpha = 0.737$); (iii) self-reported knowledge about CC, four items on a categorical scale ($\alpha = 0.770$); (iv) perception of the level of scientific agreement; and (v) participation in extracurricular activities on CC.

Data analysis

The coding of the questionnaires was performed using SPSS statistics v.25. The scores of the first 32 items in Section 2 of the questionnaire were quantified on a scale of 1 (minimum) to 4 (maximum). Because there were two types of correct answer, "completely false" and "completely true," the values of the statements in which the correct answer was "completely true" were inverted to adjust the values of the scale.

We established a category to assess knowledge levels according to the total scores for the 32 items based on each quartile's distribution and on a 100-scale ponderation: Q1 (score ≤ 64.84), Q2 ($64.84 >$ score ≤ 71.87), and Q3 (score > 71.87).

The Kolmogorov–Smirnova test indicates that our sample describes a normal distribution on the knowledge scale but a non-normal distribution in responsibility, risk perception, and self-reported knowledge. Consequently, and following Luepsen (2018), we decided to perform a variance analysis test (ANOVA) and a Student's t-test to explore whether there is a relationship between knowledge and personal appraisals.

A Pearson's chi-square test was also applied to explore differences among climate literacy levels (categorical variable) and items regarding climate change occurrence, and the scientific consensus about it.

Sampling

The questionnaires were applied between October and November 2017. A researcher from the Nucleus of Climate Change and Biodiversity Assets (in Portuguese, NACAB) in the Biology Department of the University of Aveiro presented the activity to the students, clarified possible doubts, and collected the questionnaires at the end of the application. The authorization to carry out the survey was given by the pertinent Pedagogy Department and the students were informed of the voluntary nature of their participation and confidentiality in the treatment of their data. The questionnaires were applied in the classroom setting and the participants answered simultaneously and individually.

The final sample was characterized as follows: the mean, median, and mode ages were 16.09, 16.00, and 16.00 years, respectively. Of the respondents, 41.7% were specializing in humanities and 58.3% in the sciences. Female students were represented by 56.90% of the sample, of which 48.40% were studying social sciences and humanities while the other 51.60% were studying science and technology. Males comprised 43.10% of the sample, of which 39.20% were enrolled in social sciences and 67.00% in science and technology. The relationship between academic orientation and gender follows the pattern stated in literature (Finucane et al., 2000; Fisher et al., 2020). These data are reported in Table 1.

[Table 1]

Results

Climate Literacy (scientific knowledge about climate change)

[Table 2]

Table 2 shows the descriptive statistics obtained in the second section of the questionnaire concerning climate change knowledge. The results are presented according to the total sample, academic orientation, and gender and are accompanied by the values obtained in the variance analysis (ANOVA).

Overall participant scores are not high considering that both the average and median are below 70 points out of 100 (Table 2). Furthermore, we can see that despite participants demonstrating knowledge consistent with CC science, their understanding of the phenomenon also includes alternative conceptions reflected in the lowest scoring items (9 out of 32), which will be discussed in the next subsection.

There are statistically significant differences both in relation to the academic specialization and the gender variable. Students enrolled in science and technology courses obtained better scores than those studying social sciences and humanities.

In view of these results, it is necessary to recall the relationship between the academic specialization and gender variables. Table 1 shows that 48.40% of women were enrolled in the social sciences and humanities compared with 33.00% of men, which could influence the score achieved.

Table 3 provides the percentage distribution by group (total, academic orientation, and gender) according to climate literacy level (quartile distribution). The total sample places climate literacy level 1 at 28.10%, level 2 at 45.20%, and level 3 at 26.70%.

[Table 3]

By establishing the three levels of knowledge about CC according to the quartile distribution, Pearson's chi-square test offered no statistical differences in terms of either academic specialization or gender, in contrast with mean values (Table 2).

Naïve knowledge

Focusing on the items that assess naïve conceptions found in other studies, this pattern is made evident by the low levels of correctness (less than 2.5 out of 4) of most students' answers to various statements (10 out of 32) that refer to the following (see Appendix):

Erroneous causal and/or consequential relationships between ozone depletion and CC: item 4 (mean = 1.38, $N > 80\%$), item 6 (mean = 1.87, $N > 80\%$), item 16 (mean = 1.59, $N > 80\%$), and item 27 (mean = 2.12, $N > 60\%$).

Confusions between natural greenhouse effect and CC as well as about *the origin and function of GHGs*: item 8 (mean = 1.99, $N > 60\%$), item 14 (mean = 1.91, $N > 55\%$), and item 31 (mean = 2.14, $N > 55\%$).

Relationship between CC and natural environmental phenomena such as earthquakes and tsunamis: item 15 (mean = 2.09, $N > 60\%$) (Chang & Pascua, 2016; Yazdanparast et al., 2013); and *the connection with other air pollution problems, such as acid rain*: item 7 (mean = 2.27, $N > 50\%$). In this case, there is a statistically significant relation between the different variables as shown in Table 4.

[Table 4]

The results confirm the presence of these alternative conceptions among students as more than 50% of the participants connect CC with acid rain and around 70% with earthquakes and tsunamis. The latter misconception reaches higher percentages among students of social sciences and humanities, female students, and students who declare not having participated in any extracurricular activity on CC.

The last statement, where respondents obtained low scores exponentially, regards the link between the increase in meat consumption and CC: item 11 (mean = 2.20, $N > 35\%$). In this case, there is a clear relationship with statistical significance ($\alpha = 0.000$) between the levels of climate literacy and a higher percentage of correct answers: 13.1%

for level 1, 33.3% for level 2, and 74.1% for level 3. Likewise, there is a similar trend ($\alpha = 0.001$) among the students who declared having participated in extracurricular activities on CC. Of these, 61.9% identified the increase in meat consumption as one of the causes of CC, compared with 33.1% of the students who declared not having participated in this type of activity.

Beliefs on anthropogenic CC and scientific consensus

Items 33, 34, and 35 explored belief in climate change occurrence, the certainty of that belief, and the causes of CC. Of the respondents, 99.1% stated that CC is occurring, with only 2 (0.9%) denying its occurrence (one of them indicated being unsure of their answer and the other did not provide an answer regarding the certainty of their opinion). In addition, neither answered the question about the causes of climate change occurrence. Next, the questions assessed the certainty of the previous answer (item 34) and what were considered to be the main causes of CC (item 35). Table 5 provides the frequency distribution of the answers. Although more than 80% of the survey respondents answered correctly about the causes of CC, 8% said that it was mainly due to natural causes.

[Table 5]

Concerning the perception of the existence or not of agreement among the scientific community (item 42), Pearson's chi-square test showed no statistical differences according to academic specialization, gender, or climate literacy level. Thus, 1.00% of the students declared that there is no consensus, 25.70% that there is a little, 63.60% that there is sufficient consensus, and 9.70% that there is a great deal of consensus.

In the ANOVA employing the scientific consensus variable (score from 1 to 4) and perceptions variables, results do not offer statistical differences, which suggests that the belief in scientific agreement about the causes of CC does not affect the participants' perception of responsibility or risk (see the following section). On the other hand, there

is no significant statistical relationship between climate literacy levels and the belief in scientific consensus, whose existence a considerable percentage of the students (27.1%) doubt.

Responsibility and risk perception on CC

Items 36 and 37 investigated perceptions of responsibility regarding climate change occurrence at a national level (Portugal) and at an individual level, respectively. The questions were closed-ended, with answers ranging from 1 (minimum responsibility) to 10 (maximum responsibility). Figure 1 suggests a perception of minimum responsibility at both the national and the individual level as more than 40% of respondents scored below 4. The scores for this parameter are very similar in the different groupings, both in academic specialization and gender. No statistically significant differences have been shown between any of the variables analyzed except in one case where there is insufficient evidence to draw relevant conclusions (Figure 1).

[Figure 1]

Self-reported knowledge of CC

Finally, we present the data obtained in item 40 concerning self-reported knowledge. The self-reported knowledge category is based on four dimensions of CC knowledge: general knowledge (40a), causes (40b), responses (40c), and consequences (40d). In order to properly conduct a chi-square test, we had to group the four response options into two categories as follows: *Not/A little informed*, and *Sufficiently/Well informed* (Figure 2).

Statistically significant differences have been identified in 2 of the 4 relationships analyzed regarding academic orientation and CC causes and solutions.

[Figure 2]

Answering Research Questions

This study aimed to answer two research questions. The first question was worded as follows:

(1) Do science and technology students have higher levels of climate change knowledge than social sciences and humanities students?

The findings of our study do not allow us to answer this question affirmatively. Although the ANOVA showed a higher number of correct answers by science and technology students, Pearson's chi-square test did not yield significant results when cross-tabulating the climate literacy levels and student specialization variables. Moreover, the presence of misconceptions was similar in both groups. These results suggest that although the science and technology students scored higher in the general assessment of the knowledge section than the social sciences and humanities students, these differences are not great, with both groups having medium-scored knowledge about the phenomenon and shared misconceptions.

The second research question we posed was:

(2) Do higher levels of climate change knowledge predict more appropriate perceptions of climate change?

Based on our findings, the answer to this question is negative. We cannot claim that a higher level of knowledge about CC implies a perception of risk and responsibility more coherent with the reality of the climate crisis. We found no differences to support an affirmative answer to this question in any of the variables analyzed: academic specialization, gender, or level of climate literacy.

Discussion

Our results regarding declared knowledge about CC are in line with the findings described in previous studies (Bodzin et al., 2014; Harker-Schuch & Bugge-Henriksen,

2013; Yazdanparast et al., 2013) and suggest a similar lack of development in the treatment of climate science in the U.S. and Portuguese secondary schools. The presence of misconceptions regarding the processes of CC reveals a slanted vision on the topic, already identified by Shepardson and colleagues (Shepardson et al., 2014). These conclusions were supported by Chang and Pascua (2014) who pointed out that their interviewees' explanations about CC were consistent with the arguments they used, except that these arguments were used to justify the hole in the ozone layer as the cause of CC. Respondents were thus placing the apparent coherence of their arguments from the perspective of common sense before scientific representation, and perpetuating elements of naïve knowledge as our findings with Portuguese students also suggest.

In this case, although the overall results indicate the presence of confusion between ozone layer depletion and CC in most students, there is a trend ($\alpha < 0.05$) of higher numbers of correct answers in direct relation with increasing climate literacy levels. No such relationship exists with academic orientation, gender, or student participation in extracurricular activities related to climate change. Such results were to be expected given that four items looked into this relationship; thus, correct answers to these items would imply a higher score. Nevertheless, although students who declared high levels of climate literacy showed a lower recurrence of this misconception, it was still present as only 1% answered all four questions correctly.

On the other hand, regarding the confusing use of the term "greenhouse effect," Chang and Pascua (2014) pointed to a conceptual error due to the use of this terminology, both at the curricular level and within the scientific community:

> The term 'enhanced greenhouse effect' did not come into the school curriculum until its current revision of the school syllabus. Indeed, the scientific community did not begin to elucidate the distinction between natural and [enhanced] greenhouse until the IPCC Third Assessment Report when there was

> higher confidence that the warming observed is because of human activity. (Chang and Pascua, 2014, p. 51)

Other authors (González-Gaudiano, 2012) added that the media coverage of CC, which tends to report jointly and indiscriminately on the greenhouse effect, ozone layer deterioration, and CC, has contributed to both misconceptions. The fact is that be it through the terminology used in curricula, the treatment in textbooks (Reinfried et al., 2012), or the way these phenomena have been disseminated in the media, the ozone layer and the greenhouse effect occupy an important place in the comprehension of CC, where misconceptions about these phenomena have made themselves comfortable and are easily reproduced due to the commonsensical structure and apparent coherence they provide, even though such beliefs are completely erroneous from a scientific point of view.

These findings are similar to the results regarding other misconceptions about earthquakes (Chang & Pascua, 2016; Espejel & Flores, 2015; Yazdanparast et al., 2013), acid rain (Pruneaud et al., 2002), and the relationship between an increase in meat consumption and CC (Almeida et al., 2016; De Boer et al., 2013). This last item is of particular interest due to its direct relationship with individual behaviors and habits. Although as a cultural creation diet has clear connections with the collective and community dimensions, this anthropogenic causal factor of CC should be taken into account as a critical element of great interest in educational interventions and as a fundamental content in the construction of CCE.

The differences found in this analysis seem to indicate that greater knowledge about the causes of CC, or participation in extracurricular activities related to better understanding the phenomenon, is related to a higher level of correction in the assessment of this casuistic dimension of CC. As Almeida et al. (2016) have pointed out, documentaries such as *Cowspiracy* or *Before the Flood*, available on emerging audio-visual content platforms, may be contributing to an increased awareness of the

environmental impact of the meat industry among students with greater environmental knowledge and curiosity, although a more direct connection to CC continues not to be perceived so clearly.

With regard to the gender variable, the results support the findings of Harker-Schuch and Bugge-Henriksen (2013) and Yazdanparast et al. (2013), and oppose those of McCright (2010). It should be noted, though, that the latter study only assessed three items related to general knowledge on climate change occurrence (whether CC is happening or not), its causes (natural vs. human), and the scientific consensus on the matter, whereas other studies cited applied broader questionnaires on CC knowledge. Considering all these factors, we did not find any statistical difference between gender and the three variables McCright (2010) explored. This data supports the readings of Finucane et al. (2000) and Dijkstra and Goedhart (2011) about women's lower expectations for embarking on a scientific career, which could also influence their lower scores. Either way, the discrepancies between the findings of different international studies reflect the need to carry out contextualized research given the influence of factors such as gender, which varies in different societies and cultures. In addition, an examination of different populations would allow the identification of biased conceptions within each population.

Concerning beliefs on anthropogenic CC and scientific consensus, virtually all the Portuguese respondents believe that CC is occurring (99.10%) and that human activities are its main cause (85.00%), contrary to studies carried out in other societies where the denialist movement has had more impact (Bodzin et al., 2014; Busch et al., 2018; Klein, 2015). These findings coincide with those of other studies (Chang & Pascua, 2016; Kuthe et al., 2019), which suggests that awareness of CC or belief in its occurrence does not imply a rigorous and broad knowledge of its scientific basis.

Regarding CC perceptions, our findings do not support the model of information deficit given that a higher level of scientific knowledge about CC does not seem to be related to a more science-coherent perception of the risks that this problem entails and the responsibilities it requires. Furthermore, neither can we confirm the findings of previous studies regarding women showing higher levels of responsibility and concern for environmental problems and possible risks than men (Azeiteiro et al., 2018; McCright, 2010; Stevenson et al., 2018).

Finally, our findings seem to confirm that the curricular treatment of CC from the sole perspective of the natural sciences discourages interest in the matter of students who are enrolled in social sciences or humanities programs. Our findings suggest that although the declared knowledge is similar, when asked to assess their own level of knowledge, students enrolled in academic programs other than natural sciences will undervalue the knowledge they think they possess about CC causes and possible solutions (Figure 2).

Conclusion

The similarity of the results of this study to the findings of other international research suggests that the standardization of educational curricula according to positivist and post-positivist criteria yields poor results in terms of CC understanding. In so doing, it reveals its ineffectiveness in developing an educational response that might help tackle a climate crisis that reaches beyond the confines of scientific climate knowledge. This knowledge is self-assessed as being high by students enrolled in science and technology courses, but not to the same extent by social sciences and humanities students despite their obtaining similar scores. This low assessment by the second category may be due to a curricular treatment of the climate phenomenon that prioritizes its biophysical dimension and tends to ignore or undervalue its social dimensions (ethical, political, economic, cultural etc.). This approach may generate disinterest for and detachment from the climate crisis among

students of social sciences and, consequently, among researchers, educators, and professionals in this field as some authors have denounced (Henderson et al., 2017).

Likewise, our findings identified a low perception of personal responsibility among the Portuguese students who took part in the study; however, the perception of responsibility increased slightly when defined at a national level. This underestimation of personal responsibility may be one of the factors inhibiting pro-climatic actions as some authors have already suggested (Salomon et al., 2017). In the case of risk perception, students' assessment is higher. This contrast can be attributed to reports in both the media and educational curricula that highlight the consequences of CC, especially in a country such as Portugal with a high incidence and public visibility of forest fires as evidence of its impact. However, the presence of alternative conceptions, such as linking CC to tectonic events, air pollution, or a greater risk of skin cancer due to the deterioration of the ozone layer, may generate feelings of threat erroneously associated with the phenomenon. On the other hand, factors such as social desirability may also influence the results, given the emergency discourse that accompanies the climate crisis. Be that as it may, the assessment of both dimensions (responsibility and risk) is greater at the national level, which moves the problem away from the personal sphere and discourages the implementation of specific mitigation and adaptive actions in daily life.

As stated above, the results of this study with a sample of secondary school students in northern Portugal offer a similar pattern to that described by other international studies with populations of the same educational level, thus supporting the conclusions of Bodzin et al. (2014) on the limited progress of climate education in the United States and, by extension and as suggested by the literature, in many education systems of developed societies. One of the main limitations is the curricular integration of the climate crisis as the exclusive content of climate sciences, with learning methodologies based on

positivist premises and a reductionist conception of scientific literacy. This dominant educational approach hinders the incorporation of knowledge and methodologies based on the practice of teaching social sciences, humanities, and ethics, which prevents receiving the necessary feedback that the complexity of the climate crisis requires.

As mentioned at the beginning of this text, this study focuses on Portuguese students' comprehension of the climate phenomenon as one of the four main dimensions of formal education (Chang & Pascua, 2017). Thus, future research should examine the other three dimensions by focusing on teachers' comprehension of CC, exploring how the climate issue is being taught, and by investigating the general purpose of education in the Portuguese education system. All this information would offer the stakeholders in Portugal's education system a more realistic vision of CCE in Portugal and, consequently, would guide coherent educational initiatives aimed at reaching the mitigation and adaptation goals in their national educational policy, syllabus, and daily practice.

Finally, we identify non-formal education as another focal point of interest for future research given that participating in extracurricular activities seems to have an influence on the ratio of identification of some of the misconceptions we examined. With no information on the characteristics of the extracurricular activities in which the students took part, we can assume that the non-formal educational contexts of these activities are more flexible and allow for the organization of more effective exercises such as debates, CC-themed camps, community projects, interacting with scientists etc. (Monroe et al., 2017). Such educational methodologies may contribute to giving students access to better tools to understand the climate emergency, assess the threat it poses, and respond to it.

References

Adams, J., Luitel, B. C., Afonso, E., & Taylor, P. C. (2008). A cogenerative inquiry using postcolonial theory to envisage culturally inclusive science education. *Cultural*

Studies of Science Education, 3(4), 999. https://doi.org/10.1007/s11422-008-9130-0

Almeida, A., García-Fernández, B., & Sánchez-Emeterio, G. (2016). Assessment of pre-service teachers' knowledge of the impact of livestock production on global warming: a comparative study between Portugal and Spain. *International Journal of Environmental Studies, 73*(6), 939–953. https://doi.org/10.1080/00207233.2016.1199414

Artur, L., & Hilhorst, D. (2012). Everyday realities of climate change adaptation in Mozambique. *Global Environmental Change, 22*(2), 529–536. https://doi.org/10.1016/j.gloenvcha.2011.11.013

Azeiteiro, U. M., Bacelar-Nicolau, P., Santos, P. T., Bacelar-Nicolau, L., & Morgado, F. (2018). Assessing high school student perceptions and comprehension of climate change. In W. Leal Filho, E. Manolas, & A. M., Azul (Eds.), *Handbook of Climate Change Communication: Vol. 3* (pp. 21–34). Springer, Cham.

Barros, H. C., & Pinheiro, J. Q. (2013). Dimensões psicológicas do aquecimento global conforme a visão de adolescentes brasileiros [Psychological dimensions of global warming according to the view of Brazilian teenagers]. *Estudos de Psicologia, 18*(2), 173–182. https://www.redalyc.org/pdf/261/26128209002.pdf

Bodzin, A. M., Anastasio, D., Sahagian, D., Peffer, T., Dempsey, C., & Steelman, R. (2014). Investigating climate change understandings of urban middle-level students. *Journal of Geoscience Education, 62*(3), 417–430. https://doi.org/10.5408/13-042.1

Busch, K. C., Henderson, J. A., & Stevenson, K. T. (2018). Broadening epistemologies and methodologies in climate change education research. *Environmental*

Education Research, 25(6), 955–971. https://doi.org/10.1080/13504622.2018.1514588

Cantell, H., Tolppanen, S., Aarnio-Linnanvuori, E., & Lehtonen, A. (2019). Bicycle model on climate change education: presenting and evaluating a model. *Environmental Education Research, 25*(5), 717–731. https://doi.org/10.1080/13504622.2019.1570487

Chang, C. H., & Pascua, L. (2016). Singapore students' misconceptions of climate change. *International Research in Geographical and Environmental Education, 25*(1), 84–96. https://doi.org/10.1080/10382046.2015.1106206

Chang, C. H., & Pascua, L. (2017). The state of climate change education–reflections from a selection of studies around the world. *International Research in Geographical and Environmental Education, 26*(3), 177–179. https://doi.org/10.1080/10382046.2017.1331569

Chang, C. H., & Pascua, L. (2014). Uncovering the nexus between scientific discourse and school geography in Singapore students' understanding of climate change. *Research in Geographic Education, 16*(1), 41–56. http://hdl.handle.net/10497/16630

Chi, M. T., & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice*, 3–27. Springer. https://doi.org/10.1007/0-306-47637-1_1

De Boer, J., Schösler, H., & Boersema, J. J. (2013). Climate change and meat eating: an inconvenient couple? *Journal of Environmental Psychology, 33*, 1–8. https://doi.org/10.1016/j.jenvp.2012.09.001

Dijkstra, E., & Goedhart, M. (2011). Evaluation of authentic science projects on climate change in secondary schools: A focus on gender differences. *Research in Science*

& Technological Education, 29(2), 131–146. https://doi.org/10.1080/02635143.2011.581631

Dupigny-Giroux, L. (2010). Exploring the challenges of climate science literacy: Lessons from students, teachers and lifelong learners. *Geography Compass, 4*(9), 1203–1217. https://doi.org/10.1111/j.1749-8198.2010.00368.x

Espejel, A., & Flores, A. (2015). Conocimiento y percepción del calentamiento global en jóvenes del bachillerato, Tlaxcala [Knowledge and perception of global warming on high school youths, Tlaxcala]. *Revista mexicana de ciencias agrícolas, 6*(6), 1277–1290. https://doi.org/10.29312/remexca.v6i6.576

Finucane, M. L., Slovic, P., Mertz, C. K., Flynn, J., & Satterfield, T. A. (2000). Gender, race, and perceived risk: The 'white male' effect. *Health, risk & society, 2*(2), 159–172. https://doi.org/10.1080/713670162

Fisher, C. R., Thompson, C. D., & Brookes, R. H. (2020). Gender differences in the Australian undergraduate STEM student experience: a systematic review. *Higher Education Research & Development*, 1–14. https://doi.org/10.1080/07294360.2020.1721441

García-Vinuesa, A., & Meria-Cartea, P. Á. (2019). Caracterización de la investigación educativa sobre el cambio climático y los estudiantes de Educación Secundaria [Characterization of Educational Research on Climate Change among Secondary Students]. *Revista Mexicana de Investigación Educativa 24*(81), 1013–1041. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-66662019000200507

García-Vinuesa, A., Mucova, S. A., Azeiteiro, U. M., Meira-Cartea, P. Á., & Pereira, M. (2020). Mozambican students' knowledge and perceptions about climate change:

an exploratory study in Pemba City. *International Research in Geographical and Environmental Education*, 1-17.

González-Gaudiano, É. J. (2012). La representación social del cambio climático: una revisión internacional [Social Representation of Climatic Change: An International Review]. *Revista mexicana de investigación educativa, 17*(55), 1035-1062. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-66662012000400003

González-Gaudiano, E. J., & Meira-Cartea, P. Á. (2019). Environmental education under siege: Climate radicality. The Journal of Environmental Education, 50(4-6), 386-402. https://doi.org/10.1080/00958964.2019.1687406

Gónzañez Gaudiano, E. J., & Meira-Cartea, P. Á. (2020). Educación para el cambio climático: ¿educar sobre el clima o para el cambio? [Climate change education: educating about the climate or for change?]. *Perfiles Educativos, 42*(168), 157-174. https://doi.org/10.22201/iisue.24486167e.2020.168.59464

Harker-Schuch, I., & Bugge-Henriksen, C. (2013). Opinions and knowledge about climate change science in high school students. *Ambio, 42*(6), 755–766. https://doi.org/10.1007/s13280-013-0388-4

Henderson, J., Long, D., Berger, P., Russell, C., & Drewes, A. (2017). Expanding the foundation: Climate change and opportunities for educational research. *Educational Studies, 53*(4), 412–425. https://doi.org/10.1080/00131946.2017.1335640

Hornsey, M.J., Harris, E. A., Bain, P. G., & Fielding, K. S. (2016). Meta-analyses of the determinants and outcomes of belief in climate change. *Nature climate change*, 22, 1–5. https://doi.org/10.1038/nclimate2943

Intergovernmental Panel on Climate Change (IPCC). (2013). *Climate Change 2013- The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Mitigation of climate change*. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press

Kelly, T. E. (1986). Discussing controversial issues: Four perspectives on the teacher's role. *Theory & Research in Social Education, 14*(2), 113–138. https://doi.org/10.1080/00933104.1986.10505516

Klein, N. (2015). *This changes everything: Capitalism vs. the climate*. Simon and Schuster.

Komatsu, H., Rappleye, J., & Silova, I. (2019). Culture and the Independent Self: Obstacles to environmental sustainability? *Anthropocene,* 26, 1–13. https://doi.org/10.1016/j.ancene.2019.100198

Kunkle, K. A., & Monroe, M. C. (2018). Cultural cognition and climate change education in the US: why consensus is not enough. *Environmental Education Research, 25*(5), 633–655. https://doi.org/10.1080/13504622.2018.1465893

Linn, R. L., & Gronlund, N. E. (2000). *Measurement and assessment in teaching*. Merrill/Prentice Hall.

Luepsen, H. (2018). Comparison of nonparametric analysis of variance methods: A vote for van der Waerden. *Communications in Statistics-Simulation and Computation, 47*(9), 2547–2576. https://doi.org/10.1080/03610918.2017.1353613

Lundholm, C. (2019). Where to look and what to do? Blank and bright spots in research on environmental and climate change education. *Environmental Education Research, 25*(10), 1427–1437. https://doi.org/10.1080/13504622.2019.1700066

Malandrakis, G., Boyes, E., & Stanisstreet, M. (2011). Global warming: Greek students' belief in the usefulness of pro-environmental actions and their intention to take action. *International journal of environmental studies, 68*(6), 947–963. https://doi.org/10.1080/00207233.2011.590720

McCright, A. M. (2010). The effects of gender on climate change knowledge and concern in the American public. *Population and Environment, 32*(1), 66–87. https://doi.org/10.1007/s11111-010-0113-1.

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2017). Identifying effective climate change education strategies: a systematic review of the research. *Environmental Education Research*, 1–22. https://doi.org/10.1080/13504622.2017.1360842

National Oceanic and Atmospheric Administration (2009). *Climate Literacy: The essential Principles of Climate Science, A guide for individuals and communities*. https://www.climate.gov/teaching/essential-principles-climate-literacy/essential-principles-climate-literacy

Pruneau, D., Liboiron, L., Vrain, E., Gravel, H., Bourque, W., & Langis, J. (2001). People's Ideas about Climate Change: A Source of Inspiration for the Creation of Educational Programs. *Canadian Journal of Environmental Education, 6*, 121–138. https://eric.ed.gov/?id=EJ661764

Qaqish, B. (2006). Developing multiple choice tests for social work trainings. *Training and Development in Human Services, 3*(1), 45.

Reid, A. (2019). Climate change education and research: possibilities and potentials versus problems and perils? *Environmental Education Research, 25*(6), 767–790. https://doi.org/10.1080/13504622.2019.1664075

Reinfried, S., Aeschbacher, U., & Rottermann, B. (2012). Improving students' conceptual understanding of the greenhouse effect using theory-based learning materials that promote deep learning. *International Research in Geographical and Environmental Education, 21*(2), 155–178. https://doi.org/10.1080/10382046.2012.672685

Roberts, D. (2007). Linné scientific literacy symposium: Opening remarks. In C. Linder, Östman, L., & P. Wickman (eds.). *Promoting scientific literacy: Science education research in transaction* (pp. 9–17). Geotryckeriet Uppsala. https://www.diva-portal.org/smash/get/diva2:40649/FULLTEXT01.pdf

Salomon, E., Preston, J. L., & Tannenbaum, M. B. (2017). Climate change helplessness and the (de)moralisation of individual energy behavior. *Journal of Experimental Psychology: Applied, 23*(1), 15–28. https://doi.org/10.1037/xap0000105

Sellmann, D., Liefländer, A. K., & Bogner, F. X. (2015). Concept maps in the classroom: A new approach to reveal students' conceptual change. *The Journal of Educational Research*, *108*(3), 250–257. https://doi.org/10.1080/00220671.2014.896315

Serantes-Pazos, A., & Liotti, L.C. (2020), ¿Qué deberían contar (y cómo) los libros de texto de la Educación Secundaria sobre el cambio climático? [What should (and how) High School textbooks on climate change tell?]. *Revista Brasileira do Ensino Médio*, 3, 76–90. https://doi.org/10.5281/zenodo.4011278

Shepardson, D. P., Niyogi, D., Choi, S. & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climatic Change, 104*(3-4), 481–507. https://doi.org/10.1007/s10584-009-9786-9.

Shepardson, D. P., Roychoudhury, A., Hirsch, A., Niyogi, D., & Top, S. M. (2014). When the atmosphere warms it rains and ice melts: Seventh grade students' conceptions of a climate system. *Environmental Education Research, 20*(3), 333–353. https://doi.org/10.1080/13504622.2013.803037

Siegner, A., & Stapert, N. (2019). Climate change education in the humanities classroom: a case study of the Lowell school curriculum pilot. *Environmental Education Research, 26*(4), 511–531. https://doi.org/10.1080/13504622.2019.1607258

Stevenson, K. T., King, T. L., Selm, K. R., Peterson, M. N., & Monroe, M. C. (2018). Framing climate change communication to prompt individual and collective action among adolescents from agricultural communities. *Environmental Education Research, 24*(3), 365–377. https://doi.org/10.1080/13504622.2017.1318114

United Nations (2015). *Paris Agreement*. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Vaughter, P. (2016). Climate change education: from critical thinking to critical action. *UNU-IAS Policy Brief*, 4. https://rcenetwork.org/portal/sites/default/files/UNU-IAS%20PB%204%20-%208FEB%20-%20for%20printing2.pdf

Yazdanparast, T., Salehpour, S., Masjedi, M.R., Seyedmehdi, S. M., Boyes, E., Stanisstreet, M., & Attarchi, M. (2013). Global warming: knowledge and views of Iranian students. *Acta Medica Iranica, 51*(3), 178–184. https://acta.tums.ac.ir/index.php/acta/article/view/446

Appendix

To what extent from 1 (totally agree) to 4 (totally disagree) do you agree or disagree with the following statements:					
		Totally agree	**Some agree**	**Some disagree**	**Totally disagree**
1	The greenhouse effect is a natural phenomenon	1	2	3	4
2	A warmer planet will expand the area of incidence of tropical diseases	1	2	3	4
3	The increased temperatures will favour the concurrence of extreme weather events (cyclones, hurricanes, floods, etc.)	1	2	3	4
4	The polar hole in the ozone layer causes the melting of the poles	1	2	3	4
5	If we stop emitting greenhouse gases, we will not be affected by the climate change	1	2	3	4
6	Skin cancers will increase as a result of climate change	1	2	3	4
7	Acid rain is one of the causes of climate change	1	2	3	4
8	Most of the greenhouse gases present in the atmosphere come from natural sources	1	2	3	4
9	CO2 is the main gas responsible for climate change	1	2	3	4
10	All countries will suffer climate change	1	2	3	4
11	Increasing meat consumption contributes to climate change	1	2	3	4
12	If it were not for the greenhouse effect, there would be no life as we know it	1	2	3	4
13	Every time coal, oil or gas is used, we contribute to climate change	1	2	3	4
14	The greenhouse effect endangers life on Earth	1	2	3	4
15	Climate change will increase the number of earthquakes and tsunamis	1	2	3	4
16	Climate change is a consequence of the hole in the ozone layer	1	2	3	4
17	Climate change is caused by human activity	1	2	3	4
18	Climate change is the result of natural climatic variability	1	2	3	4
19	The greenhouse effect occurs when gases retain part of the radiation reflected by the Earth's surface	1	2	3	4
20	Sea level is increasing due to the expansion of water caused by the rise in temperature	1	2	3	4
21	Climate change will decrease rainfall in my country	1	2	3	4
22	The rising temperatures will affect all regions of the planet equally	1	2	3	4
23	CO2 is a natural component of the atmosphere	1	2	3	4
24	If we stop emitting greenhouse gases, we will be less vulnerable to climate change	1	2	3	4
25	Climate change will exacerbate problems of desertification in the Iberian Peninsula	1	2	3	4
26	Climate change would be reduced if we planted more trees	1	2	3	4
27	CO2 causes the destruction of the ozone layer	1	2	3	4
28	There is scientific consensus when considering human activity as the main cause of climate change	1	2	3	4
29	According to the Earth's climate history, there have been oscillations between colder and warmer periods	1	2	3	4
30	Many islands and coastal areas will be submerged as a result of climate change	1	2	3	4

		Totally agree	**Some agree**	**Some disagree**	**Totally disagree**
31	The greenhouse effect is caused by human activity	1	2	3	4
32	Replacing private transport by public transport is one of the most effective measures to address climate change	1	2	3	4

33	Do you think climate change is happening?	Yes ☐	No ☐

34	To what extent do you think CC is happening?	Not sure ☐	Hardly sure ☐	Quite sure ☐	Totally sure ☐
35	Climate change is happening...	Only because of natural causes ☐	Mainly because of natural causes ☐	Mainly because of human causes ☐	Only because of human causes ☐

36	To what extent, from 1 (minimum) to 10 (maximum), is Portugal responsible for climate change causes?	1	2	3	4	5	6	7	8	9	10
37	To what extent, from 1 (minimum) to 10 (maximum), are you responsible for climate change causes?	1	2	3	4	5	6	7	8	9	10
38	To what extent, from 1 (minimum) to 10 (maximum), do you think Portugal will be affected by climate change?	1	2	3	4	5	6	7	8	9	10
39	To what extent, from 1 (minimum) to 10 (maximum), do you think you will be affected by climate change?	1	2	3	4	5	6	7	8	9	10

40	To what extent do you feel informed about different aspects of climate change?	Not informed	A little informed	Sufficiently informed	Well informed
a	About climate change in general				
b	About the causes of climate change				
c	About the measures against climate change				
d	About the consequences of climate change				

41	To what extent do you think there is scientific consensus about the causes of climate change?	None ☐	A little ☐	Sufficient ☐	A lot ☐

42	To what extent do you assess, from 1(minimum) to 10 (maximum), the climate change information received in High School.	1	2	3	4	5	6	7	8	9	10
43	Have you participated in any activity focus on climate change?	Yes ☐					No ☐				

Tables

Table 1. Cross-tabulation: Gender and Academic Orientation

		Social Sciences & Humanities	Science & Technology	**Total**
Female	Count	60	64	124
	Expected Count	51.8	72.2	124
	% within Portugal	48.40%	51.60%	100.00%
Male	Count	31	63	94
	Expected Count	39.2	54.8	94
	% within Portugal	33.00%	67.00%	100.00%
	Count	91	127	218
	Expected Count	91	127	218
	% within Portugal	41.70%	58.30%	100.00%

Note: Pearson's chi-square test offered statistical differences between these variables ($\alpha = 0.022$).

Table 2. Descriptive Statistics. Climate Change Knowledge

		Academic Orientation		Gender	
	Total	Social Sciences & Humanities	Science & Technology	Female	Male
Mean	68.52	67.15*	69.51*	67.56*	69.78*
Median	67.18	66.40	67.96	66.40	68.75
SD	6.06	5.34	6.37	5.65	6.38
Minimum	46.88	46.88	56.25	46.68	56.25
Maximum	99.22	82.03	99.22	89.84	99.22

* Statistical differences ($p < 0.05$); Academic orientation: $\alpha = 0.004$; Gender: $\alpha = 0.007$ (ANOVA).

Table 3. Climate Literacy Level by Quartile Distribution

		Academic Orientation		Gender	
Climate Literacy Levels	Total	Social Sciences & Humanities	Science & Technology	Female	Male
Level 1 (Q1)	26.10%	31.50%	26.00%	32.80%	22.34%
Level 2 (Q2/3)	50.00%	50.00%	41.70%	46.40%	43.61%
Level 3 (Q4)	23.90%	18.50%	32.30%	20.80%	34.05%

Note: Pearson's chi-square test did not offer statistical differences ($p < 0.05$). Q1 (score ≤ 64.84), Q2/3 (64.84 > score < 71.87), and Q4 (score ≥ 71.87).

Table 4. Naïve Knowledge about Natural Environmental and Atmospheric Problems

Variable	Categories	Existence of misconceptions regarding earthquakes and tsunamis		Existence of misconceptions regarding acid rain	
		Yes	No	Yes	No
Climate Literacy Levels	Level 1	73.8%	26.2%	65.6%	34.4%
	Level 2	72.4%	27.6%	57.3%	42.7%
	Level 3	63.8%	36.2%	46.6%	53.4%
Academic Orientation	Social Sciences & Humanities	78.0%*	22.0%*	62.6%	37.4%
	Science & Technology	65.4%*	34.6%*	52.0%	48.0%
Gender	Female	76.6%*	23.4%*	61.0%	39.0%
	Male	62.8%*	37.2%*	50.5%	49.5%
Participation in CC activities	Yes	57.1%*	42.9%*	45.0%	55.0%
	No	73.6%*	26.4%*	59.2%	40.8%

Note: To perform the Chi-square test validly, the responses “Completely false” and “Probably false” were grouped together under “No” (non-existence) and the responses “Completely true” and “Probably true” under “Yes” (existence).
*Pearson’s chi-square test offers statistical differences ($p < 0.05$).

Table 5. Frequency Distribution of Responses about Climate Change Causes

		Academic Orientation		Gender	
35. CC is happening because of...	Total	Social Sciences & Humanities	Science & Technology	Female	Male
Mainly because of natural causes	7.90%	15.90%*	2.40%*	9.20%	6.40%
Mainly because of human causes	85.00%	76.10%*	91.30%*	82.50%	88.30%
Only because of human causes	7.00%	8.00%*	6.30%*	8.30%	5.30%

*Pearson's chi-square test offers statistical differences ($p < 0.05$).

Figures

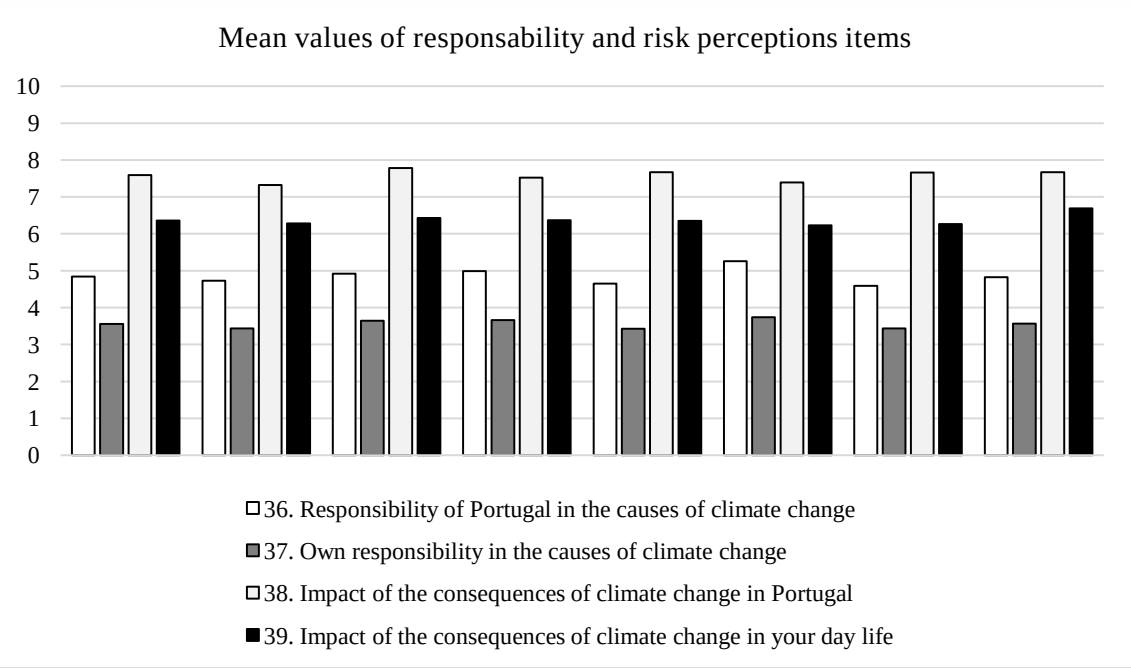

Figure 1. Mean values obtained in the items related to responsibility and risk perceptions (national and personal sphere). Student's t-test offers statistical differences among climate literacy levels 1 and 2 ($p < 0.05$) and item 36.

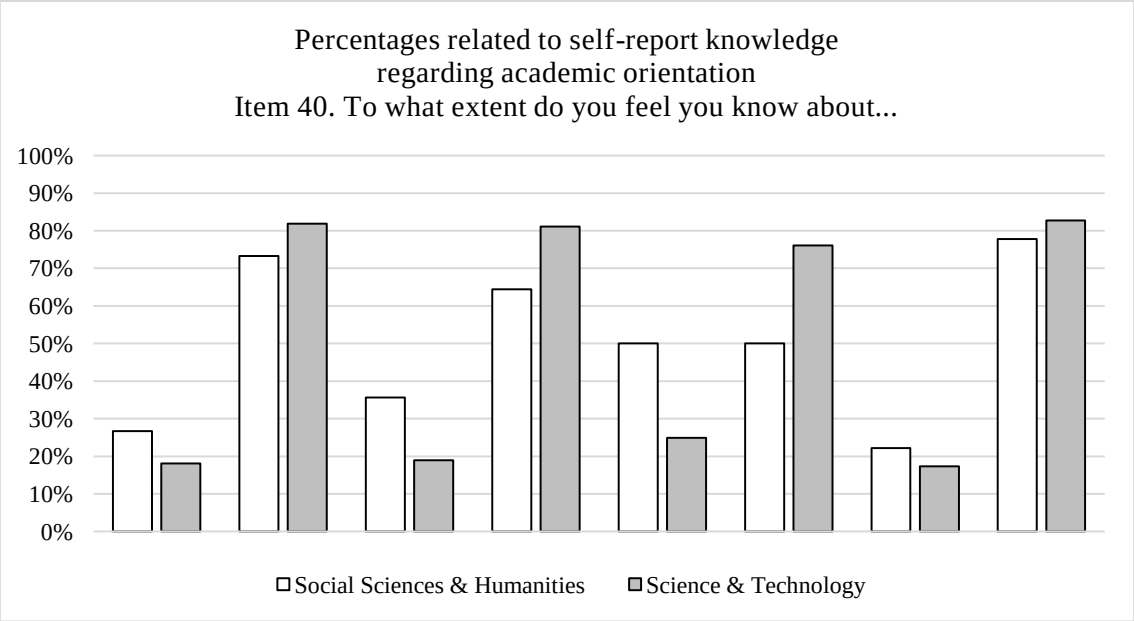

Figure 2. Response percentages to item 40 (a, b, c, and d) related to self-report knowledge. Pearson's chi-square test offered statistical significance ($p < 0.05$) in academic orientation on items 40b and 40c.