Assessing High School Student Perceptions and Comprehension of Climate Change

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1 Introduction

Goal thirteen from the *Transforming our world: the 2030 Agenda for Sustainable Development* states that we must "take urgent action to combat Climate Change and its impacts" (UN 2015). Climate Change (CC) and Global Warming (GW) is also one of the five priority areas of the Strategy 2020 of the European Commission and it constitutes a major global challenge needing local responses. CC understanding entails identifying mutually influential relationships between Nature, Society, Culture, Education and Science. Any intervention, either to mitigate or/and adapt to CC, necessarily involves the full complexity of its environmental, sociocultural, educational and science dimensions. The ways CC is viewed and addressed in a given country also depends on its cultural, political, and scientific backgrounds and,

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to a large extent, on the specific aspects of the changing climate in that country and on its actual and perceived future impacts (Carvalho et al. 2014; Viegas et al. 2014).

Today's generation of students belong to the "*climate change generation*" that grew up with more information and less scientific uncertainty about CC and GW. CC and GW is a matter of global concern, being a significant challenge facing society today and becoming a central issue to society (Leal Filho et al. 2014), and educational institutions and agents (teachers, students, other pedagogical agents from formal and informal education) need to engage and be active in the search for regional and local solutions for what is a global problem (Leal Filho 2010). However it is not always clear the correlation between levels of knowledge and behavioural change to address CC, and there is indication that behavioral engagement can occur in the absence of a complete understanding of the problem (e.g. Ortega-Egea et al. 2014; Rhodes et al. 2014). Studies conducted in Portugal (e.g. Carvalho et al. 2014; Santos et al. 2016) suggest that there is significant lack of information and that this may be impacting the ways they relate to CC.

Several studies on elementary and secondary school students' concern and knowledge about climate change (Anderson and Wallin 2000; Boyes and Stanisstreet 1992, 1993; Boon and Cook 2009; Daniel et al. 2004; Francis et al. 1993; Gowda et al. 1997; Rye et al. 1997; Shepardson et al. 2009, 2011) were conducted in recent years beginning with Boyes and Stanisstreet (1992, 1993) on British elementary students' perceptions of the causes and consequences of the "greenhouse" effect. Overall such studies stated that students held many significant misconceptions about the greenhouse effect and its relationship to climate disruption. Studies on Environmental Literacy from the Portuguese high schools national system revealed a same pattern both in students (Cordeiro et al. 2013; Gomes et al. 2014; Almeida et al. 2014) as well as in teachers (Câmara et al. 2014; Esteves et al. 2014; Marques et al. 2014).

The purpose of this study was to investigate High School (HS) students' perceptions of CC/global warming (GW). This work is the first one conducted within Portuguese HS students and the results in this context should have meaningful implications for national CC policies in the future (Jamelske et al. 2013) as well as HS Curriculum Differentiation and Education Adjustment Plans to the students' perceptions. As any other social-environmental issue, perceptions and expectations of CC, as well as knowledge on the topic, are important in the actions taken relating to this multidimensional subject. Hence, it is important that students acknowledge that anthropogenic actions are a main cause of CC (which the majority of our student's sample did), but also that humans are a key factor in mitigating CC, or by the fact that the main responsibility for CC mitigation is seen as falling upon governments and institutions, rather than in individuals (Santos et al. 2016).

2 Research Methodology

Research was conducted at a high school in Central Portugal (District of Aveiro). The survey was applied to all the high school students (n = 270) from the 10th to the 12th grade, enrolled in the areas of Sciences and Technology (Sci &Tech), Languages and Humanities (Lang & Human), Socio-economical Sciences (Socio-econ Sci) and Professionalization.

2.1 Questionnaire and Data Collection

The data were collected through a self-completion questionnaire consisting of 29 closed-ended questions and two open questions aiming at characterizing students from the socio-demographic, and from their perceptions, beliefs, motivations, attitudes, knowledge relating to the topic of CC. The questionnaire was adapted from Wachholz et al. (2012) and Manolas et al. (2010) and following studies by other authors (e.g. Leal Filho et al. 2014). This questionnaire was validated for HEI students by Santos et al. (2016). Google Drive was used to host the questionnaire and allow for the online survey. The questionnaire was pre-tested among undergraduate students not enrolled in the questionnaire application and the results of the pilot study were used to refine the questionnaire. Students took part in the survey willingly and the time required for filling in the questionnaire was ca. 10 min. Respondents were assured that their responses remain anonymous. The data was collected online, during face-to-face classes, under the supervision of the teacher, in the second week of November 2015.

2.2 Statistical Analysis

Data were downloaded into MS Excel and then exported to IBM SPSS Statistics for Windows, version 22®, for statistical analysis. Statistical exploratory univariate and bivariate analyses were performed on the data collected (frequencies, total and column percentages, adjusted residuals). Associations between categorical variables were tested through independence chi-square tests. Whenever 20% or more of the tables' cells presented expected counts below 5 or 2 × 2 tables were analyzed, independency between ordinal and/or categorical variables was assessed through Fisher Exact Tests. All statistical tests were two-tailed, with significance levels of 5%. Only statistically significant results were commented on the results section.

3 Findings

3.1 Respondents Characterisation

The questionnaire had a response rate of 100%. Respondents mostly belonged to the Sciences and Technology course (43%), followed by the Professionalization course (35%), and less to the Socio-economical Sciences (13%) and Languages and Humanities (9%). Gender distribution among the courses was different: most students in the Professionalization courses were male (73%), while they represented 50% in the Sciences and Technology, 38% in Social and Economics Science, and only 17% in the Languages and Humanities courses.

Students were mostly enrolled in the 10th or in the 12th grade (respectively 41 and 38%), and less on the 11th grade (21%). These students were 46% female and 54% male. The age groups reflected the distribution of students throughout the grades, i.e. 33% were aged between 14 and 15 years old, 45% between 16 and 17 years old, 11% were aged 18 years old, and 8% was above 18 years old.

3.2 Perceptions Relating to CC and Their Impacts

Nearly all respondents (76%) believed that CC was happening, while 20% believed that they might be happening, 3% "did not know" and 1 respondent believed "it was not happening". In what concerns their interest, recognition of the importance and level of concern with the topic of CC, these three aspects were only slightly differently perceived among the students. Most students responded that they were either "very much" (24–31%) or "a lot" (51–59%) interested/concerned/recognising the importance of the topic of CC, while fewer responded to "have little" (15–17%) or no interest/concern/recognition of importance of CC (less than 1%).

Also, the perception of the impacts of CC on biotic communities and human communities, either in one's country (Portugal) or abroad (as a whole) was sensed with different time scales, depending on the type of community and on the country. There was a generalised perception that biotic communities were already impacted by CC, particularly abroad (62 and 71%, respectively for biotic communities in Portugal and abroad). A considerable number of respondents also perceived that CC impacts were already felt in human communities abroad (60%), but less (43%) in Portuguese human communities. Still, a substantial number of respondents though CC impacts would be felt between 10 and 25 years from now (44, 31, 28 and 22%, respectively in human communities in Portugal and abroad, biotic communities in Portugal and abroad).

Students' gender influenced their perceptions of time scale of CC impact on both human and biotic communities as 66 and 77% (respectively) female respondents perceived CC impacts as "existing already" opposing to 56 and 66% (respectively) of male students.

In what relates to the students training path, irrespectively of the course in which they enrolled, there were no significant differences in their concern or perception of the importance of the CC topic. A slight difference appeared to exist in the Professionalization course students', 23% of which stated to perceive the topic of CC as having "little importance", versus 11, 13 and 6% in the Science and Technology, Languages and Humanities or Social and Economical Sciences (respectively; although differences were not statistically significant). Also, irrespectively of the training path/course, the perception of the CC impacts on both biotic and human communities was not significantly different (although there was a greater proportion of students in Science and Technology that sensed it in the more immediate future, opposing to students in the Professionalization course).

The majority of students (75%) expressed that "the scientific community assumed that CC was happening", less (10%) felt that "there was much disagreement amidst the scientists relating to the subject", or (12%) "felt not knowing enough to form an opinion". Still a minority (3%) expressed that "most scientists did not believe that CC were happening". In this issue, female students expressed more frequently than male students that "the scientific community assumed that CC was happening" (82 and 69%, respectively). On the same topic, male students responded more frequently than female that "there was much disagreement amidst the scientists relating to the subject" (15 and 5%, respectively).

In what concerns their training path, most students enrolled in the Science and Technology and in Languages and Human courses perceived that "the scientific community assumed that CC was happening" (respectively 83 and 92%) versus 59% of students in the Professionalization course. Also, in the latter course there was a relatively greater number of students stating that "there was much disagreement amidst the scientists" (19% in the Professionalization, vs. 8 and 0% in the Science and Technology or Languages and Humanities).

The majority of students (94%) also perceived that human activities were an important cause of CC (vs. 6% who expressed they were not). Again, on this topic, gender had a significantly different perception, the female respondents having a greater response rate than male respondents regarding human activities being an important cause of CC (98 and 90% respectively). When inquired if humans could mitigate the effect of CC, most respondents shared the opinion that they could mitigate effects of CC, although among these 46% expressed "it was not clear if they would do what was necessary to achieve it", and 35% thought that "people did not have the will to change their behaviour in order to achieve mitigation"; only 12% believed that "humans would manage successfully to mitigate the effect of CC". Lastly, 7% thought that humans could not mitigate CC. When considering the gender effect, the majority of female respondents considered that humans could mitigate the effect of CC, although "it was not clear if they would do what was necessary to achieve it" (52% vs. 40%, respectively female and male), while male respondents were more optimistic in what concerned the success in mitigating the effect of CC (17 and 6%, respectively for male and female).

3.3 Training and Knowledge of CC

Regarding their basic education (grades 5th to 9th) the majority of the students (70%) felt that their training had focused enough on the topic of CC, less (20%) felt that their training had been insufficiently focused on CC, and very few (3%) felt that they had too much training on the subject. Still, 7% had not attended enough classes to form an opinion. On what concerns their secondary education, 25% had not attended enough classes to form an opinion. The majority of the remaining 202 respondents, felt that their training had focused enough on the topic of CC (77%), while nearly one fifth of students felt it had been insufficiently focused (17%), and very few (6%) felt they had too much training on that subject. When inquired if they felt the need for more information on the topic of CC to form an opinion, 12% of the students expressed the need for a lot more, 48% for more information, 34% for a little more information; only 6% felt no need for further information on the subject.

Differences were found among students in enrolled in different courses. In the Professionalization course 20% of the students admitted needing much more information on the topic of CC, versus a minority in the Science and Technology or Languages and Humanities (7 and 4%, respectively). Also in the Professionalization course, 22% of the students admitted needing a little more information on the topic of CC against 44% in the Sciences and Technology who stated the same opinion (or 33% of Languages and Humanities, even though this difference was not statistically significant).

Furthermore, when inquired about their knowledge on the subject, most respondents (69%) felt they had a moderate technical knowledge about the topic of CC, while some perceived their knowledge as extended (13%), or minimum on the topic (14%). Students knowledge of how their behaviour influenced CC followed a similar pattern, most felling a moderate knowledge (59%), some perceiving it was extended (26%), and fewer feeling a minimum knowledge (12%) of how their behaviour influenced CC.

However, when asked about the effect of the ozone hole on CC, only 10% acknowledged that the ozone hole was not a main cause of CC. Most students, 81%, responded that it was a main cause of CC and 9% didn't know whether it was or not a cause of CC.

No significant differences were found, when considering the effect of gender or training path/enrolled course in their knowledge or perception of knowledge on CC.

In what concerns their ecological footprint, most students (65%) had not estimated it (76% vs. 55%, respectively female and male). For the students who declared having calculated their ecological footprint, 10% had done so on the scope of their training and a little less (8%) had calculated it as outside the scope of their training; still 17% did not know if they had calculated it. Interestingly, most students in the Science and Technology, Languages and Humanities or Socio-Economical Sciences courses (73, 88, 77%) and had not calculated their ecological footprint, in opposition to 45% in the Professionalization courses

(although not statistically significant), and 21% of the students in the latter courses had calculated it as part of their training (against 6, 4 and 0%, in the other courses).

Finally, in what concerns the perception of the importance of CC for their future professional carrier, 48% considered that this topic was "moderately important" and 29% considered it as "very important". From these, a greater proportion of students in the Professionalization courses, considered that CC was "very important" to their professional future (38%, in the Professionalization courses, vs. 24, 29, 20% in Sciences and Technology, Languages and Humanities and Socio Economical Sciences; although not statistically significant).

3.4 Governance and Actions to Mitigate CC

There was a large conviction that the main actions in mitigating CC effects should be taken by governments (50%), although a considerable number believed that actions should be the responsibility of individuals (33%), and a small number thought that the responsibility should lay upon corporations or NGOs (respectively 9 and 8%). Also, without an international agreement, e.g. Kyoto's protocol successor, most students, felt that there would be still a way to mitigate CC (60%), although many felt that such an international agreement was essential, or they "did not have an opinion on the matter" (respectively 20 and 19%). On this issue, female students were more optimistic than male students, answering more frequently that even without an international agreement there still would be a way to mitigate CC (70% vs. 52%, female and male).

Also most students from the Science and Technology (67%, although the difference was not statistically significant) and from Languages and Humanities (80%) believed that without an international agreement there still would be a way to mitigate CC, while only 45% of students in the Professionalization course shared the same opinion.

Regarding the behaviour of relational communities that surrounds each respondent, only 10% thought that most people in their relational communities acted to mitigate climate effects. Nearly half, 52%, perceived that most people in their relational community "took some actions to mitigate CC effects", and 30% perceived that they did not act in order to mitigate CC effects; 8% of the respondents did not know what was the behaviour of their relational communities.

As individuals, and globally, 74% had not taken actions to mitigate CC; among these 32% thought that the "actions of a single individual would not change anything". Only 26% of the respondents had taken some actions to mitigate the causes of CC. On this issue, female students answered more frequently than males that they had already taken some actions (16% vs. 8%, female and male), and less frequently that the action of a single individual would not change anything (27% vs. 36%, female and male). No differences were found in this issues among the students enrolled in different courses.

Finally, when inquired if they were to reduce their contribution to CC, most students felt that they would be increasing their life quality by a lot (43%) or a little (29%). Still, some felt that reducing their contribution to CC would not change their life quality (9%), or that it would decrease it by a little (12%) or a lot (7%). In this issue, female respondents answered more often than males that their contribution to mitigate CC would improve their life quality by a lot (47 and 40%, female and male), and responded less often that it wouldn't have any impacts on their life quality (3 and 14%, female and male).

As individuals, half respondents (51%) also expressed that they would support actions to reduce greenhouse gases including measures which implied e.g. paying more for fuel and electric energy, while a lesser number (35%) was not sure about it, and 14% would not support such actions. The mitigation actions taken by the respondents included reducing the use of private cars and fossil fuels and increasing "walking and cycling" (5%), increasing recycling and reutilization of materials (12%), reducing electricity consumption and water (18 and 10%).

4 Discussion

Comparing the present results with previous data obtained with Portuguese university students' (Santos et al. 2016) we see a lower comprehension of climate change issues in this younger aged group. The same trend is shown in high school students' interest, recognition of importance and level of concern with the topic of CC. Adolescence and related teacher displeasure, multiple interests or conceptual dispersion could explain part of this lesser perception of CC. A recent poll in the United States (Pew Research Center 2015) shows a clear relationship between age and views about climate change with scepticism growing with age. Comparing this research findings with the previous ones with University students (Santos et al. 2016) we do not confirm this pattern.

The low comprehension of climate change issues (scientific knowledge and assessment of climate change, mitigation and adaptation), societal challenges and perceived impacts in human systems and natural systems revealed by studies on students perceptions (Santos et al. 2016) is accompanied by levels of concern that contrast with limited understanding and rather weak behavioral dispositions to address climate change (Carvalho et al. 2014).

The perception of the impacts of CC on biotic communities and human communities, either in one's country (Portugal) or abroad (as a whole) was sensed with different time scales, depending on the type of community and on the country (the impacts of CC on biotic communities and human communities in one's country, are perceived as less impacted than abroad) and that impacts would be felt between 10 and 25 years from now (impacts are thought to appear latter in Portugal than abroad) should be explained by the searched information by high school students, the negative acceptance of thematic/environmental newspapers or audio-visual

media news by adolescents (Cordeiro et al. 2013; Gomes et al. 2014; Almeida et al. 2014), the school manuals with examples taken abroad (from extreme and more impacted geographies), and the reliance on youth magazines that are most times mere translations of Anglo-Saxon sources.

In the present study high school students' confidence in the scientific community was high (75%). On the other hand previous studies evaluating high school students environmental literacy (Cordeiro et al. 2013; Gomes et al. 2014; Almeida et al. 2014) and teachers environmental literacy (Câmara et al. 2014; Esteves et al. 2014; Marques et al. 2014) revealed low values of environmental literacy. The conjugation of this two findings make us assume that the scientific community/academia should conceptualize and structure a better interface with schools reaching high school students as well as teachers attracting them to science subjects. However the complexity of the debate among climate scientists (see Bryce and Day 2014) makes hard to communicate and teach about CC and GW at high school level. Despite the findings of climate scientists, the proportions of climate sceptics (for clarity in the concepts see Capsticka and Pidgeon (2014)) appear to be increasing in many countries (Tranter and Booth 2015). Stevenson et al. (2014) argue that we should overcome scepticism with education. We should overcome scepticism with better communication and education (intervening in Pedagogy, Curriculum, Teaching Practices, non-formal education, informal education and science divulging). Lutz et al. (2014) state that public investment in education in poor countries in the near future should be seen as a top priority for enhancing societies' adaptive capacity vis-à-vis future climate change.

A few studies (e.g. FAO 2007, Rohr 2008 and references herein) show that environmental changes impact men and women differently because of their gender roles and socio-cultural situation. Gender-differentiated roles and responsibilities in families and households, as well as gender-segregated labour markets and income gaps, cause differentiated vulnerabilities of women and men to the effects of climate change, not only in developing countries (Setti et al. 2016) but also in the European Union (Berlin Declaration 2007; European Institute for Gender Equality 2012) which explains gender differences regarding CC in our study. This findings mirror the ones of Wachholz et al. (2012) in the USA and the ones from Santos et al. (2016) in Portugal with women students demonstrating greater levels of concern.

Most students stated that in their scholar path they accessed to a large knowledge about climate change. Most students believe that CC is happening, that their main causes are anthropogenic, and they feel well informed on the topic of CC but when asked about particular concepts and processes of CC, their answers do not reflect their self-perceived knowledge. Similar results were obtained with our previous study with university students (Santos et al. 2016) and in other studies (e.g. the study of Löfstedt 1991), where the greenhouse effect was confused with the issue of ozone depletion), and other misconceptions can be found in the in other European (Manolas et al. 2010) and American (Wachholz et al. 2012 and references cited herein) university students. This type of inquiries usually reveals common misconceptions. Many pre-university students continue to identify that ozone depletion is a major factor driving climate change (Boon and Cook 2009) and that polluting less and recycling more is a way to mitigate CC, as presented in our study,

suggesting that this issues should be better addressed in the teaching curricula and at schools. Students' misconceptions of climate change (Manolas et al. 2010; Wachholz et al. 2012; Pascua and Chang 2015; Santos et al. 2016) also points to the need and urgency to intervene in Pedagogy, Curriculum, Teaching Practices, non-formal education, informal education and science divulging. Also Climate Change Education should be approached from an interdisciplinary and systems perspective (Mochizuki and Bryan 2015).

Our results also show that environmental thinking, consciousness, attitudes and behaviours are not always related, as also reported by Santos et al. (2016). However, as stated by Ortega-Egea et al. (2014), a profound shift in personal behaviour is needed to respond to the urgency of CC mitigation together with the need to actively engage future citizens as part of the solutions in their professional and private roles (Wachholz et al. 2012) starting in elementary schools and high schools. Thus, eventhough the inquired high school students pointed out to a greater role of individual action in mitigating CC, as compared to that of university students (Santos et al. 2016), they finalized by stating that for their future careers this issue is not so important (52%). This again shows the urgency for science quality and pedagogical actions in teaching about climate change, participation and citizenship, and climate governance (*Global Action Programme on ESD*; *transforming our world: the 2030 Agenda for Sustainable Development*; *European Institute for Gender Equality,* 2012). In the present study the inquired sample showed low levels of interest to be proactive in the solutions and mitigation measures to be taken to cope with solutions for this Global Change Global Problem. When asked about their actions to mitigate the causes of CC these were "short", both on the percentage that responded positively and on number of actions with effective contribution in CC mitigation. This result shows that environmental thinking, consciousness, attitudes and behaviours are not always related. As stated by Ortega-Egea et al. (2014) a profound shift in personal behaviour is needed to respond to the urgency of CC mitigation together with the need to actively engage future students (unrelated to graduation level) as part of the solutions in their future professional public and private careers (Wachholz et al. 2012).

In a context of increasing global inequality, global economic recession, conflict, and climate change is needed action in the advancement of climate science education in public schools (see for this purpose the exploratory research of Colston and Ivey 2015). A population's attitudes toward climate change can strongly influence governmental policies as well as community and individual climate-related behaviors (Leombruni 2015). Finally, as stated by Vaughther (2016), we should move beyond education systems that simply transmit knowledge to ones that promote graduates who are engaged in systemic change.

5 Conclusions

Discussions about the post-2015 education and development agenda in this context ambitiously seek to eradicate poverty, promote social and economic inclusion, tackle climate change, promote equity, and access to quality education (Sayed and Rashid 2015). This study confront us with the need for better high school climate change teaching and learning processes, quality and geographically contextualized information in science manuals, better trained/informed teachers (providing lifelong learning on climate change topics) and the need to overcome scepticism decreasing the barriers between universities teachers –academia, and researchers and high school spaces of learning. The students of today should be the environmental participative citizens of tomorrow and this study clearly shows that we still have a long but stimulating path to tread if we want to cope with the *2030 Agenda for Sustainable Development* (take urgent action to combat climate change and its impacts improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning) and the European Union *Horizon 2020 Societal challenge Climate action*.

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