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The influence of causal knowledge on the willingness to change attitude towards climate change: results from an empirical study

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ABSTRACT

Climate change is one of the significant global challenges currently facing humanity. Even though its seriousness seems to be common knowledge among the public, the reaction of individuals to it has been slow and uncertain. Many studies assert that simply knowing about climate change is not enough to generate people's behavioural response. They claim, indeed, that in some cases scientific literacy can even obstruct behavioural response instead. However, recent surveys show a rather poor understanding of climate dynamics and argue that lack of knowledge about causal relationships within climate dynamics can hinder behavioural response, since the individual is not able to understand his/her role as causal agent and therefore doesn't know how to take proper action. This study starts from the hypothesis that scientific knowledge focused on clarifying climate dynamics can make people understand not only dynamics themselves, but also their interactive relationship with the environment. Teaching materials on climate change based on such considerations were designed and implemented in a course for secondary-school students with the aim of investigating whether this kind of knowledge had an influence on students' willingness to adopt pro-environmental behaviours. Questionnaires were delivered for testing the effect of the teaching experience on knowledge and behaviour.

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Causal knowledge; willingness to change behaviour; climate change; secondary-school students; science education

Introduction

Climate change is one of the most important global challenges currently facing humanity (Osborne & Dillon, 2008). The global climate is warming and significant changes are expected in the future, with many populations at high risk. Political reaction to this global threat has been slow and uncertain so far, and the reaction of the general public seems to be similarly sluggish.

Many surveys have been carried out in the past few years about people's perception of, and reaction to, climate change. Thanks to the reliable work of organisations such as the Intergovernmental Panel on Climate Change (IPCC), belief in the existence of anthropogenic climate change and its seriousness has been consolidating in recent years, at least

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across Europe and the United States, while unfortunately the behavioural response is still limited, with few people taking relevant action (Eurobarometer, 2014; Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Rosenthal, 2014). Far fewer surveys have focused on the reason for this lack of behavioural response. A 2008 Eurobarometer 2008 directly asked interviewees why they have not taken action on climate change, and it emerged that 42% think 'it is governments, companies and industries that have to change their behaviour, not citizens'; 34% 'would like to take action but do not know what you could do to fight climate change'; and 26% 'think [that] changing behaviour will not have a real impact on climate change'.

Lack of knowledge has often been considered as a minor factor in influencing behaviour towards the environment (Boyes & Stanisstreet, 2012; Norgaard, 2006; 2009). Furthermore, surveys have reported a widespread awareness (and even a certain degree of self-reported knowledge) of climate change, but still insufficient behavioural response (Eurobarometer, 2014; Leiserowitz et al., 2014).

However, surveys that went more in-depth in the investigation of people's knowledge about climate change revealed a relatively poor understanding of some basic climate dynamics. Interviewees did not have a clear idea in their minds as to what CO_2 is exactly (Eurobarometer, 2011); they believed that the ozone hole is a significant contribution to climate change and the greenhouse effect, and that greenhouse gases in the atmosphere do not affect the average global temperature of the Earth (Leiserowitz & Smith, 2010).

By analysing the survey results, we can advance a first hypothesis: people are aware of climate change, but they lack knowledge of causal relations within climate dynamics, and, specifically, they are not aware of their role as 'causal agents' within climate problems: individuals do not know what causes climate change and do not grasp their interaction with nature, and consequently do not perceive the effect of their actions on the environment. Not knowing what causes an issue implies also not knowing how to interact with it (O'Connors Yarnal, & Wiefek, 2002), as the individual fails to understand his/her role as causal agent. This implies also a lack in the sense of moral responsibility (Pongiglione, 2012). The willingness to adopt pro-environmental behaviour, we argue, presupposes a kind of knowledge where climate dynamics are clear and explicit. What we intend for knowledge of climate dynamics is, first, knowledge of the fact that climate is a complex system composed of a multiplicity of parts. At the core of climate dynamics there is the idea of dealing with the coupling between the different components of the climate system, or of sub-portions of it, and using models to elucidate the feedback and the existence of a circular causality between the different components. This in order to explain past climate changes, to make projections of possible future scenarios, and to recognise the role of humans as agents in such a complex dynamic.

In the following section, we first discuss the key literature addressing the issue of lack of behavioural response to climate change, ranging from psychological barriers to various forms of resistance to changes in behaviour, from the lack of knowledge, interest, and commitment to various forms of educational strategies proposed in the literature. Following this, we describe a teaching experience we ran with secondary-school students in order to investigate the relationship between knowledge and willingness to adopt pro-environmental behaviour (if any). Finally, we discuss the data collected and propose a possible interpretation.

Theoretical framework

Much research has been conducted on the elements that hinder people's direct engagement with pro-environmental behaviour. One approach emphasises the psychological barriers to behavioural change. Norgaard, in an extensive literature review (Norgaard, 2006; 2009), listed some of the psychological barriers that have been identified by scholars. Specifically, lack of behavioural reaction can be due to cognitive dissonance and a desire to protect identity – individuals tend to blank out information that poses a threat to personal identity by requiring a change of habits and lifestyle. Incorrect mental models and misconceptions about climate change pose a further obstacle to behavioural change. Finally, perception of personal inefficacy is also responsible for people's apathy, as when an individual perceives that there is no easy solution to climate change, he/she tends to feel helpless, and ceases to feel responsible. The desire to avoid fear and negative emotions arising from this issue, feelings which are emphasised by the perception of one's own powerlessness, is also analysed by Norgaard in a separate study on this significant barrier to engaging in pro-environmental behaviour.

Norgaard's exhaustive review also takes into account the role of knowledge in influencing behaviour. She points out that together with the knowledge-deficit models (which have been suggesting for years that people lack knowledge about climate facts), there is a growing body of literature according to which knowledge is rather ineffective in generating behavioural changes, a view which Norgaard tends to support.

The role of knowledge in influencing behaviour is, to say the least, considered controversial. Some scholars have proposed that different kinds of knowledge should be taken into account, before drawing conclusions on its role in influencing behaviour. Frick, Kaiser, and Wilson (2004) identified three forms of knowledge: *system* (basic understanding of the natural state of ecosystems), *action-related* (what can be done about environmental problems), and *effectiveness knowledge* (knowledge about the benefits of pro-environmental actions). They found that the first is a sort of pre-condition of behaviour but cannot directly influence it, while the latter two have a more direct effect on performance. Truelove and Parks (2012) went further in the investigation of various kinds of behavioural potential of knowledge, and emphasised the importance of people's beliefs about the impact of behaviour on climate change. The two scholars found that effectiveness knowledge is probably the kind of knowledge most closely related to behavioural intention, although an important distinction has to be made: what is important is *not* knowledge about climate change mitigating behaviours, but rather the belief (whether accurate or not) that a certain behaviour can mitigate climate change. Aitken, Chapman, and McClure (2011) also investigated the role of knowledge in promoting pro-environmental behaviour, focusing specifically on the feeling of powerlessness: they were interested in verifying whether those who claim to possess greater knowledge about climate change actually feel more or less powerless. They conclude by suggesting that effective information campaigns should not be limited to basic information provision, but rather to 'providing information about the role of human actions in climate change and specific options for taking action'.

Understanding *if, how, and what kind* of knowledge had an impact on students' involvement in climate change has been also investigated by science education. Specifically, in the field of science education, knowledge is usually not intended as simple information but as conceptual knowledge (strictly related to scientific content), which can be a source of misconceptions that obstruct the learning of fundamental scientific principles. Particularly, the issue of knowledge related to students' changes in their attitudes about climate change has been investigated within the research strand of conceptual change. Among others, Sinatra and colleagues sustain that influencing students' attitudes about climate change and their willingness to take action to mitigate its effects constitutes a huge challenge (Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2012). They identify a number of difficulties related to misconceptions about the topic, which hinder individual behavioural change. Firstly, there are conceptual difficulties, as students often do not understand the true nature of the issue. The challenges of understanding climate change stem, in part, from its inner complexity and multidimensionality, from the need to reason in terms of systemic thinking. In addition to conceptual challenges, there are specific sources of misunderstanding such as recognising the distinction between weather and climate. Sinatra and colleagues (2012) suggest that knowledge of *deep time* helps to understand the distinction between weather and climate. Supporting this point, Dodick and Orion (2003) confirm that the misattribution of short-term weather fluctuations to long-term climate factors may arise in part from the conceptual challenges of understanding deep time or the timing and relationship between geophysical events that have occurred during the Earth's history. Another problem underlined by Sinatra is that learners are often committed to their own views, especially on socio-scientific issues, and these firm opinions may cause individuals to actively resist altering a proper belief or behaviour. Sinatra and colleagues also suggest that people who are motivated to seek closure wish for definitive answers and tend to deny ambiguity and uncertainty, that is, the uncertainties surrounding scientific as well as political debate on human-induced climate change could cause a kind of *freezing*, which can shut down access to the issue. They accurately argue that misconceptions, deep commitments, epistemic motives, and attitudes towards knowledge can present challenges, but also that, by addressing a complex topic like climate change, these issues may co-occur and be heightened in their valence due to the complexity and controversial nature of the topic (Sinatra et al., 2012). However, their findings suggest that students who have a more accepting attitude towards human-induced climate change are more likely to express a willingness to take action.

An important part of the literature focuses on pro-environmental education. Within this research strand, one approach investigates people's commitment to changing individual behaviour, with the practical aim of influencing it (e.g. Kollmuss & Agyeman, 2002). Another approach studies people's motives for taking action and develops education programmes to stimulate action. Whilst the first approach advocates a kind of education focused mainly on scientific knowledge about the effects of environmental problems and on prescribed strategies for solving them, the second focuses on knowledge in a broader sense, including, for example, the root causes of environmental problems. The aim of this second type of education is rather to enhance people's 'action competence', which requires more than mere knowledge (e.g. Jensen, 2002).

A general finding from our analysis is that the role of knowledge in influencing behaviour is often considered controversial and the topic involves multiple facets. However, as a common feature in the literature analysed, there emerged the importance of the need to act on knowledge about human role in climate change (Sinatra et al., 2012) and to provide specific options for taking action related to human role in climate dynamics

(Aitken et al., 2011). By analysing the literature focused on pro-environmental education, we see a gap between educational studies which mainly focus on scientific knowledge about the effects of environmental problems (Kollmuss & Agyeman, 2002) and studies which focus on knowledge about the root causes of them (Jensen, 2002).

In this paper, we attempt to address the points raised by the literature by further investigating the role of knowledge in influencing the willingness to adopt pro-environmental behaviour, specifically that kind of knowledge focused on clarifying causal climate dynamics.

The hypothesis we forward is that a scientific knowledge focused on clarifying causal relations within climate dynamics can make people understand their interactive role within the environment. In our empirical work, we addressed the various types of causal relationship along a multidimensional path, and insisted on the notion of circular causality as opposed to linear causality, which is simplistic for explaining and understanding climate dynamics. This, we think, could be a starting point, allowing people to causally interact with climate change instead of passively accepting an apparently unchangeable threat.

As well as clarifying the role of individuals in the causal relations that lead from popular behaviour to climate change, we further deemed it necessary to add information on the impact of daily actions. This may allow students to understand how they can effectively contribute to climate change mitigation and overcome the feeling of inefficacy and powerlessness that can prevent their behavioural engagement (Nye & Hargreaves, 2009).

In order to test our hypothesis, we designed some teaching material (Tasquier, Pongiglione, & Levrini, 2014) for Italian secondary-school students (grades 11–13) and implemented it in a multidimensional laboratory-course (15 hours). The teaching experiences were carried out in two different contexts, and data were collected with the aim of investigating whether we were successful in improving students' 'causal' knowledge and whether this had an influence on their willingness to adopt pro-environmental behaviour.

This study attempts to answer the following research questions:

> RQ. May improving students' knowledge about climate dynamics trigger and increase their willingness to adopt pro-environmental behaviour?

We analysed the data collected by using a qualitative methodology, and we developed some specific analytic tools that we called *patterns of knowledge* and *patterns of behaviour*.

Rather than making a contribution to the strand of teaching/learning climate change in science education research, this study aims to enrich the research regarding the crossover between science education and behavioural science. Our general aim is to contest the popular view that knowledge does not influence pro-environmental behaviour. Importantly, we do not argue that knowledge is the *only* element responsible, as we acknowledge that multiple factors concur in motivating people to take action on climate change (Pongiglione, 2014). We set out rather to emphasise that there is a certain kind of knowledge that can actually favour people's willingness to change behaviour.

The course content

The teaching experiences consisted of after-school laboratory-courses held in science-oriented secondary schools in 2012–2013–2014. The teaching materials implemented in the laboratory-courses were designed in light of the multidimensional nature of the problem and is intended to mirror the complexity of the issue. Indeed, the teaching materials explicitly implemented an epistemological *fil rouge* on modelling (Tasquier, 2015a, 2015b; Tasquier, Levrini, & Dillon, 2016) and developed a causal reasoning both in the scientific explanation of the complex causal dynamics and in the causal agency role of individuals in such environmental dynamics. The laboratory-course was structured into five lessons (Table 1).

Specifically, during the first three lessons, students were introduced firstly to climate science and then to the explanation of the balanced causal reasoning about greenhouse effect, by emphasising the IPCC statement that 'global warming is very likely [90%] due to anthropogenic causes of greenhouse gases increases' (IPCC, 2014). The crucial point of the first lesson was the qualitative introduction of the notion of feedback mechanism, presented as a typical way of reasoning in complex systems (e.g. climate system, social system). In the experimental parts of the lessons, the students were helped to construct a phenomenological relation between the absorbance (a) of a body and its temperature (T), through lab-experiments and simple modelling, in order to interpret

Table 1. Structure of the lab-course and summary of crucial points.

(I) Introduction to climate change: the scientific research and new terms of the scientific controversy (climate science)	
Aim: To stress what, about climate change, is shared by the scientific community (e.g. the increase of temperature of the Earth surface, the reduction of the ice-surface and the ice-thickness) and what is still object of controversial issues.	*Crucial point*: Introduction of the notion of feedback, presented as a typical way of reasoning in complex systems (e.g. climate system, social system) and explaining climate dynamics.
(II) Experiments on examples of interaction between radiation and matter (physics)	
Aim: To revise and/or construct the basic physics concepts needed to explain greenhouse effect (e.g. concept of equilibrium and energy balance, concepts of absorbance (a), reflectance (r) and transmittance (t), as well as the Stefan-Boltzmann law and Kirchhoff's law).	*Crucial point*: Zoom in on a physical phenomenon which is part of the causal dynamic by: (a) constructing the phenomenological relation between absorbance of a body (atmosphere) and its temperature; (b) stressing why absorbance is the crucial property for interpreting the thermal effects of radiation.
(III) Experiments for the construction of a Greenhouse model (physics)	
Aim: To guide students to construct a model of a 'greenhouse', which can explain why and how a change in atmospheric composition can produce temperature rise on the Earth's surface.	*Crucial point*: Interpretation of the phenomenological relation between absorbance and temperature as the bridge between anthropogenic causes (i.e. greenhouse gasses emissions) and the physical explanation of global warning.
(IV) The epistemological perspective of complexity: Introduction to the basic concepts for analysing complex systems (mathematics and physics)	
Aim: To introduce some concepts typical of the perspective of complexity, in particular re-analyse the notion of feedback in order to stress the epistemological distinction between linear and circular causality.	*Crucial point*: Exploration of different cause-effect relationships in complex dynamics and illustration of the simple model of Schelling about social segregation in order to analyse the relation between a system and its sub-parts in an example concerning the relation between individuals and society and to stress, again, that small (individual) changes can produce big social effects.
(V) Political scenarios, with an overview of climate treaties; data on individual environmental impact regarding (i) energy consumption at home; (ii) food environmental footprint; and (iii) transport (social sciences)	
Aim: To make students to understand that human activity plays a crucial role, both with regard to the collective aspects, related to political and economic scenarios and the institutional choices, and individual aspects related to the behaviour of the individual in his daily activities and in its interaction with the environment.	*Crucial point*: Illustration of the water and carbon footprints of common habits and daily activity, along with details on energy consumption of household appliances by emphasising the impact of individual role in the complexity of climate dynamics.

why and how a change in atmospheric composition can produce temperature rise on the Earth's surface (Tasquier 2015b; 2016). This relation between the absorbance of a body (atmosphere) and its temperature is particularly meaningful both from a scientific and from a behavioural perspective because it has several implications. Firstly, absorbance can be interpreted as the bridge between anthropogenic causes (i.e. greenhouse gasses emissions) and the physical explanation of global warming. Secondly, it gives the opportunity to exemplify, by means of physical phenomena such as the melting ice caps, the concept of feedback mechanism: the melting ice causes an increase of water vapour, carbon dioxide, and methane gas, so their emission in the atmosphere causes an increase in absorbance that in turn causes an increase in temperature (example of circular causality, where causes and effects cannot be clearly distinguished).

The fourth lesson introduced some concepts aimed at refining the epistemological discourse and addressing, from a new perspective, the causal reasoning previously explored. In particular, the notion of feedback was re-analysed to stress the epistemological distinction between linear and circular causality. Moreover, the concepts of time evolution, self-organisation, and multiplicity were introduced in order to discuss the notion of predictive power of a model and to stress that, in complex systems, the space–time scale of self-organisation is different from that of single sub-systems. Finally, the simple model of Schelling regarding social segregation (Edmonds & Hales, 2005) was illustrated to analyse the relation between a system and its sub-parts in an example concerning the relation between individuals and society, and to stress again that small (individual) changes can produce large-scale effects.

During the last lecture, students were first introduced to the situation today regarding climate agreements: the Kyoto Protocol, the Conferences of the Parties, and the advances regarding emission cuts at an international level were discussed, in order for them to apprehend the current response to climate change of 'large-scale players' such as national states. After that, students received some information about the impact of individual behaviour – the amount of CO_2 emissions produced by: (a) energy consumption at home (kWh and equivalent kilograms of CO_2 consumed by washing machine, hairdryer, air conditioning, TV, computer, etc.); (b) food consumption (ecological, carbon, and water footprints of food); (c) transport systems (cars, trains, planes, and ships and their share in the total emissions globally produced).

Students were never told if they ought to do something (or what) – they were encouraged in reasoning about carbon footprint of many common and daily behaviours and activities, and were left to draw their own conclusions about the impact of individual behavioural change and their own possible role as causal agent. Since in our final questionnaire we asked students about their willingness to change behaviour after the course, we did not want them to feel 'forced' to declare they would do something. We simply wanted them to understand that they are not helpless, that it is their choice to engage in pro-environmental behaviours, and to choose which actions to take.

The last lesson represented the moment of synthesis in which students could apply the acquired physical and epistemological skills in looking at climate change with a rational attitude. The complexity of natural phenomena was here used both as mirror and metaphor of the societal complexity and a special emphasis was given to stress the importance of the role of individuals. The example of the model of Schelling about social segregation was again discussed, so as to re-consider the interaction between Man and Society, that is, Man and Environment.

The contexts of implementation and the sample

Climate change has recently been added to the Italian school curricula but remains an optional topic. The course was implemented in two different contexts: an extra-curricular and a classroom curricular class. The experiences differed in period of implementation, number of students, age, and school level (Table 2).

The first sample is represented by 23 voluntary students from different schools (grades 12 and 13; 17–18 years old – hereafter identified as Volunteers) who personally opted to do this course on climate change within a ministerial Italian National project called 'Progetto Lauree Scientifiche'. The lab-course was an extra-curricular activity.

The second experience was in class at a science-oriented secondary school in Bologna. The 25 students involved were younger (aged 16–17, 11th grade) and did not choose to attend the course (being instead co-opted by their teacher), and so are identified as Non-Volunteers.

The questionnaires

During the course, various data were collected, taking into account the different dimensions of the study. In order to investigate the level of students' involvement in climate change and the quality of their knowledge we designed a pre-questionnaire (Q1) and a post-questionnaire (Q2), respectively given at the beginning of the first lesson (Q1) and at the end of the final lesson (Q2). The purpose of Q1 was to investigate the students' level of knowledge of climate change and the actions they were taking on it (if any). Q2 was aimed at verifying whether the students' level of comprehension regarding climate change had improved, and whether the information received made them willing to change something in their behaviour (and, if so, what).

Pre-questionnaire (Q1)

The first question concerned students' belief in the existence of climate change. Possible answers ranged from 'very sure' to 'not at all sure' with two intermediate answers ('quite sure' and 'not so sure') and a 'don't know' response. If their answer was 'not at all sure', they were asked to explain it.[1]

Question 2 concerned the causes of climate change. Their purpose was to understand whether students had a fair idea of the basic causal relationships within climate change, and were able to indicate its main causes and consequences. In question 2 we listed a series of environmental issues (some responsible for climate change and some not): the

Table 2. The teaching experiences.

	Context	Number of students	Age of students (years)	School level (grade)	Status
1st	PLS (extra-curricular)	23	18–19	12th – 13th	Volunteers
2nd	Classroom	25	16–17	11th	Non-Volunteers

accumulation of greenhouse gases produced by single individuals; the accumulation of greenhouse gases produced by industry; livestock holdings; the ozone hole; deforestation; pollution; nuclear power; and 'other'. We asked, how much the students thought each of these were causes of climate change (a lot; fairly; not much; not at all; don't know), and asked them to briefly motivate their answers.

Question 3 was an open-ended question which asked about the consequences of climate change; we also asked students to specify which possible consequences (if any) worried or scared them most. Although risk perception has often been considered an important element for generating a behavioural change, and it is common to think that the more urgent a risk appears, the more likely people are to react (Krosnick, Holbrook, Lowe, & Visser, 2006), there is an increasing body of literature that suggests that risk perception and the feeling of fear it generates can actually hinder a behavioural response (Hellevik, 2002; Norgaard, 2006). We decided to address this question principally in order to understand whether the very concept of consequences, as something completely different from (in fact, consequent to) causes was clear, or whether students' idea of causal relations within climate change was so confused that they were not able to make this distinction. This is the reason why the question was left open.

Question 4 was about current behaviour. Students were asked if they were currently taking action on climate change (answers were 'yes/no'). If they answered 'yes', they were asked (question 4.a) to specify what they were actually doing in practice (open question). If they answered 'no', they were asked to specify why (question 4.b), with the options: 'I would like to do something, but I don't do it because … ..'; and 'I'm not taking action, nor would I, because … '.

Questions about people's behaviour are very common in climate change surveys. Instead of giving predefined answers, we left question 4.a. open, in order to understand whether students could generally indicate actions that actually help mitigate climate change, or if there was a certain degree of confusion about the actions that most contribute to preventing it (commonly expressed by actions such as 'trying not to pollute' or 'recycling waste'). The aim of question 4.b. was to find out the reasons for not taking action. We left this question open-ended, as we wanted students themselves to express what was hindering them.

Other open questions were asked, regarding the greenhouse effect ('What is this phenomenon? Try to explain how it works'); the relation between greenhouse effect, global warming, and climate change ('Do you think they are connected?'); an eventual relation between greenhouse effect and ozone hole and/or pollution ('Do you think they are connected? If so, how?'). The aim here was to assess students' knowledge about causal relations within climate science, and to test students' ability to frame a reasonable and consistent response.

Post-questionnaire (Q2)

The second questionnaire was delivered at the end of the course. In question 1, students were asked whether their opinions about climate change had changed and in what sense. In question 2, they were asked whether their opinion about the *causes* of climate change had changed. We again listed the elements from the first questionnaire's question 2, and students were asked whether their opinion regarding the importance of such elements in causing climate change had changed or not. They were asked to explain their answer in order to understand if they had achieved a fair level of comprehension of climate dynamics. Question 3 asked again what they believed to be the consequences of climate change, and how afraid of these consequences they were.

Question 4 was about their *willingness to change behaviour* and to help prevent climate change. Students were asked whether they would modify something in their lifestyle as a result of what they had learned. Those who answered 'yes' were asked in 4.a. to specify how they would change their behaviour; those who answered 'no', were given two options in 4.b.: 'I would like to do something, but I will not do it because … ' and 'I will not do anything, and I would not because … '.

Questions 5 to 7 addressed the same issues as the first questionnaire: greenhouse effect; the relation between greenhouse effect, global warming, and climate change; and the relation between greenhouse effect and ozone hole and/or pollution.

Methods

Students' answers were analysed through a bottom-up iterative process, aimed at discovering ways to reveal whether and how their level of knowledge and behavioural attitudes evolved. We carried out a phenomenological search for emergent patterns which can provide insight into students' level of knowledge and behavioural attitudes.

The analysis allowed us to identify some *operative markers* which could reveal *whether* and *how* students (i) enriched and refined their level of knowledge, (ii) were willing to change behaviour; and *if there are* (and *what kind of*) correlations between level of knowledge and behavioural response.

The identification patterns of knowledge and behaviour allowed us to track the evolution of the whole group of students along the two dimensions investigated.

In order to reach an acceptable level of internal validity, the patterns were identified through a process of triangulation among different researchers: by the authors and by an external scholar (expert in science education), collaboratively and interactively (Anfara, Brown, & Mangione, 2002). Each of the authors carried out the analysis by separately searching for the emergent patterns in a bottom-up manner. Then the scholars exchanged and checked their work separately, before discussing each case of the sample together. The work was repeated several times and the special cases were collectively discussed. After a first identification of the patterns, in order to check if the structure of the analysis worked, the two authors and the external scholar separately collocated each student in the identified patterns and discussed together each configuration. This process of triangulation led to a progressive refinement of the patterns. Finally, the work was validated by an external referee.

Table 3 shows the knowledge patterns which have been identified.

In Q2, students' improvement can be measured both via their raised level of knowledge and with an improvement in simply assessing the importance of the causes of climate change, which they express by changing opinion on some of the factors listed in question 2. However, this was not accompanied by any improvement of the arguments in open questions about greenhouse effect. Such patterns are indicated by adding an 'X' to the existing ones (P1X-P2X-P3X-P4X-P5X).

Table 4 shows the behavioural patterns which have been identified.

Behavioural patterns are the same in Q1 and Q2.

Table 3. Knowledge patterns in Q1 and Q2

P1	The student is not able to correctly assess the importance of the factors listed in provoking climate change. He/she tends to consider the ozone hole and nuclear power as very important factors, whilst severely underestimating the role of individual emissions, deforestation, and livestock farming. Arguments given in open questions (about consequences of climate change and greenhouse effect) are poor in both logic and content, showing widespread confusion and a general inability to distinguish between causes and consequences.
P2	The student is not able to correctly assess the importance of the factors listed in provoking climate change. He/she tends to consider either the ozone hole or nuclear power as important factors but often not both, sometimes opting for a wiser 'don't know' response[2]. There is a general (but not excessive) underestimation of the role of individual emissions, deforestation and livestock farming. Arguments given in open questions (about consequences of climate change and greenhouse effect) are logically coherent, but there can be severe conceptual mistakes. At times, confusion between causes and consequences is still evident.
P3	Mistakes remain in assessing the importance of the factors listed in provoking climate change, awarding too much importance to either the ozone hole or nuclear power, and underestimating the role of individual emissions, deforestation and livestock farming. Arguments given in open questions are logically coherent; the student is able to distinguish well between causes and consequences, to correctly mention some consequences of climate change and to give a correct explanation of greenhouse effect (albeit often quite limited) and talk about causal dynamics. Content is generally quite good, with some residual mistakes.
P4	The student is able to correctly assess the importance of factors contributing to climate change with some minor over- or under-estimations and demonstrated to have a good level of knowledge about climate dynamics. Both arguments in open questions and contents are good, despite some minor imprecision.
P5	The student is able to correctly assess the importance of factors contributing to climate change and demonstrated to have a high level of knowledge about climate dynamics. Both arguments and content in open questions are good.

Table 4. Behavioural patterns in Q1 and Q2.

O	No answer.
A	The student does not take action on climate change (nor is willing to in Q2) as he/she thinks that individual efforts are ineffective.
B	The student does not feel like changing lifestyle and habits (nor is willing to in Q2).
C	The student would like to do something about climate change, but does not know what to do.
D	The student says he/she is taking action (Q1) or willing to take action (Q2) on climate change, but then either indicates actions that are not entirely consistent with the problem (such as recycling waste), or declares (especially in Q2) things such as 'I will consume/pollute less'. This pattern in Q1 can still be seen as a relatively good pattern, as it at least expresses current engagement with the environment, while in Q2 it represents somewhat disengaged students, who feel they must declare themselves willing to change behaviour, but then refer simply to some random or general action.
E	The student says he/she is taking action/willing to take action on climate change, and mentions a general emission reduction or awareness raising among friends and family, but no specific actions.
F	The student says he/she is taking action (Q1) or willing to take action (Q2) on climate change, and mentions *one* concrete action that is able to help mitigate climate change (i.e. a reduction in the use of car, energy saving at home, decrease in consumption of meat and/or out-of-season food, home insulation, etc.).
G	The student says he/she is taking action (Q1) or willing to take action (Q2) on climate change, and mentions *two* concrete actions that can help mitigate climate change.
H	The student says he/she is taking action (Q1) or willing to take action (Q2) on climate change, and mentions *three or more* concrete actions that can help mitigate climate change.[a]

[a]We considered behavioural patterns progressive from D to H in this sense: D represents a declared willingness to do something for the environment, but very general and often not relevant ('I will pollute less'); E represents instead general actions directly connected to climate change ('I will try to reduce my emissions'), while F, G, H respectively indicate one (F), two (G) or three or more (H) precise action(s) aimed at mitigating climate change. From D to F, therefore, there is a progression from general to precise actions; while from F to G the progression is seen in how many actions are performed, and more specifically, in how many of the behavioural main areas (energy, food, transport) the student is willing to change behaviour. This approach does not consider the impact of each behavioural change in terms of CO2 emission saved, but rather the willingness to change habits, assuming that the more dimensions are involved, the better.

Data analysis and results

The first point we investigate is whether there is a correlation between what students know about climate change, and how they willing to behave about it.

After that, we compare students' knowledge levels before and after the course to see whether any improvement was made. Subsequently, we comment on how behavioural responses change in Q1 and Q2, and finally we consider the correlation between knowledge and behaviour from Q1 to Q2.

Knowledge and behaviour in Q1

The following graph (Figure 1) represents the correlation between knowledge and behaviour in Q1.

The graph first shows how students with a low level of knowledge (patterns P1 and P2) are definitely less engaged in actions that they perceive as climate change prevention: 23 out of 48 (about 48%) students with low knowledge patterns (P1 and P2) belong to behavioural patterns O, A, B, or C. Of the remaining six (about 13%), half (3) are in pattern D, which reveals a positive attitude towards climate change prevention but then displays lack

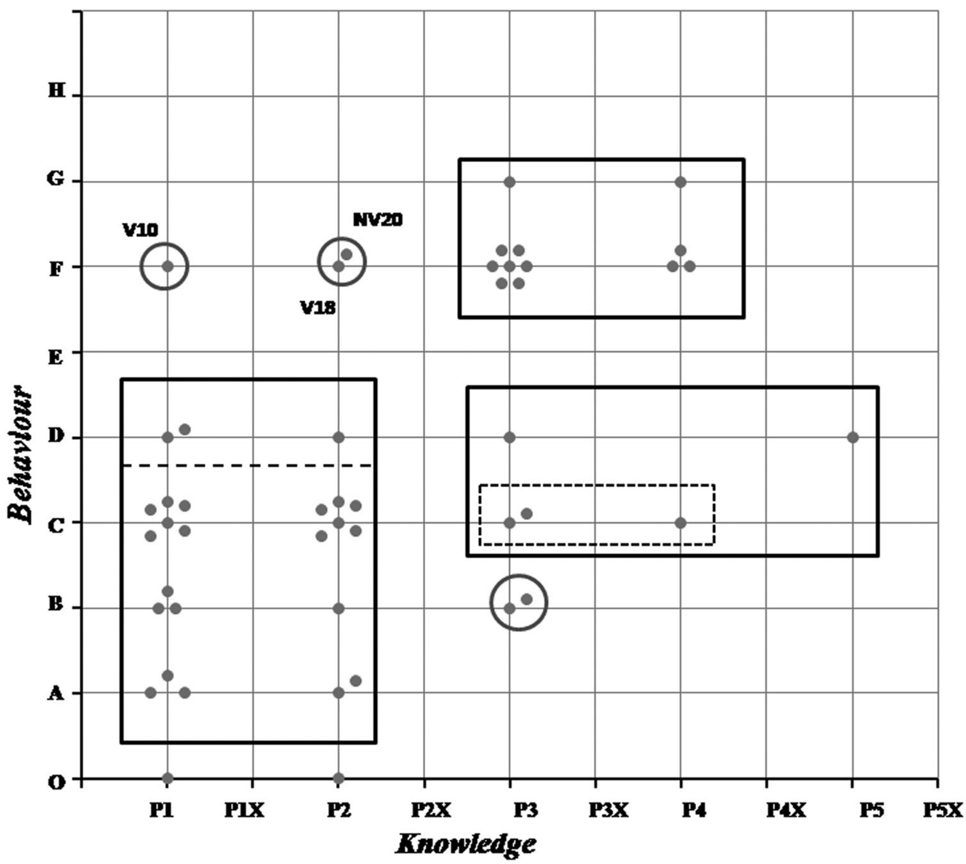

Figure 1. Correlation between knowledge and behaviour in Q1 and Q2.

of knowledge of what actually constitutes useful actions, and can be coupled with pattern C, which corresponds to lack of action but willingness to take measures if the right information were possessed. Only the three remaining students with behavioural patterns F can therefore be considered exceptions, and will be discussed later.

Students with a higher knowledge pattern are conversely more likely to engage in pro-environmental behaviour – 12/19 students (63%) in P3, P4, or P5 take action on climate change, and demonstrate behavioural pattern F or G. Of the seven remaining students, two display behavioural pattern D, and three behavioural pattern C – they are therefore willing to do something, but seem to lack the part of knowledge concerning individual causality.

Two students with high knowledge patterns are unwilling to take action on climate change (behavioural pattern B). This is not surprising, since knowledge is one element that influences behaviour but certainly not the only one. Cultural background, personal attitude, social norms, and other factors may all play an important role in influencing behaviour.

What can be generally stated is that knowledge pattern P3 seems to be the minimum knowledge level that in most cases correlates with positive action. There are, of course, exceptions to this trend, such as the 3/29 students who answer F in BQ1 despite having a low level of knowledge. Such students are respectively 1 Non-Volunteer and 2 Volunteers.

In the first case (the Non-Volunteer student), the initial level of knowledge was low, but revealed a somewhat 'wiser' profile: the student gave four 'don't know' responses in question 2 (where some possible causes of climate change were listed), which we considered slightly preferable to giving wrong answers,[2] and gave quite correct answers for the remaining three causes (being able to indicate that the ozone hole was 'not much' to be considered a cause of climate change). Regarding open questions, the student either gave very limited and short answers (such as, about the greenhouse effect, 'it is a phenomenon that makes the Earth warmer', which is not actually wrong, but is very approximate), or answered 'I don't know' to other questions. We considered therefore her knowledge pattern as a P2. From the behavioural side, the student answered that she was sorting waste for recycling (which we do not accept as a reasonable answer, as it is not related to climate change), but also that she was using either public transport or a bike rather than 'polluting' transport means – and was therefore considered a pattern F. The fact that her profile, although departing from a low knowledge level, was better than that of students falling in average in P2, was proved by the final questionnaire: she reached P4 in Q2, and, regarding behaviour, she added willingness to reduce energy consumption.

The second exception (from the Volunteer group), was in pattern P1 in Q1 and showed widespread confusion about everything. Interestingly, unlike most other students who were in P1 in Q1, this student made an effort to justify her answers in open questions, which were extensively discussed but completely wrong (e.g. she wrote that the greenhouse effect and the ozone hole were *consequences* of climate change). In Q2, she improved to P2X, being able to assess the causes of climate change quite correctly, and being able to approximately explain what the greenhouse effect was. We believe that she was very interested in the course, and quite motivated on environmental issues even before the course started (she wrote that she had participated in an environmental fair in Rimini). In Q1, the student said she was using her bike rather than other transport means in order not to pollute, and in Q2 added that she would try to reduce energy consumption at home.

The third exception (from the Volunteer group) was in pattern P2 in Q1, and remained there in Q2. The student was able to distinguish between causes and consequences of climate change, but displayed great confusion about the greenhouse effect. Responses were short and not well discussed. The student did not improve in Q2, and this was quite apparent also in her responses about behaviour. In Q1, the student mentioned the use of bike or public transport rather than private car (pattern F), while she was less precise in Q2, claiming she would be 'more aware' and would talk about environmental issues at home (pattern D). This student was perhaps the only real exception: she seemed quite disengaged and did not make any improvement. The relatively good behaviour could be explained as family-induced, or simply as a habit.

The evolution of knowledge from Q1 to Q2

The differences in knowledge between the two groups (Non-Volunteers and Volunteers) were, as could be expected, quite apparent. Students belonging to the Non-Volunteers group showed a lower level of knowledge, while Volunteers benefitted from a more advanced initial knowledge. However, the analysis highlighted that there were a specific difference between the samples in the level of achievement both in knowledge and in behaviour that is not regarding the amount of change, but rather their starting point. This could be due to a number of factors, such as previous interest in the topic, but also age and school grade, although, since climate science is not commonly taught in high school, students' grade should not be considered as a strong determinant of knowledge level. Although the Non-Volunteers started from a lower level, what is most important is that the 'gradient' of improvement appears the same as that of the Volunteers, who reached a higher level but also started from higher patterns. Such results led us to decide to merge the samples together for the next step of analysis.

Figure 2 shows the correlation between knowledge patterns in Q1 and Q2 in both samples.

The X axis defines knowledge patterns in Q1, and the Y axis concerns knowledge patterns in Q2. Each point represents one student and his/her answers in Q1 and Q2. The points that lay on the bisecting line represent students who have not changed knowledge pattern. The dots that are located close together around a specific combination of patterns are representative of a same correlation pattern. In the graph, we have set up the programme so as to distribute the dots in order to avoid overlapping, otherwise the number would not have been visible. This method was applied to all the graphs of correlation.

One first finding that emerges from the graph above is that no student's level of knowledge worsened – no sample is placed below the bisecting line. The lowest-level patterns (P1 and P2), which were highly populated in Q1, are significantly less populated in Q2, and medium-to-good knowledge levels (P3 to P5) are definitely more populated in Q2 than in Q1: this allows us to conclude that an improvement has been achieved.

Students who place themselves in P1 and P2 in Q1 represent approximately 60% of the total sample, and about a half of these then go on to make progress in Q2. It is interesting to note that, despite the significant differences in knowledge levels between the two samples, both samples P1 and P2 halve their population in Q2.

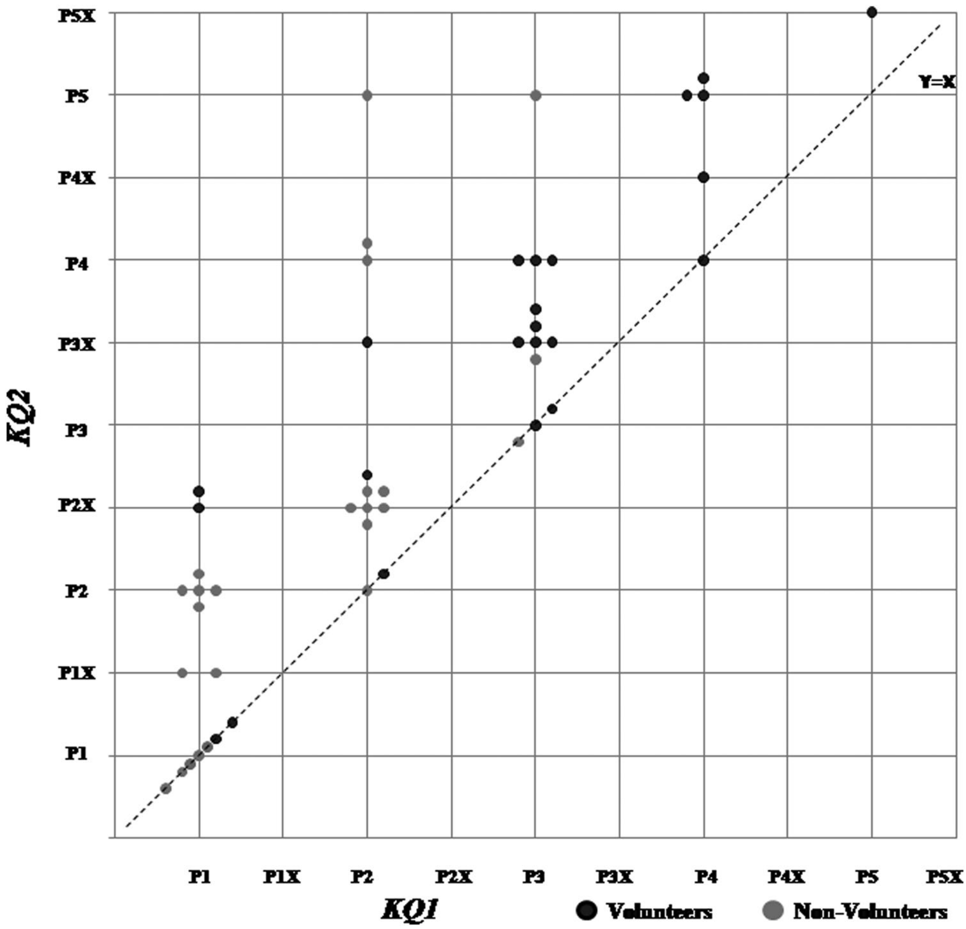

Figure 2. Correlation between KQ1 and KQ2.

Behaviour in Q1 and Q2

As this study focused primarily on investigating the correlation between knowledge and behaviour, we were specifically interested in the analysis of how knowledge improved and how such improvement was reflected in students' behaviour. The correlation between students' behaviour before and after the course was not to be evaluated per se, as it, alone, cannot contribute much to answering our crucial question about whether behaviour is a function of knowledge. Yet there are some interesting observations that can be made by looking at how students' behaviour changes from Q1 to Q2 (see Figure 3).

Patterns O, A, and B can be considered as being at the same level, representing merely different motivations given by students for *not* taking action, without one reason being 'better' than the others. Pattern D is a borderline pattern, as in Q1 it mostly indicates a willingness to do something to prevent climate change and the (wrong) belief of actually doing it, while in Q2 it is likely to indicate disengagement but willingness to give a 'right' answer (a typical answer in Q2 is 'I will pollute less'). Patterns E, F, G, and H are instead progressive, and a shift towards them in Q2 can be seen as an improvement, regardless of the answer given in Q1.

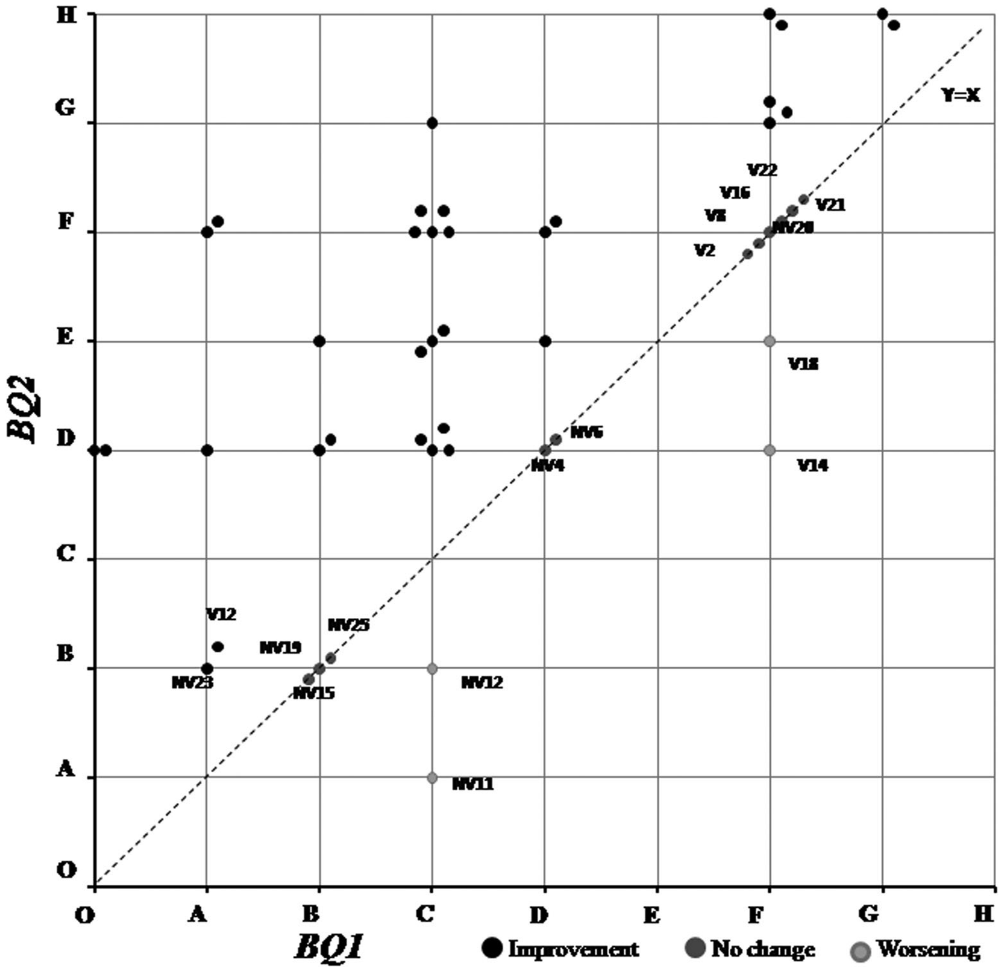

Figure 3. Correlation between BQ1 and BQ2.

As a result, 46% thus have definitely improved their behavioural pattern in Q2 (placing themselves in patterns E, F, G or H in Q2), while 19% migrated to pattern D (from O, A, B, and C), which can be seen as a partially good result. Eleven students have not changed behavioural pattern, while four students have apparently worsened their responses in Q2 (those below the bisecting line). Yet, it might not be appropriate to consider any shift from C, B, or A to a lower pattern in Q2 as a 'worsening', as patterns O, A, and B are not progressive. Therefore, concerning the points below the bisecting line, NV11 and NV12 have not really worsened in their behaviour – they just provide a different motivation for not taking action in Q1 and Q2. Interestingly, both students who are in knowledge pattern P1 in both Q1 and Q2 have not improved in the knowledge level. Concerning instead V14 and V18, they were both in pattern F in Q1, but shift respectively to patterns D and E, and therefore can be said to have somewhat worsened their behavioural pattern. Also, these students did not improve their knowledge from Q1 to Q2: they registered respectively as P2 and P3 in both Q1 and Q2. Somehow, the worsening of behavioural pattern seems related to lack of improvement in knowledge.

Lastly, pattern C, which was the most populated in BQ1 (with 31%), is not populated at all in BQ2: this means at least that no student left the course with the feeling of not knowing what to do about climate change.

Knowledge and behaviour in Q2

Figure 4 traces the evolution of both knowledge and behaviour from Q1 to Q2.

Even at first glance, it is quite apparent that there is a shift from the bottom-left area of the graph (light-grey dots) to the upper-right (dark-grey dots). Such shift indicates a general improvement in both the knowledge and behavioural dimensions: lower knowledge patterns are less populated in Q2, as are behavioural patterns expressing an unwillingness to change behaviour (patterns A and B).

The following graph (Figure 5) focuses only on Q2, and shows the correlation between knowledge and behaviour observed after the course.

Poor knowledge levels (P1, P1X, and P2) correlate with low behavioural patterns. Those who are still in such knowledge patterns in Q2 can at best reach behavioural pattern D. There is just one exception to this inference, represented by V18. This student also figured as one of those with a good behavioural pattern in BQ1 (pattern F) despite

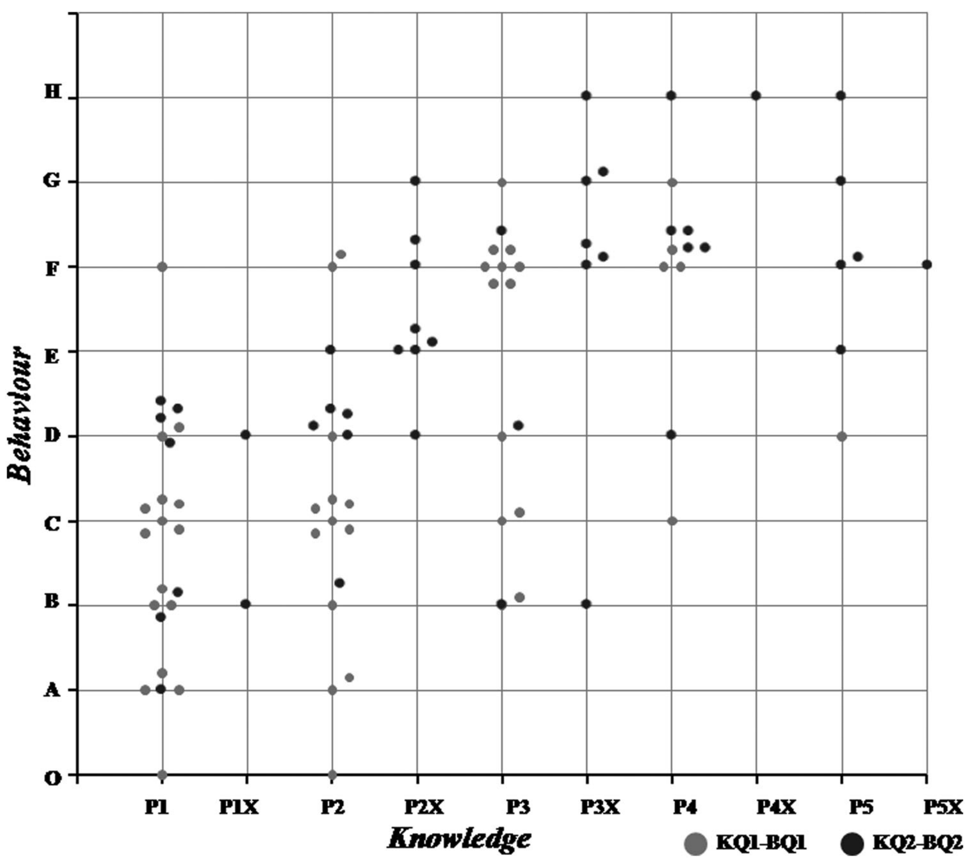

Figure 4. Correlation between KQ1-BQ1 and KQ2-BQ2.

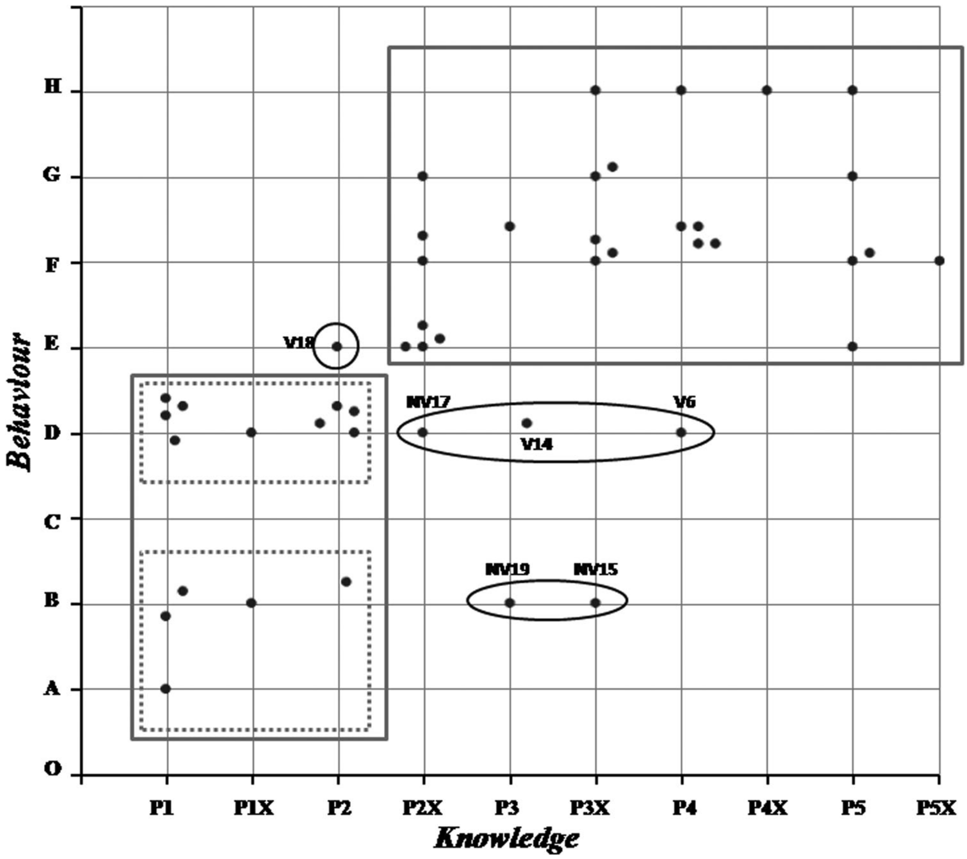

Figure 5. Correlation between KQ2-BQ2.

having a low knowledge level (P2). Her level of knowledge does not improve in Q2, and her result worsens on the behavioural side, going from F to E. In this case the non-improvement in knowledge is manifested primarily in an inability to rightly assess the importance of climate change causes listed in Q2. This reflects in less precise claims about behaviour – the student mentions a willingness to be more 'aware' of what she does, and to talk about the environment at home, but no practical actions.

In Q2, high behavioural patterns (from E to H) presuppose the minimum degree of knowledge of P2X. P2X is a quite low pattern, as students are still not able to write fully correct answers to open questions, showing difficulties in providing good argumentations. Yet, they improve in assessing the importance of climate change causes as listed in question 2. In short, they have a very basic knowledge about how the greenhouse effect works, but have changed their mind about what causes climate change. And this is what allows them to understand how to 'interact' with it, and to choose to take action. Those who lack even this minimum knowledge (P1, P1X, P2) are not able to indicate any recommended practical behaviour, and at best respond with a general answer about changing behaviour (such as 'I will pollute less'), falling in pattern D, or otherwise declare themselves unwilling to change behaviour (pattern A or B).

P2X is, in other words, the lowest knowledge level in Q2 that allows a behavioural change. This leads to the second main observation: willingness to change behaviour regarding climate change (displayed by a behavioural pattern E, F, G or H in Q2) is either associated with a knowledge level ≥ P3, or with an improvement in knowledge level, at least regarding the assessment of importance to climate change causes (represented by patterns with the 'X', with the exception of P1X, where knowledge is still poor and very approximate).

Low knowledge patterns (P1, P2) predict a low behavioural pattern, while higher knowledge patterns are more often associated with good behavioural patterns. Thirty-one students have a good level of knowledge in Q2, but five of them are in behavioural patterns D (3) or B (2). This may allow us to infer that, while not possessing enough knowledge may in fact obstruct behavioural change, possessing it does not necessarily mean engaging in climate change prevention. This does indeed make sense, as humans act on many different reasons, and we do not claim that knowledge is necessarily the most important. As 26/31 students whose level is ≥P2X have a behavioural pattern ≥E in Q2, we may at least conclude that an individual with a greater level of knowledge is definitely more likely to take action than someone who does not.

Summary of results

The paper had the research goal of investigating if improving knowledge of causal dynamics within climate change may increase students' willingness to change behaviour.

When we started the course, 54% of students knew very little about climate dynamics, and 56% declared that they were not taking action on climate change (despite the fact that 52% of these were willing to, but did not know what to do). By the end of the course, the number of students who still understood very little about climate dynamics and who declared themselves unwilling to change behaviour had greatly decreased. We must also consider a group of 12/48 students who fall in pattern D in Q2, whose apparent willingness to change behaviour was so vague that we cannot consider it as genuine. This leaves 29 students in patterns E, F, G, H in Q2, while in Q1 we had only 16.

It could be tempting to infer that, since P2X seemed to be the minimum knowledge level required for a willingness to change behaviour, what counts most is having a fair knowledge of what causes climate change in order to help prevent it, while a more precise knowledge on climate dynamics is not as useful. Yet, if we consider behavioural patterns F to H (those that include an indication on precise pro-environmental actions), out of 21 students belonging to these patterns, only 3 were in P2X and 1 in P3, while 17/21 had a fairly advanced knowledge level ≥ P3X, which presupposes a good understanding of climate dynamics (especially regarding the greenhouse effect).

Since P2X appeared to be the minimum level of knowledge needed to trigger a significant behavioural response, it represents a sort of 'threshold pattern' of knowledge. While it merely showed an improvement in Q2 from either P1 or P2, and therefore still indicates a low level of general knowledge, the improvement in assessing the importance of climate change causes can be seen as a turning point. Such level allowed students who were less interested (the most sceptical, the most confused, etc.) in the subject to abandon their initial disinterest and to trigger a behavioural response, somehow reasoned and not enforced by the situation. The existence of a minimum threshold of knowledge (P2X) shows that the size specification is a necessary condition to foster a behavioural response to a conscious and non-ideological interest. The development of this form of awareness represents a crucial point for perceiving science as a reliable source of knowledge, and an important goal in the challenge of educating young people in scientific citizenship.

Climate science is not an easy subject, and not everyone is necessarily interested in learning more about it. This experiment shows that, although a more advanced starting level makes it more likely for students to take correct actions, even a basic knowledge of what causes climate change and the impact of simple daily actions on the environment may be of help in promoting a willingness to act.

Final remarks and implications

This study was intended to provide a contribution to a science education research issue that has so far been of interest mainly for behavioural scientists (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007; Norgaard, 2006, 2009; Weintrobe, 2012), but is coming to the forefront also in science education (UNESCO, 2009).

The study originated from the hypothesis that there is indeed a kind of knowledge that can positively influence willingness to adopt pro-environmental behaviour – a scientific knowledge focused on clarifying climate dynamics, which can make people understand the existence of a complex interaction between man and nature, through modelling climate phenomena like greenhouse effect and global warming, and recognise their role as causal agent in such a complex dynamic. We conjectured that willingness to adopt pro-environmental behaviours presupposes a kind of knowledge where individual causality is clear and explicit, and that acquiring some practical knowledge on the impact of daily actions on the environment may allow people to help prevent climate change.

By analysing the research literature on the psychological barriers and on conceptual change, we were guided in the process of designing our materials, especially regarding the construction of design criteria able to address psychological barriers, conceptual difficulties, and epistemological obstacles simultaneously (Tasquier, 2015b).

By analysing the research literature focused on pro-environmental education, we identified a gap between educational studies which mainly focus on scientific knowledge about the effects of environmental problems and studies which focus on knowledge about said problems' root causes. As we argued in the theoretical framework, the original approach of our research is to explore and analyse in-depth the cause–effect relationship in different ways, rendering it increasingly dynamic. Such an approach helped make students able to grasp/understand the role of humans as causal agent in climate dynamics. Particularly, (i) cause–effect relationships were addressed from several perspectives in several disciplines (i.e. climate science, physics lab, maths of complex systems, social and behavioural sciences); (ii) different cause–effect relationships were explored and addressed by showing different kinds of reasoning beyond them (in particular the distinction between linear causality *vs* circular causality); and (iii) the evolutionary aspects of the cause–effect relationship were stressed by exploring the space–time scale of the climate system and correlating different actions (cause) with different possible scenarios (effects) (e.g. IPCC graphs).

These ways of addressing and exploring the causal–effect relationship support, in our opinion, the increase in a particular kind of knowledge, which we referred to as *causal knowledge*.

In this sense, in order to trigger willingness to take pro-environmental actions, what is needed is not *knowledge per se* (an understanding of the essential features of the climate system or greenhouse effect) but *causal knowledge* (the exploration of the many causal relationships and the emphasis on individual role in the complexity of climate dynamics).

Starting from this perspective, it is important to stress that knowledge is necessary but not sufficient alone (Kollmuss & Agyeman, 2002). Cultural background, personal attitude, social norms, and other factors may also play an important role in influencing behaviour. What results instead from our study is that a certain kind of knowledge (*causal knowledge*) represents a fundamental and successful triggering factor in order to push students into feeling as though they play an active part in the environmental dynamics.

We have one final note concerning the debate on the curriculum reform (Dillon, 2009). Very often, the conceptual difficulties linked to the issue of climate science hinder teachers in dealing with it. Moreover, in Italy, the topic is not mandatory at school but is merely suggested by the curricular guidelines.

Despite the intrinsic complexity of the topic, our results confirm the possibility to successfully address climate change at school, and also the benefits of addressing it from different disciplinary perspectives (Tasquier, 2015a, 2016), favouring the cooperation among teachers of different disciplines (physics and social sciences especially) (Levrini, Fantini, Pecori, Tasquier, & Levin, et al., 2014).

Notes

1. Many studies suggest that changing students' attitude in socio-scientific issues such as climate change presents unique challenges. Our results, though, show that the level of awareness concerning climate change does not correlate to behavioural engagement (nor to a higher knowledge level). Respectively, 84% of Non-Volunteers and 93% of Volunteers declared themselves either 'very sure' or 'quite sure' about the existence of climate change. We therefore proceeded with our hypothesis that sometimes, students need more knowledge rather than a change in attitude.
2. In building the knowledge patterns, we observed that the 'I don't know' responses usually correlated with more correct responses (when given) and a higher capacity in providing better arguments in some open questions. Students seemed to be more aware of the limits of their own knowledge, and, instead of guessing at the right answer, preferred to respond that they did not know. Therefore, we considered the 'I don't know' response as slightly preferable to a wrong answer.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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