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ARTICLE

Different People in Different Places

Secondary School Students' Knowledge About History of Science

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Abstract This article presents the results of an exploratory study of students' knowledge about scientists and countries' contributions to science, aiming at answering two research questions: "In which ways are students aware of the history of scientific development carried out by different people in different places of the world? What can be influencing and shaping their awareness?" Thus, this study aimed at depicting students' knowledge about History of Science (HOS), focusing on what they know about science being done by people and communities from different parts of the world and on how this knowledge is constructed through their engagement with school science. An exploratory research was carried out at two multicultural state secondary schools in London, UK, involving 200 students aged 12–15 (58.5% girls, 41.5% boys) and five science teachers. The method involved an initial exploration of students' knowledge about HOS through an open-ended survey, followed by classroom-based observations and semi-structured interviews with the participants. Results showed a disconnection between remembering scientists and knowing about their work and background, hinting at an emphasis on illustrative and decontextualised approaches towards HOS. Additionally, there was a lack of diversity in these students' answers in terms of gender and ethnicity when talking about scientists and countries in science. These findings were further analysed in relation to their implications for school science and for the fields of HOS, science education and public perception of science.

1 Introduction

The inclusion of History and Philosophy of Science (HPS) in school science has been advocated by several science educators and historians (e.g. Collins and Shapin 1989; Matthews 1994; Millar and Osborne 1998; Solbes and Traver 2003; Höttecke et al. 2012; Allchin 2014; Garcia-Martinez and Izquierdo-Aymerich 2014) and explored by different academic

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journals (such as *Science & Education* and *Journal of Research in Science Teaching*), conferences (such as those organised by the International History, Philosophy and Science Teaching Group, and by the European Science Education Research Association) and curricular reforms around the world in recent decades.

Suggestions of the association between HPS and science education began to gain force more systematically in the post-World War II period, aiming at showing that science is a human enterprise and promoting reflection about the relations established between science, technology and society (Figueirôa 2009). One of the landmarks of this movement was a proposal deployed by James Conant and other professors of Harvard University in the 1950s, known as the *Harvard Case Histories in Experimental Science*, through which students were stimulated to study historical cases based on the analysis of key processes in the development of science (Collins and Shapin 1989).

In the following decades, different contributions were developed bringing these two fields of History and Philosophy of Science together. Matthews (1992), for instance, discusses some relevant local initiatives, such as the report written in 1963 by the British Association for the Advancement of Science advocating teacher training in HPS, and a conference on History of Science and Science Teaching organised in 1987 by the British Society for the History of Science. In the curricular field, some countries also acted innovatively in relation to HPS, such as the first National Curriculum (from 1989) in England (Taylor and Hunt 2014), which argued that:

> Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed. (NCC 1988, p. 113).

Since the 1950s, the number of contributions developed to aid the inclusion of HPS in science lessons has grown, both at higher and elementary education. The several purposes that HPS can serve in science education have been presented and systematised by many authors, and they involve, for instance: motivating students, humanising science, teaching about how the scientific community works, teaching about scientific inquiry and instruments, promoting conceptual changes, among other possibilities (Matthews 1992, 2014a; Solbes and Traver 2003; Henke and Höttecke 2015).

According to Henke and Höttecke (2015, p. 350), education practices and teaching formats involving HPS can encompass, for instance: "Reading, analyzing and discussing original historical research papers, lab-diaries or technical reports"; "Telling rich historical anecdotes, short stories or interactive vignettes accompanied by conceptual, methodological and philosophical reflections"; "Conducting historical (thought) experiments or replicating actual laboratory procedures, tracing the development of scientific methods, concepts and theories"; and "Combinations of the above strategies within the context of detailed historical case studies spanning multiple lessons".

The implementation of HPS into science lessons remains, however, a challenge, mainly due to traditional views about the science curriculum and about what science teaching should encompass, coupled with science teachers' limited knowledge of HPS and the lack of historic-philosophical materials available (Höttecke and Silva 2011). Hence, whether HPS is being routinely used in school science and how this is done by different science teachers are enduring questions within this field. This specific attention to classroom practices, realities and possibilities, that is, to what is actually happening inside the classrooms regarding HPS, must be taken into account if we want to help science teachers embrace innovative approaches such as historical-philosophical ones.

In other words, after at least 30 years of teacher training, empirical interventions and curricular debates about the implementation of HPS in school science practices, what are the impacts of this body of research on learning settings? In order to partially address this question, this article describes an investigation of secondary students' knowledge about History of Science (HOS), and of how this knowledge can be related to school science practices and curricula. This study was carried out as part of a larger research project that aims at helping science teachers to incorporate HOS into their regular lessons using an "intercultural model" (Roberts 2009; Sarukkai 2014). In this scenario, an initial and exploratory classroom-based investigation about the current place of HOS in the participating teachers' lessons and their students' knowledge about HOS was crucial, especially if aiming at fostering innovative practices.

2 HPS and Science Education: a Brief Review

2.1 Why and Which HPS in Science Education?

When advocating the introduction of HPS into science education, it is important to reflect on how this field can contribute to science teaching and learning. In other words, in the context of regular schools, what type of enrichment can HPS bring to science lessons? The answer to this question will inevitably be connected with specific views on what science education and education in general should be about, which means that the different roles of HPS will vary according to the type of science learning that is being pursued in each case.

These possibilities have already been discussed by several authors in recent decades (among many others, Collins and Shapin 1989; Matthews 1994; Millar and Osborne 1998; Solbes and Traver 2003; Höttecke et al. 2012; Alvarez-Lire et al. 2013; Bächtold and Guedj 2014; de Berg 2014; Garcia-Martinez and Izquierdo-Aymerich 2014). Matthews (1992) highlights, for instance, the following contributions brought by HPS to science education:

> (1) it motivates and engages pupils; (2) it humanises the subject matter; (3) it promotes the better comprehension of scientific concepts by tracing their development and refinement; (4) there is intrinsic worth in understanding certain pivotal episodes in the history of science - the Scientific Revolution, Darwinism etc.; (5) it demonstrates that science is mutable and changeable, and that consequently current scientific understanding is liable to be transformed, which (6) thus combats scientistic ideology; and finally, (7) history allows a richer understanding of scientific method and displays the patterns of change in accepted methodology. (Matthews 1992, p. 17–18).

Based on this list, there seems to be three main aspects of science education that HPS can be related to: learning a scientific concept, learning about science as a process and its nature (NOS), and fostering students' positive attitudes towards science. Höttecke and Silva (2011) also present, grounded on an extensive literature review, a similar group of contributions from HPS: learning about science as a process, promoting conceptual change, learning about nature of science (NOS), fostering public understanding of science, and fostering students' positive attitudes towards science.

Therefore, HPS can be employed in different ways in school science depending on the main goals of a specific science teacher and/or science curriculum. It can aid the learning of scientific concepts by illustrating how they were historically developed by the scientific community, including the analysis of historical data, instruments and experiments (such as seen in Bächtold and Guedj 2014; Besson 2014; Levrini 2014). On the other hand, it can foster discussions about NOS (as seen in Develaki 2012; de Berg 2014; Taylor and Hunt 2014; Fouad et al. 2015), including its epistemic nature (such as theories, models and evidence), inquiry aspects (such as methods, experimentation and instrumentation, data collection and interpretation) and its socio-institutional dimension (such as peer reviewing processes, certification of knowledge, collaborative work and ethics and economy in science).

There is also the potential of HPS to humanise scientists by showing that scientific work is carried out by regular people working in a community that is also connected with the regular public. This idea is related to promoting positive attitudes towards science and scientific careers, and the "public understanding of science" regarding the image of science and scientists. Here, among the benefits of introducing HPS into science education, authors (Matthews 1995; Hodson 1999; Kampourakis and McComas 2010; Kampourakis 2013; Krugly-Smolska 2013; Allchin 2014; Sarukkai 2014; Fouad et al. 2015) highlight its impact on students' understanding of the scientific enterprise as a dynamic, fallible and negotiated community.

Nevertheless, this potential of HPS to humanise science and to challenge traditional views about scientists and scientific work has been recently questioned (Hodson 1999; Jegede and Aikenhead 1999; Krugly-Smolska 2013; Allchin 2014; Sarukkai 2014), with special attention to which type of HPS is being advocated. The current debates about gender and cultural diversity in science, such as the ones promoted by the US Department of Commerce (see http://www.esa.doc.gov/under-secretary-blog/education-promotes-racial-and-ethnic-equality-science-technology-engineering) and by the Royal Society in London (see https://royalsociety.org/topics-policy/diversity-in-science/) are not the only ones that should be brought into light. Historically, achievements and prizes in the scientific community also lack diversity. For instance, a quick search at the Nobel Prize webpage (see https://www.nobelprize.org/) reveals that prizes in scientific areas (physics, chemistry and physiology/medicine) were awarded to 558 men and to only 17 women between 1901 and 2016, and only 2% of all recipients of these prizes were scientists from non-Western countries, such as Pakistan, India and Morocco. Similarly, women only started to be accepted by the Royal Society in London in 1945 (Mason 1995), while Ardaseer Cursetjee (1808–1877) was one of the first non-European and non-American scientists to be elected as a fellow in 1841 (Kochhar 1993).

Therefore, the field of HPS, if focusing solely on these types of scientific, prize-winner achievements, is under the risk of promoting a non-diverse view about the scientific community. More than 20 years ago, Dennick (1992) and Hodson (1998) already discussed how school science materials, such as textbooks, often downplay or completely erase historical contributions to science and technology made by different cultures. More recently two large projects, one European (see http://hipstwiki.wikifoundry.com/) and one from the USA (see https://www.storybehindthescience.org/; Clough 2011), aimed at introducing HPS into science lessons, developing in total more than 50 "historical cases" (teaching materials and guidelines). Among these cases, only three included some kind of mention and/or discussion about contributions to the topic by non-European and non-American scientists or communities (namely: the history of cooling and refrigeration in Africa and India; Muslim Medieval science and the concepts of image and vision; Muslim Medieval science and their ideas about motion).

Sarukkai (2014) argues that the constant use of European scientists only from HPS in school science has the danger of propagating a historically unrealistic image of modern science as an exclusive European achievement. He argues, for instance, that the "explicit emphasis on the figures of Western Enlightenment" by HPS (Sarukkai 2014, p. 1696) can portray a specific image of science, scientific work and community that only foster a biased humanisation of science and scientists.

Hence, different authors (Hodson 1999; Krugly-Smolska 2013; Allchin 2014; Gurgel et al. 2014; Sarukkai 2014), informed by contemporary research from the fields of HOS and Post-colonial and Decolonial Studies of Science (Roberts 2009; Elshakry 2010; Fan 2012), defend the potential of HPS to foster a more historically and culturally accurate view of who scientists are and where scientific knowledge has come from. Besides promoting conceptual change and learning about NOS, and motivating students, HPS presents the possibility of challenging hundreds of years of preconceptions and biased views about scientific communities, essentially by showing that different types of cultures, people and societies (and also gender, race, ethnicity) are (and have been) connected with scientific work.

Hodson (1999), for instance, discusses how HPS can help to overcome some distorted views about NOS, such as the notion that science is an exclusively western and post-Renaissance practice, by using more examples of scientific work carried out by different cultures. He suggested some topics (such as medicine, astronomy and agriculture from Indian, Chinese, African and Arabic cultures) that could promote students' understanding that different communities around the world have their own traditions of production of knowledge about nature.

This type of approach, closely connected to ideas of cultural pluralism from the field of multicultural science education (MSE), usually tends to acknowledge that several societies and cultures other than the traditional European ones also developed their own scientific practices at different historical times (Pomeroy 1994; Krugly-Smolska 2013). This idea, however, is generally a target for critics (Nola and Irzık 2005; Matthews 2014b), who are suspicious of some extremely relativistic statements that either equalise all systems of knowledge (for instance, modern, indigenous, ecological), giving all of them the same epistemic status (including correctness), or that mainly consider them as different and disconnected from each other.

Another way of introducing a more diverse view of HPS into school science is through an intercultural and dynamic perspective about the development of modern science—an "intercultural model of HOS" (Pomeroy 1994; Sarukkai 2014; Gandolfi in press). Contrary to the previous model, which is often related to more traditional and relativistic views of MSE, this intercultural model is related to the field of "Global History of Science" (Roberts 2009; Elshakry 2010; Fan 2012), which is based on the argument that modern western science is in fact a product of exchanges and collaborations between different cultures, and of the circulation of diverse types of knowledge around the world, all enabled by historical and geographical contexts such as the trade in the Silk Road, and the European colonisation and imperialism (Gandolfi in press).

As argued by Fan (2012, p. 251), "[i]nstead of looking at science and technology as products in a particular nation or civilisation, the main focus of global history of science is on the transmission, exchange, and circulation of knowledge, skills, and material objects". Thus, according to Roberts (2009) and Elshakry (2010), the global history of science model offers a way out of the epistemological problems posed by extreme relativistic approaches towards HPS by avoiding a comparative/dichotomous approach (one that focuses on similarities and difference between systems of knowledge) and promoting instead an understanding of "western science", the one in the science curriculum, as a dynamic product of a several cultural and economical encounters and exchanges among different (western and non-western) communities.

According to Sarukkai (2014), this model (which he calls "multicultural origin of science") can bring a more diverse view of science to science lessons, challenging traditions in HPS that "led generations of students in non-Western societies to believe that their cultures have had no contribution to the science of the modern world" (Sarukkai 2014, p. 1696). Additionally, this global/intercultural approach can also foster the learning of NOS, another relevant aspect of school science, since it involves topics such as collaboration, negotiation and adaptation of scientific knowledge, exploitation of and power-struggle regarding natural resources, ethical, economical and political aspects of science, among many others (Gandolfi in press).

In sum, the possible benefits brought by HPS to science education reveal its potential to transform it into a more critical and open-ended form of learning and seeing the world of scientific development. The different ways in which this introduction can be done open up the space for science teachers to diversify their lessons not only in terms of goals for using HPS but also of which activities and historical cases will be employed. It would be naïve to think, however, that this introduction can be easily done by any teacher, at any level of education, especially when considering the pressures posed by large scale assessments, and the diversity of science curricula adopted around the world.

2.2 Bringing HPS to Science Lessons

According to Basu (1999), there are different arguments regarding the obstacles to the use of HPS in science education, but the most recurrent ones are related to practical issues. There are concerns, for instance, about how to develop instruments to assess the learning of both scientific and historical aspects, since evaluation is often part of the educational process (Henke and Höttecke 2015). Another problem is the introduction of HPS in science lessons through anachronistic and triumphant perspectives (Taylor and Hunt 2014): distorted approaches in which "history of science is viewed in light of current knowledge" and only its positive aspects are presented (Klassen and Froese-Klassen 2014, p. 1520).

These practical issues are connected to how to implement HPS in science lessons and, therefore, they could be overcome, to some extent, if careful work was done to stimulate and help teachers adopt different and innovative approaches. However, the obstacles for implementing new routines inside classrooms are numerous, as shown by different research (Höttecke and Silva 2011; Levrini 2014; Henke and Höttecke 2015). Twenty years ago, Monk and Osborne (1997) suggested, for instance, that after the launch of the English National Curriculum in 1989, several projects were developed, but few were successful in incorporating HPS into everyday science teaching.

In this context, some traditional conceptions about science teaching appear as barriers, such as the preference for content-driven activities and evaluations, and the notion that historical scientific ideas are outdated or wrong, not being the modern portrait of science (Henke and Höttecke 2015). Results from the European project previously mentioned in this article (History and Philosophy in science teaching (HIPST); hipstwiki n.d.) highlighted some general obstacles to the implementation of HPS in science lessons (pointedly in physics teaching): the culture of teaching science/physics; the lack of HPS materials available for teachers; teachers' skills, attitudes and beliefs; and institutional frameworks of science teaching—curriculum development (Höttecke and Silva 2011).

Therefore, the complexity of the educational systems, and institutional and teachers' defence mechanisms against changes appear to be the main challenges to the implementation of HPS activities in science teaching. Nevertheless, while researchers tend to agree that these issues are still present around the world, they also highlight some positive experiences using HPS to foster scientific literacy, and enhance interest about the scientific field (Höttecke and Silva 2011; Guerra et al. 2013; Besson 2014; Levrini 2014; Taylor and Hunt 2014; Henke and

Höttecke 2015). Thus, the apparent political interest in developing higher scientific literacy levels among the population seems to have been promoting a slow but progressive introduction of innovative approaches into science lessons, and HPS activities have been constantly receiving attention in this field. To this end, what do we know about the current use of HPS in science classrooms?

2.3 Current Use of HPS in Science Teaching and Learning

With a general agreement on the benefits and obstacles to the introduction of HPS into school science, research in this field has currently been paying attention to two main areas: the development of different strategies (such as materials, lesson plans and training programmes) to support teachers in the introduction of historical accounts into their lessons, and the investigation of whether and how teachers actually bring these accounts into their classrooms. For instance, in the recently published *International Handbook of Research in History, Philosophy and Science Teaching* (Matthews 2014a), more than 20 chapters were dedicated to discussions about different historical cases (such as the history of the pendulum motion, the development of the fields of relativity and quantum mechanics, the history of atomic models and of genetics and genomics, among many others) and their possible uses in the teaching of science at primary, secondary and post-secondary levels.

Of course, there are still many other types of studies in this field, as also shown by the numerous chapters in the aforementioned handbook related to theoretical studies about NOS, multiculturalism, science and religion, scientific literacy, among many others (Matthews 2014a). We cannot deny, however, that empirical studies about HPS and science education occupy a relevant position in the agenda of the field, as mentioned by Matthews (2014a, p. 8): "[s]ince Mach's time, educators have looked to history and philosophy in order to improve and make more interesting and engaging the classroom teaching of science and mathematics". In this case, it is important to understand how these historical accounts are being included in science teaching and learning; in other words, what is happening when HPS enters the science classrooms?

Some studies have been developed to investigate this, focusing mainly on how teachers bring (or not bring) these accounts to their lessons. Forato et al. (2015), for instance, while reporting their research on the didactic transposition of HPS at the high school level in Brazil, highlight teachers' difficulties in avoiding the simplifications and omissions of historical aspects during their lessons. That is, how much of history should be included? According to the authors (Forato et al. 2015, p. 2), by attempting to simplify history to students, teachers usually build a "naïve or faulty view concerning the scientific endeavour".

Similarly, Allchin (2004) and Höttecke and Silva (2011) discuss the importance of paying specific attention to the context behind the historical narrative. They argue that science textbooks and other materials traditionally employed by science teachers usually contain accounts of HPS only in an illustrative, decontextualised way, and can end up misleadingly informing teachers' practices regarding these historical narratives. Results from the HIPST project mentioned in the previous sections showed that, in Europe, history is often used as an anecdotal introduction to a specific topic or content (as a historical background) and is rarely seen in science textbooks in a different way (Höttecke and Silva 2011). Other classroom-based research (Forato et al. 2010; Gandolfi 2017) also showed how historical accounts, when employed in an anecdotal and romanticised fashion, can lead to misunderstandings about the nature of scientific work and of the scientific community (Allchin 2014).

While the aforementioned studies argued about the importance of avoiding oversimplifications of the historical narratives and criticised many science textbooks for the way they employ HPS (see also Dagher and Ford 2005, on biographies of scientists for children), few others have been recently paying attention to the impacts of these decontextualised/illustrative uses of HPS on students' views about the scientific community. Many studies are interested in evaluating the impacts on students of specific projects ("good practices towards HPS") elaborated to aid teachers in the process of bringing HPS to their lessons (e.g. Höttecke and Silva 2011; Fouad et al. 2015; Guerra et al. 2013), but very few investigate the relationship between students' views about the scientific community and HPS in cases where the science lessons are taught without the support of an external project (that is, without the aid of academic research and initiatives).

This article thus aims to fill this gap, trying to understand the impacts on students of the use (or non-use) of HPS by science teachers without any specific training in teaching with HPS—which unfortunately seems to still be the reality of the majority of these professionals around the world (Höttecke and Silva 2011). Since "the story implicitly is the message" (Allchin 2010, p. 1922), what is included in the historical narrative and how it is told to students during these science lessons can be closely connected to images and ideas they will form about the scientific community, as already showed by similar research about teaching about NOS implicitly or explicitly (McComas 2008; Fouad et al. 2015).

This article addresses the impacts of the HPS introduced by these teachers' practices, and also by science curricula and teaching materials on students' views about scientific communities. Therefore, besides investigating the ways in which HPS has been introduced by teachers into their regular lessons (the way the story is told), this study is also interested in if and how the selection of historical cases (the origins of the story) is relevant to how the scientific community will be portrayed.

As showed by recent reviews (Lee and Buxton 2010; Krugly-Smolska 2013; Allchin 2014; Sarukkai 2014), almost no attention has been paid in the field of HPS to discussions about the type of historical cases that have been employed to introduce HPS into science lessons. As previously discussed, in most cases, "science" is understood solely as "western science" and the introduction of HPS has been made almost exclusively by using traditional examples from historical and contemporary cases focusing only on western science, such as geocentricism in sixteenth century in Europe and the atomic models. In the case of the already mentioned "International Handbook of Research in History, Philosophy and Science Teaching" (Matthews 2014a), for instance, among the more than 20 chapters dedicated to examples of historical cases, only two explicitly mention ideas and stories from non-European countries (and non-modern USA).

Thus, this research, aligning itself more specifically with those who advocate for HPS as a means to show science as an intercultural endeavour, asks the following exploratory question: "In which ways are students aware of the history of scientific development carried out by different people in different places of the world? What can be influencing and shaping their awareness?" In the following sections, a small-scale study about students and teachers not involved in any specific project dedicated to the introduction of HPS is described, and its main findings are further discussed in relation to their implications for school science, and for the fields of HPS, science education and public perception of science.

3 Method

This study aimed at depicting students' knowledge about HOS, with special attention to what they know about science being done by people and communities from different parts of the world and to how this knowledge is constructed through their engagement with school science. In order to investigate this topic, an exploratory study was carried out at two secondary schools in London, UK. The research design involved an initial exploration of students' knowledge about HOS through an open-ended survey, followed by interviews and classroom observations. The choice of an exploratory approach was related to the aim of having an initial general understanding of students' knowledge about HOS, and then to subsequently gather more in-depth information about why and how these views are built.

The methods of data generation (survey, interview and observations) and analysis employed were qualitative, trying to describe and find patterns in what participating students knew about HOS, and then to ascribe meanings and reasons for these patterns. This approach was informed by Erickson's (2012) discussion about the importance of using different sources of data when working with qualitative studies in science education. More specifically, it was the aim of this study to not only "ask" (e.g. written questions and interviews) students what they know about HOS but also to "look" (e.g. observations) at their classroom realities and try to compose a more complete picture of their experiences of school science (Erickson 2012, p. 1455).

Similar approaches towards investigating students' views and the reasons behind them have been widely employed in the field of science education, such as in research about understandings of NOS. Different investigations (e.g. Abd-El-Khalick and Lederman 2000; Rudge et al. 2014; Fouad et al. 2015) about students' views on NOS have adopted both written questionnaires/follow-up interviews with students and classroom-based observations. That was the case, for instance, in Abd-El-Khalick and Lederman's (2000) study of the influences of HOS courses on college students' and pre-service science teachers' conceptions of NOS, in which "an open-ended questionnaire in conjunction with follow-up, semi-structured interviews was used to assess participants' conceptions of NOS" (Abd-El-Khalick and Lederman 2000, p. 1069), also involving the analysis of course syllabi and observations of lessons.

The choice of following this research tradition from the field of NOS in this investigation resulted in a research design that included a survey about HOS to gather students' knowledge about the topic, and follow-up interviews with them and their science teachers, coupled with participant observations of some of their science lessons to inform a study of reasons behind the results from the survey.

3.1 Settings

This investigation was carried out at two secondary state schools in London, UK. This level of schooling was chosen because of its historical connection with HOS during the 1980s and 1990s in England, which could have created a tradition of using HOS in English secondary schools (Taylor and Hunt 2014). The schools were specifically approached due to their long-term relationship with the research institution, and also due to their diverse nature when compared with each other. Carrying out this study at two schools enabled the diversification of the sample of participant students (and, consequently, of science lessons, curricular approaches, science teachers), allowing for an analysis of different aspects related to the use of HOS.

School A is an outstanding, non-faith and mixed-sex school, specialising in STEM subjects; school B is a catholic and single-sex school for girls also with an outstanding evaluation by OFSTED.[1] Both schools are attended by a highly multicultural group, with at least 50% of the students having English as a second language. Schools A and B have, respectively, around 860 and 900 students enrolled in their curriculum cycles known as Key Stage 3 (KS3)[2] and Key Stage 4 (KS4).[3] In school A, the KS3 cycle comprises years 7 (11–12-year olds) and 8 (12–13-year olds) and KS4 comprises years 9 (13–14-year olds), 10 (14–15-year olds) and 11 (15–16-year olds). Meanwhile, in school B, years 7, 8 and 9 are part of KS3, and only years 10 and 11 follow the KS4 curriculum.

3.2 Sample

The sampling process involved two criteria (convenience sampling): year group of the students, and science teachers' willingness to participate in the study. Years 8, 9 and 10 (ages 12–15) were chosen as potential participants in order to ensure a mix between two different cycles (KS3 and KS4). Other years that are also part of these cycles were excluded due to students' young age (year 7 students, who are still new to the secondary school setting and could feel overwhelmed by engaging with the extra work involved in this research) or to concerns about official assessments (year 11 students, who were at their last year of secondary school and largely focused on official exams).

Among all year 8, 9 and 10 classrooms at the schools A and B, a total of nine were chosen as participants to this study. This selection was based on science teachers' interest in participating in the investigation, an important criterion since it also involved classroom-based observations and follow-up interviews with these teachers. The final group consisted of 200 students (58.5% girls, 41.5% boys) from years 8, 9 and 10 from nine different classrooms. The distribution of participant students and their demographic information are displayed by Table 1.

Additionally, five science teachers who were responsible for the science lessons at these nine classrooms were also interviewed and observed, as already described in a previous work generated by this study (Gandolfi 2017). Demographic information about the participant teachers are displayed by Table 2.

3.3 Data Collection

The initial source of data for this investigation consisted of an open-ended survey about HOS given to all participating students, which aimed at gathering an overview of their knowledge about people and places involved in science. The survey items were designed to elicit main topics and trends related to the proposed research question, and also to inform a more detailed discussion about its results during the follow-up interviews. Since the goal of this instrument was to elicit students' own ideas about people involved in science, a decision was made to give

[1] Office for Standards in Education, Children's Services and Skills (OFSTED) is an office in the English government responsible for inspecting and regulating services provided by educational institutions for learners of all ages.
[2] Key Stage 3 (KS3) is a curriculum cycle in England that usually comprises the first 2 (years 7 and 8) or 3 years (years 7, 8 and 9) after primary school, with students aged 11–14.
[3] Key Stage 4 (KS4) is a curriculum cycle that usually comprises the last 2 (years 10 and 11) or 3 years (years 9, 10 and 11) of compulsory study in England, with students aged 14–16.

Table 1 Participant students who answered the research survey

School	Classrooms: Year	Classrooms: Ability group[a]	No. of students	Gender	Ethnicity		Total
A	8	Mixed	23	Female = 52; male = 83	Asian = 40	White East European = 38	135
	9	Set 1	26		Black African = 18	Middle Eastern = 12	
		Set 2	24		Mixed = 11	White British = 7	
		Set 3	16		Black Caribbean = 4	East Asian = 2	
	10	Set 1	25		White African = 1	Chinese = 1	
		Set 2	21		Other = 1		
B	8	Set 2	25	Female = 65; male = 0	Black African = 29	Black Caribbean = 11	65
					Mixed = 6	Asian = 6	
	9	Set 3	17		White East European = 5	Middle Eastern = 3	
	10	Set 1	23		White British = 3	East Asian = 1	
					Other = 1		
Total	9		200	Female = 117; male = 83	Black African = 47	Asian = 46	200
					White East European = 43	Mixed = 17	
					Black Caribbean = 15	Middle Eastern = 15	
					White British = 10	East Asian = 3	
					White African = 1	Chinese = 1	
					Other = 2		

[a] Ability groups (sets 1, 2 and 3—from high to low abilities) are classrooms where students with similar abilities (assessed by their schools) are placed together, in opposition to mixed groups, where students with different abilities are placed together

it the form of an open-ended questionnaire rather than using forced-choice items, which would mean providing them with specific choices of names of people and places, diminishing their own contributions to their responses (Driver et al. 1996).

The questionnaire used in the survey was an adapted version of one developed by Gurgel et al. (2014) in their study of Brazilian students' views on who participates in scientific research. Their original open-ended questionnaire consisted of a total of four questions:

(a) During your lessons you may have heard of many scientists who contributed to the development of science. Cite some of their names;
(b) Do you know of any Brazilian scientist who made important contributions? Who?;
(c) Cite the countries that most contribute to the development of science;

Table 2 Participant teachers

School	Teacher[a]	Gender	Ethnicity	Years of teaching
A	B	Male	Asian	10
	F	Male	White British	8
	P	Female	Asian	15
B	A	Female	Black African	8
	K	Female	Black Caribbean	15

[a] Teachers' names have been changed to ensure anonymity

(d) Do you believe that Brazil contributes to the scientific world? Why? (Gurgel et al. 2014, p. 369)

Considering that their original questionnaire was intended to also investigate students' views on Brazilian participation in science, some changes were made in order to adapt it to a non-country-specific inquiry, especially in relation to questions (b) and (d) displayed above. Additional questions were also included, as further discussed below, to get a deeper understanding of their knowledge about these scientists and countries. The final questionnaire, composed of seven items, included the following questions:

Q1. During your lessons you may have heard of many scientists who contributed to the development of science. Please, name some of them.
Q2. Do you know where these scientists were born?
Q3. Do you know what these scientists' studied, developed or did in science?
Q4. Which countries do most to contribute to the development of science nowadays?
Q5. Which countries/civilisations did most to contribute to the development of science in the past?
Q6. Besides those countries you named in questions 4 and 5, have you ever heard about scientific work developed in any other different place/country/civilisation or maybe in a community with the same ethnic origin that you are?
Q7. If you said YES to the previous question, where did you hear about these scientists and contributions?

Since there was no information in the article (Gurgel et al. 2014) about the process of testing and validating their original questionnaire, and due to the modifications introduced by this investigation to it, different rounds of pilot studies of the adapted questionnaire were carried out. The first was done by giving this questionnaire to two senior researchers in science education, who were also aware of the rationale behind this investigation, in order to check for any inconsistencies both in the content of the questions and in the phrasing used.

Secondly, four rounds of pilot studies were carried out with groups of four to five students from years 8, 9 and 10 at one of the participant schools (school A). These pilot studies involved students working on the questionnaire and participating in a subsequent group discussion about any language misunderstandings (confusing sentences and unknown vocabulary) and general doubts and confusions about the questions being asked. Small modifications and clarifications in terms of language were then incorporated into the instrument before a final large pilot with a whole classroom (23 students) from a year 8 group at school A (not participating in the main study). Right after the final pilot, a final discussion with all the students of that group was carried out to check for any other possible language misunderstandings, doubts or confusions about the questions. The final version of this instrument, after these different stages of content and language validation, is the one composed of seven questions presented above.

This instrument was then administered to students during their science lessons, and it took an average of 30 min to be completed (including initial demographic questions). Students were asked to answer it individually and without consultation with any external source of information. Students were given the option not to participate in this survey, and since it was applied in the absence of their teachers, with only the researcher in the room, these teachers were not aware of who actually responded or not to this instrument.[4]

Question 1 (Q1) sought to gather information about students' recollection of different scientists, identifying "to whom the students attributed the responsibility or, more generally, the role in developing scientific knowledge" (Gurgel et al. 2014, p. 358). Students were asked to write down all the names they knew, and not just simply one or two, in order to guarantee the minimal validity of the information gathered through this survey, that is, to avoid the option of writing 'only a few names' and not all they knew. It is important to remark, however, that this question was not employed as a way of assessing the number of scientists cited (a checklist of scientists), but to open up space and context (by mentioning scientists they had heard about) to the following questions (Q2 and Q3), through which the "quality"/depth (and not the "quantity") of their knowledge about scientists was investigated.

Therefore, this article does not advocate that students should be motivated to memorise scientists' names in a "the more the better" fashion, or even that HOS should be introduced into science lessons through a list of names. Instead, this study was interested in understanding what students already knew about HOS, in the form of names of scientists (a traditional approach towards HOS seen in many science textbooks) or in the form of thinking about countries/civilisations/contexts that were important to science (a contextualised approach towards HOS assessed through Q4, Q5, Q6 and Q7). What students really knew about these scientists (their work and who they were) was more important to this research than how many names they were able to remember. It was expected, with these first three questions, to evaluate if knowledge about the names of scientists also implies knowledge about their lives and works, or if students' recollection of scientists were superficial and decontextualised. Nevertheless, it has to be acknowledge here that, by asking these students to name scientists, the instrument could be conveying a more traditional view of HOS, with the assumption that scientific practices are mainly individualised, ahistorical and cognitive (a product of the individual work of "geniuses"), rather than collaborative, historical and socio-cultural.

In order to partially avoid this problem and to include those students who tend to remember stories and contexts more easily than names, other questions in the instrument (Q4, Q5, Q6 and Q7) aimed at eliciting a more socio-cultural image of science. Thus, by asking about different countries/civilisations' contributions to science, the goal was to investigate if and how these students think of science as a contextualised historical activity. Furthermore, as argued by Gurgel et al. (2014), this type of question can help to evaluate students' ideas about the contexts (countries/civilisations) where science can develop, including different social aspects and policies adopted.

Q1, Q4, Q5 and Q6 were also introduced to explore students' immediate view of who usually participates in science. In other words, these questions also aimed at revealing their implicit view of who the important players in science are, both in terms of types of countries (societies) and of people (gender, ethnicity) involved with scientific research.

The analysis of students' answers revealed the main views about important people and places in HOS, which were then further investigated through follow-up interviews. This choice

[4] All the ethical approvals related to the methods of data generation and analysis were obtained prior to the realisation of this study, both at the school level (including students' and parental consents) and at the research institution level.

of talking to students about their answers to the questionnaire was based on different research in the field of science education about the uses of surveys to gather students' and teachers' views on specific topics, such as NOS (e.g. Driver et al. 1996; Lederman et al. 2002; Lederman 2007; Deng et al. 2011). According to Lederman et al. (2002), follow-up interviews can not only help ensure the face validity of the instrument items used in surveys, but also to assess "the respondents' reasons for adopting those positions as well" (Lederman et al. 2002, p. 504).

These follow-up interviews were carried out with a sample of the students in the form of nine focus groups (one for each participating class). Students were given the choice, in the absence of their teachers, to not participate in these follow-up interviews if they did not wish to, but all those who were selected agreed to engage with this stage of the research. These nine focus groups (each one comprising four to six students, totalling 20% of the participants) were broadly representative of the classroom community, being formed by different students in terms of their abilities, gender (when possible), ethnicity,[5] and also interest in their regular science lessons and diversity of their answers to the survey. These interviews were of semi-structured in nature,[6] consisting of questions intended to cross-check their answers to the survey and to gather their own perceptions for the reasons behind these answers.

In addition, results from the survey and follow-up interviews were also anonymously discussed with their science teachers during semi-structured interviews,[7] which also comprised talks about HOS and school science practices and curriculum. One of the main aims of these interviews was to triangulate students' views about their science lessons and curricula with their teachers' own perceptions of school science, their practices and the curriculum. Interviewing these teachers enabled the construction of a larger picture regarding how HOS had been introduced in school, including the reasons behind their practices and their perceptions about their students' views on the topic.

All the information gathered from the survey and interviews was also complemented by the observation of approximately 50 lessons during the same school year at the participating classrooms and described in a previous work (Gandolfi 2017). These observations, among other goals, aimed at understanding if and how science teachers integrate HOS into their science lessons, which historical and/or contemporary cases they choose, how much time they dedicate to teaching these examples, why they employ these cases during the lesson (for instance, to talk about NOS or to talk about the life of individual scientists) and how students engage with them in these situations.

The choice of complementing the other methods employed in this study with classroom-based observations is connected to what Erickson (2012) called "looking" in educational research, that is, investigating the realities of the classrooms where participating students and teachers are immersed. Taber (2013, p. 98) argues that in order to explore, for instance, students' ideas about a specific topic, it is important not only to ask a range of questions, but also to look for other types of data sources that could be possibly related to these answers, since "the more 'degrees of freedom' in what is being explored in research, the more 'slices of data' are needed to build an authentic representation".

[5] See Table 3 for demographic comparison between the participant classrooms and their representatives in the focus groups.
[6] See Appendix 2 for interview protocol for students.
[7] See Appendix 3 for interview protocol for teachers.

In order to maximise the diversity of data produced by these observations, all participating teachers were observed for during at least six lessons and during teaching at least two different topics in chemistry, biology and/or physics (for instance, drugs and alcohol, stem cells, energy changes, space/universe, magnetism). Data were collated through research field-notes and an audio-recording device placed with the science teacher during the lesson.

In sum, students' answers to the survey were triangulated with in-depth, follow-up interviews with them and their teachers, and were also related to observations of some of their science lessons, contributing to an exploratory study of classrooms' realities in relation to HOS, teachers' and students' perceptions about these realities and their impact on students' views about the contribution of different people and places to science.

3.4 Data Analysis

Answers to the survey were tabulated and counted in terms of scientists cited (Q1), knowledge about their origins (Q2) and work (Q3), countries with important contributions to science nowadays (Q4) and in the past (Q5), and other answers about countries (Q6 and Q7). Results from Q1, Q2 and Q3 were plotted in one column graph per school in order to display differences between knowing a scientist (Q1), knowing her origins (Q2) and knowing about her work (Q3). Column graphs were chosen to display the contrasts between these three answers for each scientist mentioned (see Figs. 1 and 2), and also to enable the visualisation of patterns when comparing different scientists. Meanwhile, results from Q4 and Q5 were plotted in two separate pie charts per school ("countries in science nowadays" and "countries in science in the past"; see Figs. 3 and 4) to show the proportion of citations (which countries received more and less mentions). On the other hand, Q6 and Q7, having received very few answers, were only tabulated and separately analysed.

The analysis of the survey results focused on two main patterns found in students' answers: specific knowledge about the scientists they were citing (origins and work) and who the scientists and countries being cited were. These main trends were then investigated during the semi-structured interviews and through a qualitative analysis of these conversations and triangulation with their initial responses. The field notes from teachers' lessons and the transcriptions from their interviews were also qualitatively analysed under a descriptive-

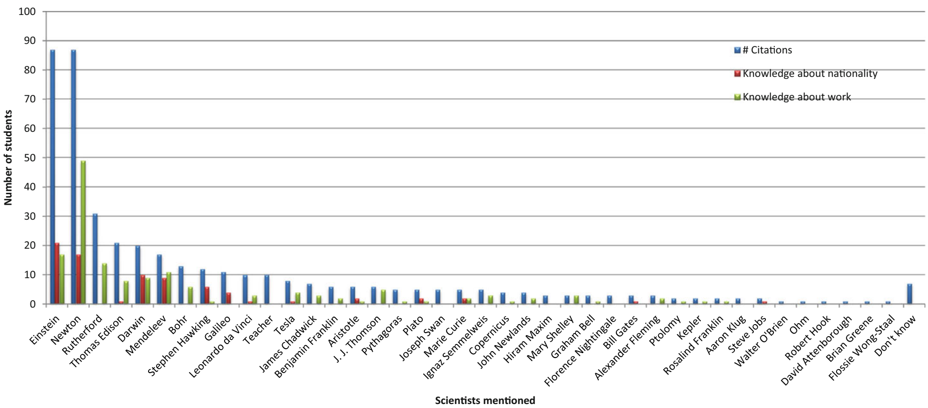

Fig. 1 Scientists mentioned by students from school A (Q1 + Q2 + Q3) ($n = 135$)

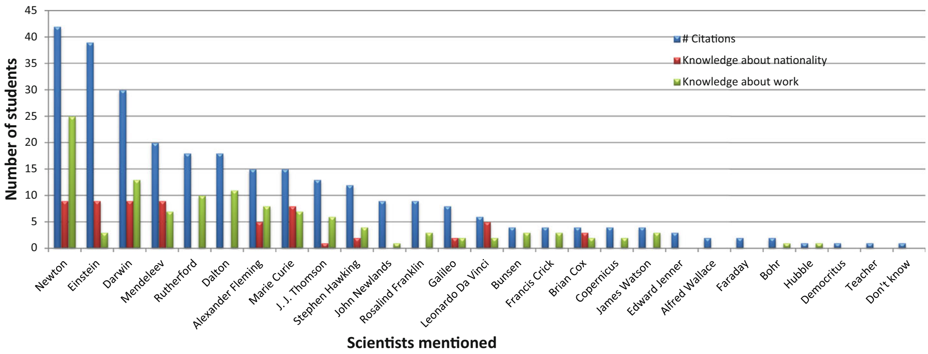

Fig. 2 Scientists mentioned by students from school B (Q1 + Q2 + Q3) ($n = 65$)

interpretive approach (Dey 1993; Charmaz 2014) in terms of their specific use of HOS, talks about scientists and countries in Science and views about their students' answers to the survey.

The choice of a descriptive-interpretive approach to guide the connections between survey, interviews and observations is related to the aim of first describing students' views about the contribution of different people and places to science, and then understanding/interpreting the possible reasons behind these views: "[this method is] orientated to providing thorough descriptions and interpretations of social phenomena, including its meanings to those who experience it" (Dey 1993, p. 3). By using a descriptive-interpretive approach, neither specific results nor pre-conceived categories of analysis were expected and/or employed, and students' ideas (both in the survey and in the interviews) were constantly described as they were and then interpreted in connection with the particularities of their settings, that is, the curricular approaches adopted by their schools and their teachers' classroom practices and views regarding HOS and science education.

Furthermore, according to Taber (2000, p. 483), the use of this descriptive-interpretive approach in science education studies also allows the researchers, especially when investigating specific groups of students, teachers and/or classrooms, to "bridge the divide between authentic accounts of the individual case (rich in detail, but only able to offer 'insight into' or 'resonances with' other cases), and generalised accounts which offer meaningful advice for curriculum planners and classroom teachers". In other words, the patterns generated by specific qualitative studies (like the one being described in this article) and their subsequent analysis for meanings and connections between different data sources can also promote an expansion of these findings to larger contexts through the understanding of the causes and reasons behind these patterns.

For instance, in their research on the effectiveness in learning about NOS through a historical controversy, García-Carmona and Acevedo-Díaz (2017) adopted this descriptive-interpretive method of analysis to understand (by describing and looking for reasons) the changes in pre-service science teachers' views about NOS during a specific course. The use of this approach allowed the researchers to offer different implications for other teacher training programmes about NOS that were grounded on their own findings. Other studies in the field of science education (e.g. Guisasola et al. 2006; Karelina and Etkina 2007) also adopted this descriptive-interpretive analytical method, with similar results in terms of understanding localised empirical results within broader educational scholarship.

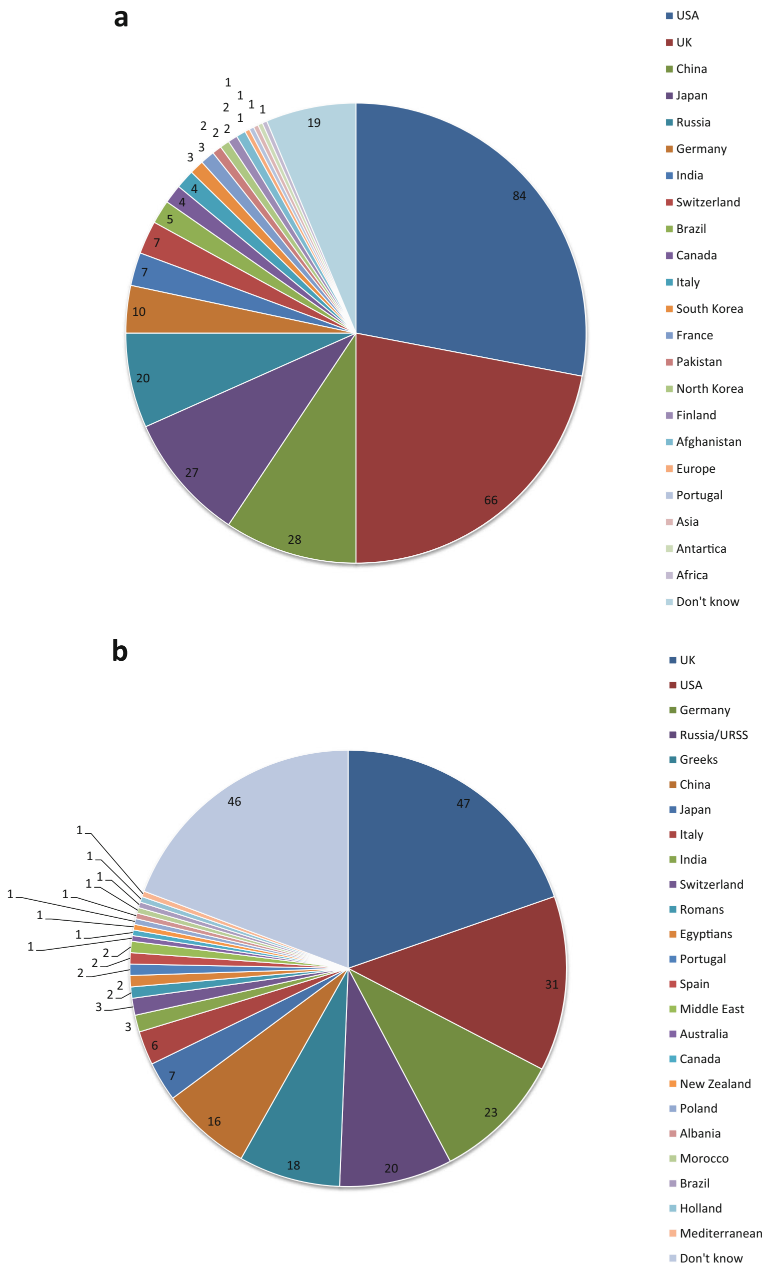

Fig. 3 Countries mentioned by students from school A; **a** countries nowadays (Q4) and **b** countries in the past (Q5) ($n = 135$)

4 Findings and Discussions

This section presents the main findings from the survey, follow-up interviews with participating students and teachers and insights from the observations of science lessons and aims at

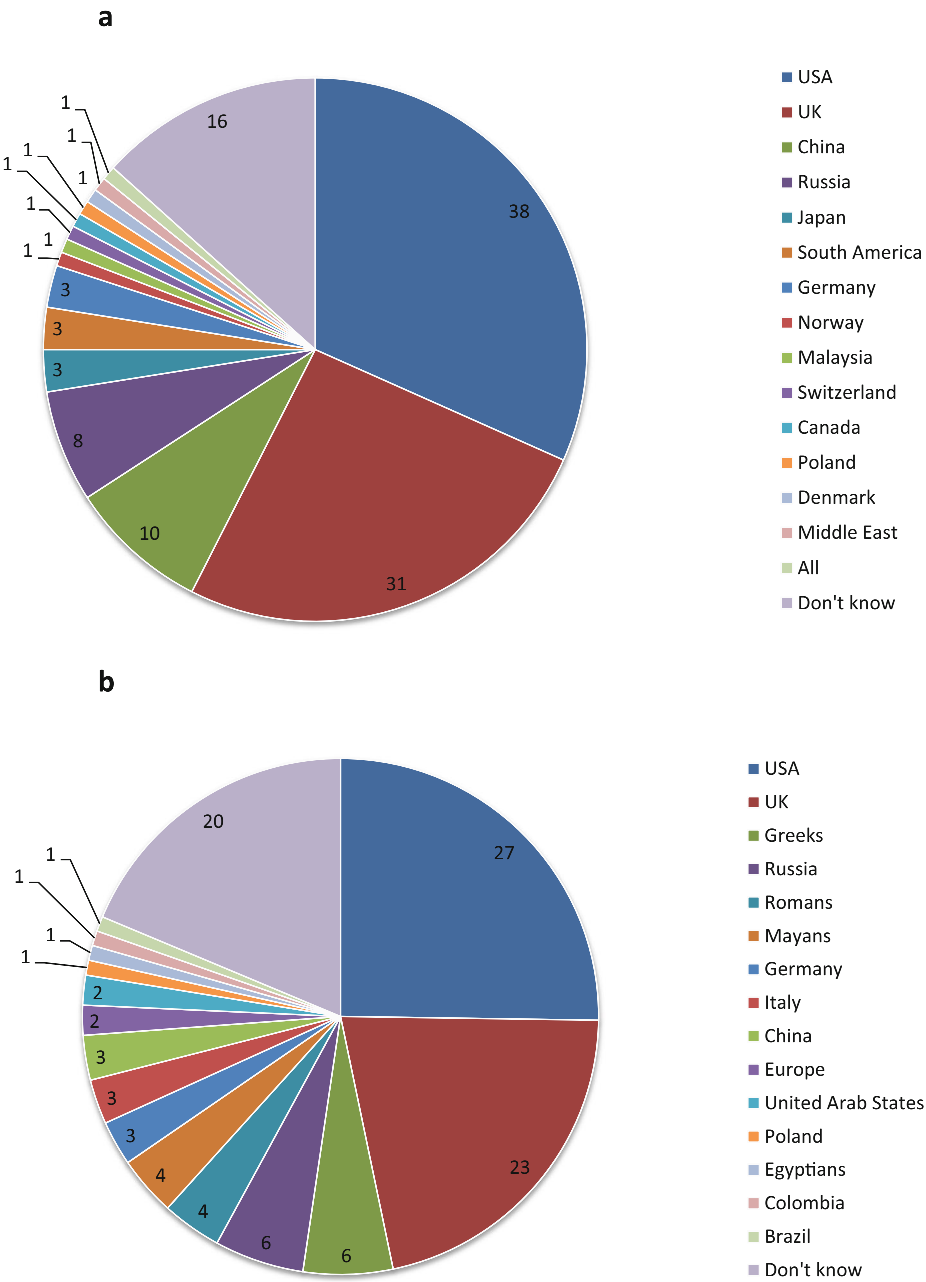

Fig. 4 Countries mentioned by students from school B; **a** countries nowadays (Q4) and **b** countries in the past (Q5) ($n = 65$)

addressing the following research questions: "In which ways are students aware of the history of scientific development carried out by different people in different places of the world? What can be influencing and shaping their awareness?"

4.1 Students' Knowledge about Scientists and Countries in Science

Figures 1 and 2 (respectively, schools A and B) display students' answers to Q1, Q2 and Q3. In both schools, the majority of students (95% at A and 98% at B) cited at least one scientist when asked about specific names.

In school A, Einstein, Newton and Rutherford received the largest number of mentions (64, 64 and 23%, respectively). Most of the 135 students at this school, however, were not able to name these scientists' contributions to science, that is their field of work: among the students who knew some scientists' names, most of them only knew that and did not possess any specific knowledge about who those scientists were/are as individuals (also seen in their responses to the question about nationality) and as professionals.

Meanwhile, in school B, Newton, Einstein and Darwin appeared on the top of students' list (65, 60 and 46%, respectively), and, in comparison with the results of school A, one can observe that a proportionally larger number of students was able to provide more information about these scientists, mainly in terms of their contributions to science. There was still, however, a large difference between citing the names of scientists (Q1) and actually knowing about their origins (Q2) and work (Q3).

In both schools, there is a clear influence of the subject being studied by these students immediately previous to or at the time of this research. For instance, one group at school A (year 8) cited a large number of examples connected to the topic of the solar system (such as Copernicus, Plato and Aristotle), which had been taught by their science teacher 2 weeks before the study, in contrast with other participants who generally did not mention these names. Similarly, at school B, Alexander Fleming was the second most mentioned by students in year 9, who had learned about him some weeks before the study; meanwhile, he was less remembered by students in the other groups. It is important to remark, however, that the participants in years 9 and 10 of school A and in year 10 of school B had previously learned these topics, which means that they must have heard about Copernicus, Plato, Aristotle (school A) and Fleming (school B) before. Furthermore, results show that having recently heard about these scientists did not necessarily lead to more connections between them and their work.

Figures 3 and 4 (respectively, schools A and B) display students' answers to Q4 and Q5. When specifically asked about countries' contributions to contemporary science, the number of responses was high at both schools (86 and 75% of responses at schools A and B, respectively). It is worth noting that these answers were generally related to countries that could be easily connected to any dominant position in the world, not only in science, such as the USA (62% of students at school A and 58% at school B) and the UK (49% of students at school A and 48% at school B).

The question related to countries/civilisations in science in the past received the lowest number of responses: 34% and 31% did not know how to answer it at school A and at school B, respectively. Among those cited by the students are: UK (35% at both A and B), USA (23% at A and 42% at B), Germany (17% at school A), Russia/USSR (15% at A and 9% at B) and Greece (13% and 9% at A and B, respectively).

It is important to remark that this part of the instrument was divided in several items in order to push students into more diverse answers, such as Q6. As a result, 30 students (15% overall) elaborated on their original answers about countries in science, but they mostly cited other western societies (such as France, Canada or Switzerland) that had little to do with their own cultural background or any underrepresented group. Among those who talked about science being done by communities closer to their cultural background,[8] there were an African boy who cited the Egyptians; a Lithuanian girl who talked about going to Lithuanian science webpages to search about scientific work being done there; a Chinese boy who talked about China's work on solar power; a girl with Iraqi origins who learned about Persians' and Arabs' historical contributions to science from her family; and a boy with Iraqi background who read a book about the historical works carried out in the country on the circulatory system and heart surgery.

The analysis of these results reveals relevant trends regarding students' knowledge about scientists and countries in science. First, there seems to be a disconnection between knowing the name of scientists and actually knowing about their work and lives. More specifically, whereas the majority of students were able to cite at least one scientist, they were generally unaware of these scientists' origins and/or contributions to science. This contrast was further explored during the interviews with students and their teachers, and also through the results from observations of their science lessons. These findings, including participants' own reflections about this scenario, are presented in Sect. 4.2.

Another trend arising from these initial results is related to which scientists and countries are deemed as relevant to science: a qualitative analysis of these names hints at the lack of knowledge about scientists from different backgrounds (race, ethnicity and gender) and about different countries' contributions to Science. These initial results point out to the problem with representativeness in historical and contemporary accounts about the scientific world, which was also investigated during the interviews and classroom observations and will be discussed in Sect. 4.3.

4.2 Knowing Scientists Versus Knowing about Scientists

Students' answers about scientists, their origins and work revealed that most of them were able to name people involved with science, without actually knowing much about these people and their contributions to scientific research. This result raises a question of how young people have learned about the scientists' stories through school science, and also through mass media. Even though it should be recognised that asking students to name scientists can influence the type of recollections they will have to make (in terms of images of these scientists), there is a memory-based and superficial status of students' knowledge, which can be at least partially explained by an illustrative approach towards HOS and accounts of contemporary science (Allchin 2004; Höttecke and Silva 2011; Gandolfi 2017).

An illustrative approach towards HOS can be understood as a superficial mention of a scientist merely as a representative of the topic being taught, without any further discussion about his/her work and life, or of the social and historical contexts of this work. In the school scenario, this can be exemplified by citing Newton as the discoverer of gravity or Dalton as the one responsible for one atomic model when teaching these topics, as seen during some of the observed lessons. In the case of mass media (internet, movies, cartoons and TV programmes), this approach usually appears in anecdotal and stereotypical representations of scientists, with no further discussions about their actual work, histories and contexts (Christidou 2011).

[8] The relationship between students' answers to Q6 and their cultural background was established through a self-identification process since at the beginning of this survey students were asked to self-identify their ethnicity and gender.

The traditional image of Albert Einstein and his association with the $E = \mathrm{m\,c}^2$ equation is an example of the power that mass media has in circulating names and images of scientists in a decontextualised way (Gurgel et al. 2014). This situation can help explain why Einstein (and also Stephen Hawking) was cited by the majority of students at both schools (64 and 60% overall at schools A and B, respectively), similar to results obtained by Gurgel et al. (2014), even though his theories (and Hawking's) are not discussed in secondary school science in England. Furthermore, the fact that only 16% of these students knew about his contributions to science highlights the impact of illustrative accounts about scientists on students' actual knowledge about their work.

During the focus groups with these students, it became clear that they knew about Einstein and Hawking mainly from the mass media, such as TV shows and cartoons, Internet videos, documentaries, and movies. Students from all nine investigated classrooms stated that they had learned about these scientists outside school, and that they were also part of the "pop culture" nowadays: "everybody knows who he [Einstein] is, because he was the smartest guy in the world".[9] Furthermore, among the 38 students interviewed, only eight of them remembered Einstein's or Hawking's works, confirming the results obtained with the survey regarding the disconnection between knowing these scientists and actually knowing about their contributions to science. When asked why this was the case, students commented that most of these mass media sources usually concentrate their discussions on biographical information, such as Einstein not being good in mathematics, not liking school or having dyslexia.

In the case of the other scientists cited, the majority of the students interviewed stated that the main source of their knowledge about them were their science lessons, highlighting the relevance of classroom practices on what students know about scientists.

During the lessons observed, HOS was mainly employed by the teachers under an illustrative approach, that is, by introducing the names of some scientists historically related to the topic being taught, but without any contextualised/in-depth discussion of their actual work on the topic (Gandolfi 2017). Teacher F at school A, for instance, mentioned several Greek figures (such as Plato, Aristotle, Ptolemy etc) in a lesson on the geocentric and heliocentric models (year 8), but only carried out a contextualised discussion when talking about Galileo's works on the topic (mentioning his trial and his dealings with other scientists at the time), paying no attention to these other scientists/thinkers' contexts and lives. Similarly, during a lesson on radioactivity (year 9), teacher K at school B cited Ernest Rutherford as the discoverer of the alpha, beta and gamma rays, but did not discuss this process of discovery (or any other relevant context to his work), nor who this scientist was.

By having at least heard a scientist's name and work during a science lesson (e.g. Rutherford and radioactivity), students should be able to answer the survey question about one's contributions to science without any problem; the lack of context and life story should only then impact their answers about this scientist's origins. Nevertheless, it can be argued that it is exactly this lack of in-depth/contextual analysis of a scientist's work that hinders students' knowledge about her contributions to science, as evidenced by the already mentioned cases of older students not remembering examples they had learned in previous years, both at schools A and B. In other words, without the connection between a scientist's name and the context of her scientific work, students could hardly build any kind of long-term association between names and achievements, thus only remembering scientific concepts and scientists separately, not associating both of them as part of scientific development.

[9] Year 9—set 2—school A

Both teachers and students agreed, during the follow-up interviews, that little time is spent in science lessons in studying and understanding these scientists' contexts and works, with more emphasis given on connecting names to theories, ideas and experiments. Different students explained why they did not remember what these scientists did or where they came from:

> Student 1[10]: "It's like *briefly mentioned*, they don't go into like details, they just tell us what the person did and who the person is. *They don't go into detail about like what they actually researched*."
> Student 2[11]: "[...] And also in the lesson sir *doesn't talk about in detail*, he just talks about their names."
> Student 3[12]: "*We only know their names, we've never learned about what they did or where they came from*. [...] Yeah, we just hear that he [Newton] was hit in the head with an apple and that's it." (emphases added)

There were, however, situations where teachers adopted a contextualised/in-depth approach towards HOS.[13] For instance, during the same lesson on radioactivity at school B, teacher K also talked about Marie Curie's contributions to the topic and discussed her life and work with her students, with the help of a video narrating her personal and professional life. This video helped the teacher discuss her life history and main achievements as a researcher and the relevance of her research to society at the time. Interestingly, students from both schools who cited Marie Curie as an example of a scientist (Q1) had a very good knowledge about her work (Q2) and origins (Q3) in comparison with other cited scientists. This can be related to the special place that Marie Curie seems to occupy in school science (especially as one of the few female role models in science), granting more time to discussions about her life and work than in the case of other scientists.

Therefore, the little amount of time dedicated to these scientists' life and work in school science[14] (an illustrative approach) can result in the disconnection between knowing them and knowing about them. Furthermore, the majority of the interviewed students remembered situations when their teachers had had these more contextualised/in-depth conversations about scientists and their work with them, recollecting specific lessons and using them as counter-examples when trying to explain that teachers do not adopt this approach very often.

The choice between an illustrative or contextualised/in-depth approach can also explain, at least partially, the differences found in Q2 and Q3 when comparing schools A and B. While students from both schools presented a generally disconnected knowledge about scientists and their works and lives, those from school B did better in Q2 and Q3 than those from school A. Based on the lessons observed, this can be related to a greater dedication of teachers at school B to a more contextualised discussion about HOS than teachers at school A. In other words, teachers at school B tended to use this approach when introducing a historical case (as seen by teacher's K lesson on Marie Curie) more than teachers at school A, where only teacher F was seen doing something similar in some of his lessons (as seen with Galileo's trial).

In addition, during the interviews, the teachers from school A stated that they do not address aspects of HOS and/or names of specific scientists very often in their lessons. And,

[10] Year 9—set 2—school A
[11] Year 8—mixed—school A
[12] Year 9—set 1—school A
[13] It is important to remark that the researcher's presence in their lessons could have influenced their choice for this approach, since all participant teachers were aware of the aims of this research. They were, however, constantly assured that they should plan their lessons as usual when the researcher was around and that she wanted to observe what they usually do when teaching those specific topics.
[14] And also in other school subjects and their respective practitioners, such as geography (and geographers), mathematics (and mathematicians), history (and historians) etc.

when they do it, it is usually under a more illustrative approach to only quickly connect the "name of the scientist" with the scientific concept they are teaching, because some exams can directly ask students those questions (about Darwin, Ignaz Semmelweis and Mendeleev, for instance). In this scenario, these teachers made it very clear during the interviews that, in the case of KS4 groups, they only mention scientists that are officially part of science specifications, that is, names that can be found in the exams:

> Researcher: "Do you think *the way you work with the example* changes? [after talking about illustrative and in-depth approaches and the differences in KS3 and KS4]"
> Teacher F: "*That's definitely true*. And I think that, in a perfect world, you'd have the same amount of time for both [KS3 and KS4 groups], but the difference is that *the amount of content in KS4 is so much higher that is a far more sort of like descriptive process* of `this is everything you need to know; I'm gonna give you this example because you need to know this example`. Whereas in KS3, I tell them about the twin study and things, that it isn't come up in the test, but I know it makes really interesting learning about that as a lesson objective." (emphases added)

Therefore, it is important to remark that the introduction of HOS into school science and the way this introduction is made (illustrative or contextualised) does not seem to be simply a choice made by the teachers solely based on their views about school science, but it is in fact connected to what they feel they need to teach in terms of the curriculum, as also found by Höttecke and Silva (2011). During the classroom observations, teachers constantly dedicated most of their lessons to teaching specific concepts more than developing scientific skills or thinking about NOS, arguing that these are almost the sole object of assessment in official exams. Thus, it seems reasonable that the majority of them dedicated their lessons to a more direct and to-the-test teaching of concepts, with little attention to HOS.

Consequently, their choice of examples (including their approach towards HOS), especially in KS4 classrooms, seems to be related to this aim of discussing, throughout the lesson, and learning, by the end of it, a new content. This could be an explanation for their choice of usually addressing historical examples under an illustrative approach, with fewer situations where contextualised/in-depth work was carried out. Similarly to Höttecke and Silva (2011)'s findings, teacher A highlighted during the interview that the freedom to have more in-depth/ contextualised discussions with students quickly disappears with the pressures and time constraints presented by the KS4 curriculum and accountability.

> Teacher A: "That's the case because *whatever you do as a teacher, you're judged by your students' grades*. So you need to think about that all the time. *Expending so much time with those examples and in-depth, it would make a massive difference to what they get at the end*. So you would really love to expend so much time to go in-depth into what the examples tell and things like it. [...] But if it's gonna mean that you won't have enough time to teach what your content is... *which is we argue all the time, it's just curriculum, curriculum, curriculum, and if you're not careful, focusing too much on that is going to mean that you lose the interest of the students*. So it's hard to get the balance right, but there're just some things that you need to get to the end of it." (emphases added)

In this case, HOS can acquire a merely representative/descriptive usefulness, hinting at an approach towards school science more as teaching about the products of science than about how science works to develop these products. Here this study agrees with Forato et al. (2015), who argued that there is a danger in bringing HOS into science lessons as only an illustration (that is, emptied from its original context), because it can promote a naive view of the scientific endeavour, where HOS is only another memory-based practice developed inside the classroom. These reflections are closely connected with what Allchin (2003, 2004) called "Pseudohistory", an approach towards history that "uses facts selectively and so fosters misleading images" (Allchin 2004, p. 179) and also involves a lack of respect for historical context (Whiggism).

Additionally, several authors (e.g. Wang and Marsh 2002; Allchin 2004; Clough 2011) have also argued about the extent to which this decontextualised (illustrative) approach towards HOS, with the sole mention of names and/or anecdotes, should be considered satisfactory in terms of science education and, more importantly, of advocating the introduction of HOS into school science. Thus, contextualised/in-depth historical cases can do more for school science than teaching a "comprehensive `greatest hits` survey course" (Allchin 2004, p. 192), an approach that, according to the findings from this research, has clearly little impact on what students really know about science and scientists. A question that remains, however, is how to address teachers' constant concerns about official curricula and assessment when advocating this contextualised approach towards HOS in secondary school science lessons.

4.3 Representativeness in Science and Its Ramifications for School Science

The issue of mythical and stereotypical images of scientists and their impacts on students' ideas about who can participate in scientific research has been discussed by several authors within the science education field. That is the case, for instance, of different research (e.g. Buck et al. 2008; Archer et al. 2010, 2012; Christidou 2011; DeWitt et al. 2011; Christidou et al. 2016) on how school science portrays scientists and their work, most of them with the goal of understanding and improving pupils' engagement with science and interest in scientific careers.

These studies highlight problems with stereotypical images and representativeness in science, constructed and perpetuated both by mass media and school, as also briefly discussed in the previous subsection. Stereotypical views of scientists, as shown by different investigations carried out in different countries, usually involve images of male, white and eccentric persons, summarised by the popular figure of Albert Einstein (Buck et al. 2008; Christidou 2011). According to Kessels et al. (2006, p. 764), this image "reflects cultural beliefs within a given society" and is strongly influenced by interpretive and judgmental frameworks, which attribute particular features or skills (doing science) to particular social groups (usually white, male, eccentric, genius).

These popular images can influence students' notions of the type of people scientists are or have to be, consequently creating several discontinuities between this traditional "scientific identity" and their own personal identities, as shown by different research (Cleaves 2005; Hazari et al. 2010; Archer et al. 2010; Christidou 2011; Christidou et al. 2016). Thus, we can argue that this "scientific identity" portrayed and disseminated to young people is related to serious issues regarding representativeness in science, helping to create a vicious circle where the lack of diverse representations discourages people from different backgrounds to get into science (DeWitt et al. 2011; Archer et al. 2012).

Results from this research show that this issue of representativeness in school science is still relevant, especially in terms of gender and cultural backgrounds. Taking into account the scientists cited by the students in Q1, there is a lack of knowledge about women (except for from Marie Curie and Rosalind Franklin) and about people from minority groups (non-European or from the USA) in science. Interestingly, girls from year 10 at school B realised, while working on the survey, that they did not know almost any scientists from minority groups. Girls in a top set science class (with about 60% of black students and 25% from other ethnical minority groups) were shocked to discover that they were talking only about white

European men in Science, with very few female and minority group examples coming to their minds:

> Student 1: "Sometimes we don't even learn about them [scientists from other backgrounds or gender], *even if they do make that discovery, whenever we are taught in the classroom, they don't go and deemed them as significant enough to go and teach it to us*. And it's really really sad, because you see all these European people and you kind of wonder if you're not from a European country, `*did anyone from Asia, did anyone from Africa do anything to go and contribute to science?*`" (emphases added)

This situation is very similar to the one found by Archer et al. (2012, p. 981) during their study on girls' attitudes towards science. While very interested and engaged with school science, these girls presented a tacit alignment with masculine views of science: "it was notable that many of the girls we interviewed identified male (rather than female) scientific role models". Additionally, in a previous work, this research group (Archer et al. 2010, p. 635) pointed out that this is not only a girls' view of science, but in fact boys share this same masculine image about scientific work: "the boys argued that boys are better at science, explaining that the scientists they know are all male".

This highlights the impact of school science on students' perceptions about science and, more importantly, the position of schools as reproducers of (out-of-school) social norms and traditions, such as a white, male, upper class scientific identity. A group of students from school A (year 9—set 2), for instance, talked about that when explaining why they had never heard about scientists from different backgrounds or genders:

> Student 1: "It's because of History. Because back then, *women didn't have any rights, black people most of times were slaves*, and stuff like that. [...] If you look around, there has only been... like *black people have only been good in History*, like Nelson Mandela and stuff like that."
> Student 2: "I just feel like it's not brought because *we live in like a diverse world, but we don't accept it. And we don't acknowledge people that are other than white or other gender*."
> Student 3: "Or sometimes they don't even say on TV. They just say it when it's probably too late. Or if they do say it, *they don't say it in the way they say it about the white men*. They only talk about the great things they did, and sometimes *it makes you wonder 'what about the other people?'. They don't represent the other people in the way they represent white men***.**" (emphases added)

Among the explanations given by the students for this situation, there are two main trends, one related to historical reasons and the other connected to contemporary problems. In the first case, students highlighted a historical lack of equity in terms of rights and opportunities ("being in the right place at the right time") in non-European countries and also for women (see student 1's quote above). They also talked about the absence of education, resources and interest for non-mainstream people to carry out scientific research in the past:

> Student 1[15]: "Maybe society thinks that, you know, the mainstream countries maybe have *more education than other countries.*"
> Student 2[16]: "Maybe *they [mainstream countries] valued science more than other civilisations*. (...) I'm not saying that others didn't. But like they valued it more maybe." (emphases added)

On the other hand, some students focused their explanations on the fact that nowadays we only talk/learn about popular male western scientists because they are the ones who are popular, being responsible for big discoveries; they also talked about how we do not acknowledge diversity, including discussions about racism and distrust about science being done by "outsiders":

[15] Year 8—mixed—school A
[16] Year 8—mixed—school A

Student 1[17]: "I think that's because *men were more accepted*, like their breakthroughs were more talked about than women's. *Women aren't really as known by their discoveries*. Maybe that's why *they're not really as talked about*."
Student 2[18]: "I think that's because *men had more opportunities to make like big discoveries* than women did, and *big discoveries are really the only important ones*."
Student 3[19]: "Maybe at the time when these discoveries were made it was mainly the Caucasian race, the people that were in charge of that, were doing that. *Anyone else that was doing it* was seen as, maybe their *work was discarded, or people taught it wasn't right*."

Likewise, if we analyse their answers to Q4, Q5 and Q6, we again observe this lack of diversity regarding cultural backgrounds. Similar to the results obtained by Gurgel et al. (2014), students in this research focused their answers on countries that currently dominate the world's economy and systems of production (USA, UK, China, Russia, Japan). This outcome can be related to a dominant public image of science as strongly connected to power and resources, but having little to do with exchanges and collaborations between different communities occupying difference places in the world, as discussed by Miller et al. (2006) and by Hazari et al. (2010). This explanation was indeed confirmed during the interviews, when students attributed their choices of countries to ownership of technology, money and power, and access to education and mass communication (more exposure), while also using terms like "developed countries" and "important countries" in the global scenario.

The lack of diversity, not only regarding gender, but also cultural backgrounds, in students' responses is very relevant to school science and research in science education, since it illustrates their lack of knowledge about science as an intercultural community, with its own history of exchanges and contributions made by different people in different parts of the world (Roberts 2009; Elshakry 2010; Hazari et al. 2010; Fan 2012). Once again, these findings indicate the need for reflection about the place of HOS in teachers' practices and about which type of HOS is being included into school science.

During the classroom observations, for instance, very few examples discussed by the teachers involved some kind of diversity in the production of scientific knowledge. Some exceptions to this trend were teacher K's choice of intercultural examples during her lesson on theories of the Earth, and teacher F's discussion about the historical origins of selective breeding in China and how it later spread to Europe. These two teachers, alongside teacher A, were seen teaching the most creative and diverse lessons in relation to examples, interactions with students and talks about science among the cohort of teachers observed (Gandolfi 2017). This can be connected with their own professional epistemologies and views of science education, leading to the adoption of a position against the constrained curricula and assessment pressures, in order to make the most of their lessons in their multicultural classrooms (Hargreaves 2003). About that, teacher K says:

Researcher: "You use your questions to connect with something from their culture [...]. Do you always do that? Do you often try to do that?"
Teacher K: "I do try to do that, I do try because *I like to know where my students have come from and to make it applicable to them*. Because a lot of time, you know, *they only see scientists of a certain race or a certain sex only, and that's all they see. So I like to open up their minds a little bit*; that's partly why I did the board as well, with the women in science, because I wanted to show them there's lots of women who do amazing things in science, from different races, different backgrounds, you know, different abilities. And *hopefully it will inspire them*. [...] *And that's definitely what I like to do, you know, not just give them*

[0] Year 8—mixed—school A
[17] Year 8—set 2—school B
[18] Year 8—set 2—school B
[19] Year 10—set 1—school A

just one side, one dimension, `this is how the Western world` sees it. So I try to give them a bigger view." (emphases added)

The "selection bias" (Allchin et al. 2014) towards historical and contemporary narratives about science can have important impact on students' views of scientific identity (Sarukkai 2014). Similarly, Archer et al. (2010 p. 618) correlated students' lack of aspirations in Science to, among other things, a "mismatch between popular representations of science (...) and the aspirations, ideals, and developing identities of young adolescents", a view also shared by some of the participant students in this research:

Student 1[20]: "I feel that sometimes *people might be like feeling down because of other scientists, because if they are not represented in the world like these [mainstream] scientists do*, then they might give up on their dreams of being [a scientist]. Or maybe they did discover something that no one did, and that could just make them feel down."
Student 2[21]: "I guess this [lack of diversity in science] might be a problem, because it goes to show, it might *spread the wrong message that everyone else can't really make scientific discoveries*."
Student3[22]: "Yeah [it's a problem], because *it may not empower them to go into science if they think that their work isn't going to be accepted and listen[ed] to*." (emphases added)

As also discussed in the last subsection, curriculum constraints and assessment pressures cannot be forgotten when analysing teachers' practices towards representativeness in school science. In the lessons observed during this study, the focus on conceptual knowledge, and the use of decontextualised (illustrative) accounts of scientific development seemed to be strongly connected to a reality of school science in England where the time available for in-depth/contextualised discussions about how science works is very restricted.

Another important constraint to their practices is the fact that most of the teaching materials available, even those coming from a historical perspective, still do not take into account the debates about representativeness in science (Dennick 1992; Hodson 1998), as discussed at the beginning of this paper. As shown by a brief analysis of the textbooks used by the teachers during the lessons observed, very few examples involved contributions from different cultures or people to science, with some exceptions like Marie Curie's works, different views on the origins of the Universe, and theories about the Earth. Interestingly, these specific scenarios were all incorporated by the teachers into their lessons, hinting at the importance of having more diverse accounts about science available to them, as mentioned by teacher A:

Teacher A: "It's just *the amount of workload*: you're either marking, planning lessons, doing this, doing that. So, *it just makes that time less and less available for you to say 'I want to dedicate time to find things like that'*. While if we said in lesson planning [at the beginning of the year, when science teachers from this school meet to plan their year] that we're gonna put those things in our lesson, maybe one topic that is relevant and things like that, then it wouldn't be a too massive search in one time, it wouldn't be too much." (emphases added)

Therefore, when advocating the introduction of HOS into regular school science, the important question about who will be part of the narrative and about which examples (countries/cultures/civilisations) are going to be employed needs to be raised. In contexts of increasing multicultural encounters such as urban schools, the images of science and scientists that traditional practices are still portraying seem to be largely disconnected from these students' own backgrounds.

[20] Year 9—set 2—school A
[21] Year 10—set 1—school A
[22] Year 10—set 1—school A

Once again, however, the question about how to work with science curricula that are traditionally non-diverse and large-scale assessments that do not address these issues remains, as stated by teacher K above. Even if changes in practices are acknowledged as necessary, the possibilities to do so are still very constrained by the field of science education itself, with its long-term association with non-diverse views of the history of scientific development.

5 Implications

This article described an exploratory study, carried out at two secondary schools in London, UK, on students' knowledge about different scientists' and countries' contributions to historical and contemporary science. The aim was to investigate who and which countries these students deemed as relevant to the history of scientific development and, more importantly, how these views can be connected to science lessons and teaching using HOS.

There are limitations in this study that was carried out only at two schools (and with a total of 200 students) and, more importantly, that employed a memory-based survey about scientists and countries as one of the methods for data collection. Due to this small sample of participants, one cannot infer that the results discussed here are the case for all secondary students and schools, not even in the English context. The combination of a main survey with classroom observations and interviews with teachers and students, however, allowed for the exploration of the realities of school science and of how these practices have a significant influence on students' knowledge about HOS. As discussed in the previous section, this collective analysis wielded results that are similar to other investigations about representativeness in school science (e.g. Archer et al. 2010; Archer et al. 2012; Gurgel et al. 2014) and the illustrative use of HOS (e.g. Allchin 2004; Höttecke and Silva 2011; Forato et al. 2015), also generating qualitative information about how the introduction of HOS into school science is being made regarding curricular and pedagogical aspects.

The decision to use the memory-based survey as a starting point for this research has its drawbacks, especially in relation to the several different ways that HOS can be discussed during a science lesson; that is, by having used a very specific survey, this study might have prevented some students from expressing their knowledge about HOS in a different way, which was not covered by the instrument. However, during the interviews, they had the opportunity to talk more about science and scientists of the past, overcoming, at least partially, some of the drawbacks related to using only surveys to investigate people's knowledge about a topic.

It is also worth noting that, even though not explicitly discussed in the previous sections, some characteristics of students' general historical knowledge (i.e. their understanding about history and their perception about historical timelines) can have an important impact on their answers. For instance, when asked about countries that were relevant to science in the past, these participants seemed to concentrate their answers in a not so distant past, mentioning countries like Germany, the USA and the USSR, which can be considered historically still very young in comparison with Greeks, Egyptians and Romans. Here, it seems clear that students' understandings of what 'past' means can influence how they engage with HOS.

In relation to the main findings of this investigation, they have shown how secondary students still hold a very narrow view about scientists, not only in relation to their work (knowing scientists versus knowing about scientists), but also about who they are (representativeness in science). Furthermore, they also perceive science as concentrated in very few and dominant countries, which are seen as the only ones possessing the necessary features to foster relevant scientific development, in opposition to the rest (and majority) of the world.

As discussed by other researchers (Buck et al. 2008; Archer et al. 2010, 2012; Christidou 2011; DeWitt et al. 2011; Christidou et al. 2016), diverse role models (gender, race and cultural backgrounds) and contextualised and real accounts of scientific work are important for students' engagement with school science and attitudes towards scientific careers. In face of its results, this study highlighted the relevance of these statements, especially when most of the observed lessons were very constrained by curricular and assessment pressures, and also by the lack of resources available for teachers to try and overcome this lack of diverse and contextualised historical accounts.

Here, one has to agree with Buck et al. (2008) and Christidou (2011) about the importance of diversifying science curricula if we aim to change the view that "scientists are not like us" (not only in the case of girls, but also in the case of different cultural backgrounds):

> A presentation of scientific knowledge as a human-centered investigative construction, progressive and constantly evolving, produced by broad communities of researchers independently of gender, race, or nationality, and in continuous interaction with society, along with pedagogical practices legitimating diverse identities and roles for girls would also contribute to this direction. (Christidou 2011, p. 149–150)

But how might this come about? Literature review of this article introduced the idea that HOS can play an important part in this process of counteracting the traditional (and mostly Eurocentric) views about scientists and scientific development, but only if disassociated from an illustrative/decontextualised approach when introduced into school science, and associated with a more intercultural/global perspective. HOS can and should encompass teaching about different people and different countries/civilisations contributions to the production of the scientific knowledge students are currently learning, through historical accounts coming not from European History, but from Global History (Roberts 2009; Elshakry 2010; Fan 2012).

From a more practical viewpoint, this article advocates the need for more historical activities based on accounts of the scientific development under an intercultural model of HOS (Roberts 2009; Sarukkai 2014; Gandolfi in press), showing how different scientific concepts have been developed through exchanges and collaborations between different people and cultural traditions. Here, instead of a dichotomous approach towards "western" and "non-western" science, that is, instead of a perspective that separates these "two systems of knowledge", the intercultural model employs a global narrative about the development of scientific knowledge, bringing these traditions together not as simply different from each other, but under a collaborative and dynamic network.

A careful choice of scientific cases could help teachers not only to discuss the official science curricula using HOS, but also to bring more contextualised and culturally diverse examples to their lessons. Furthermore, as already stated, a thoughtful reflection about these scenarios and how they are going to be incorporated into the lessons could also lead to relevant discussions about NOS (processes of science) alongside the traditional scientific content (products of science) (Gandolfi in press).

For example, a lesson plan about the topic of Medicines and Drug Development[23] could be developed through a narrative to highlight, among other things, the importance of natural resources to the use of medicines, how native and local knowledge about these resources were employed by specific cultures and how the frequent contacts with other groups enabled exchanges, collaborations, adaptation and exploitation of this expertise (Gandolfi in press). This could encompass learning about practices and knowledge about medicines in, for instance, Native American, African, Arabic and Asian traditions, and how the processes of expansion of different communities, including the Europeans, through maritime and land route travels, commerce, forced migration, colonisation, and

[23] Official topic in the English Science curriculum for students aged 12–13.

naturalist travels enabled the advancement of what is considered modern knowledge about drug production.

Here, scientific content from the official curriculum, such as principle ingredient, natural and artificial medicines, stages of drug development and drug trials come into light as part of this global and historical narrative. Furthermore, important aspects from NOS could also be explored, since they are naturally connected to these themes: social and cultural influences and controversies in the production of scientific knowledge; the importance of natural resources for the production of scientific knowledge and the consequences of their exploration (including environmental issues and intellectual property in science); the collaborative and collective nature of the scientific work; the relationship between science, ethics, economy, politics etc.; the role of experiment, controlled investigation and quality control in science (Gandolfi in press).

That does not mean, however, that using this intercultural model is a straightforward work for science teachers, especially due to their lack of training in HPS. What it is being argued here is that the fields of HPS and science education have a lot to contribute to this scenario not only through the production of teaching materials incorporating these ideas, but also through the acknowledgement of these intercultural aspects of modern science in teacher training programmes about HPS and NOS and in collaborative projects developed alongside teachers and their schools.

And it is especially because this institutional (school) level is traditionally bounded to official assessments and time constraints that researchers in the field need to help teachers with teaching with HOS and under an intercultural perspective in a way that still results in learning the concepts and procedures covered by exams. The next steps of this research will involve a close work with teachers at school A aimed at developing lesson plans (such as the one about medicines described above) incorporating the teaching of concepts alongside NOS using this intercultural model of HOS (Gandolfi in press). In order to evaluate the possibilities and pathways of this type of approach, these activities will be developed as regular lesson plans about official curricular content, to be taught during regular science lessons instead of being used only as extra-curricular activities or in after-school clubs.

In relation to possible impacts of this approach, students seemed interested in learning more about scientific research and inventions done by different people in different parts of the world when some historical examples[24] were briefly mentioned to them during the interviews:

> Student 1[25]: "I like learning about the ones maybe from my culture because *it's inspiring for me to know that people that are from the same country as me can also do empowering things*. That's aspirational."
> Student 2[26]: "I think also like, how we leave them out in our science lessons. *Because we don't talk about the background of this, all that we know is just the European ones*."
> Student 3[27]: "I think it's interesting, because *I think we always have this stereotype that everyone was dumb before they were colonised by the Europeans*. It actually opens your eyes. It opens a lot of questions."

If even after only a very brief moment of discussion and not actually having them as part of an official science lesson, these students' reactions to the examples mentioned have a lot to say about how scientists are being portrayed by school science and, more importantly, they have a lot to say about the possibilities of a more intercultural and contextualised approach towards HOS in multicultural schools. Therefore, science educators and other researchers in the field of

[24] Metal technology in Africa, Arabic astronomy, Indian maths, Chinese inventions and medicine in the native Americas.
[25] Year 8—set 2—school B
[26] Year 10—set 1—school A
[27] Year 10—set 1—school B

HPS have an important responsibility to help teachers and students to challenge colonising and stereotypical views about scientific development throughout our History.

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Compliance with Ethical Standards

Conflict of Interest The author declares no conflict of interest.

Appendix 1: Demographics of the focus groups

Table 3 Demographic information from the participant students in the focus groups

School	Year	Ability group		Gender		Ethnicity	
		Whole classroom	Focus group	Whole classroom	Focus group	Whole classroom	Focus group
A	8	L = 25%; M = 50%; H = 25%	L = 40%; M = 40%; H = 20%	F = 48%; M = 52%	F = 60%; M = 40%	White East European = 57%; Middle Eastern = 26%; Asian = 9%; Black African = 4%; mixed = 4%	White East European = 40%; Middle Eastern = 20%; Asian = 20%; mixed = 20%
	9	H = 100%	H = 100%	F = 42%; M = 58%	F = 40%; M = 60%	Asian = 46%; White British = 15%; White East European = 11%; Black African = 8%; Black Caribbean = 4%; mixed = 4%; Chinese = 4%; East Asian = 4%; Middle Eastern = 4%	Asian = 20%; White British = 40%; White East European = 20%; Chinese = 20%
		M = 100%	M = 100%	F = 54%; M = 46%	F = 60%; M = 40%	Asian = 29%; White East European = 25%; Black African = 22%; Black Caribbean = 8%; mixed = 8%; White British = 8%	Asian = 40%; White East European = 20%; Black African = 20%; White British = 20%
		L = 100%	L = 100%	F = 12%; M = 88%	F = 50%; M = 50%	White East European = 31%; Black African = 19%; mixed = 19%;	White East European = 25%; mixed = 25%; Asian = 25%;

Table 3 (continued)

School	Year	Ability group		Gender		Ethnicity	
		Whole classroom	Focus group	Whole classroom	Focus group	Whole classroom	Focus group
						Asian = 19%; White British = 6%; White African = 6%	White African = 25%
	10	H = 100%	H = 100%	F = 44%; M = 56%	F = 50%; M = 50%	White East European = 32%; Asian = 28%; Middle Eastern = 16%; Black African = 12%; mixed = 4%; Black Caribbean = 4%; East Asian = 4%	White East European = 50%; Asian = 25%; Middle Eastern = 25%
		M = 100%	M = 100%	F = 19%; M = 81%	F = 40%; M = 60%	Asian = 43%; Black African = 19%; Mixed = 14%; White East European = 14%; Middle Eastern = 5%; other = 5%	Asian = 40%; Black African = 20%; White East European = 20%; Middle Eastern = 20%
B	8	M = 100%	M = 100%	F = 100%; M = 0%	F = 100%; M = 0%	Black African = 52%; Black Caribbean = 16%; White British = 8%; White East European = 8%; Asian = 8%; mixed = 4%; other = 4%	Black African = 40%; White British = 20%; Mixed = 20%; other = 20%
	9	L = 100%	L = 100%	F = 100%; M = 0%	F = 100%; M = 0%	Black African = 41%; Black Caribbean = 29%; mixed = 18%; Middle Eastern = 6%; White British = 6%	Black African = 41%; Black Caribbean = 29%; Mixed = 18%; Middle Eastern = 6%; White British = 6%
	10	H = 100%	H = 100%	F = 100%; M = 0%	F = 100 M = 0%	Black African = 39%; Asian = 17%; White East European = 13%; Middle Eastern = 9%; Black Caribbean = 9%; mixed = 9% East Asian = 4%	Black African = 50%; Middle Eastern = 16.7%; Black Caribbean = 16.7%; East Asian = 16.7%

L, low abilities; M, medium abilities; H, high abilities; F, female; M, male

Appendix 2: Interview protocol (students)

a. I want to start by talking about the first questionnaire you helped me with, that one about names of scientists and countries that are important to science. A lot of students mentioned Albert Einstein and Stephen Hawking. Have you ever heard about them?

  – If yes, can you tell me where you heard about them and what you know about them?
  – If no/yes, can you tell me where you heard about the scientists you named for me?

b. In that questionnaire, I also asked you if you remembered where these scientists came from and what they did in science. However, most students only remembered the names and nothing about where these scientists were born and what they did (present some examples from their answers). Why do you think that happened?

c. Does your science teacher talk about scientists during her lesson?

  – If yes, what do you think about that? Do you like it? Why?
  – If no/yes, would you like to know more about scientists in your lessons? Why? And what would you like to know?

d. Let us talk about these scientists. Almost all scientists the students cited are men, white and European or from the USA (present some examples from their answers). Why do you think this list of scientists is like that?

  – Do you know any scientists (famous or from your family/friends) from other backgrounds, like women, black and from different parts of the world?
  – In your opinion, which type of person becomes a scientist? Who do you have to be to become a scientist?
  – Do you think the lack of diversity in science can influence people's choice of career? What about yours?

e. Let us talk about countries in science. The most cited countries were USA, UK and China (present some examples from their answers). Why do you think this list of countries is like that?

  – In which type of places (countries, communities) do you think science is usually developed?
  – Talk to them about examples of science being done in different parts of the world at different times (e.g. metal technology in Africa; Arabic astronomy; Indian maths; Chinese inventions; Medicine in the native Americas) and ask if they would like to learn more about it.

f. Let us talk now about the other questionnaire you helped me with, that one about how science works. Can we talk about what science does? What do you think a scientist's job is?

g. Most of you talked about the importance of having evidence to science. What do you think evidence is? Can you give me examples?

- How do you think scientists gather this evidence?
- And what about the situations where gathering evidence is very difficult (like in the dinosaurs case or when they research outer space)? How you think scientists work in these situations?

h. Do you think that gathering evidence is the only important part of scientific work? That is, is this enough for developing scientific ideas and new technology?

- What else do you think is important in this task?

i. Can we talk now about how scientists and the general public receive new scientific ideas? Do you think people nowadays trust scientists and their work? Why?

- Can this situation occur between scientists? Do you think scientists can distrust each other? Why do you think that happens?
- Do you think social contexts (e.g. politics, economy, culture etc.) can affect the way scientists work? Why? How?

j. Lastly, I want to talk about where all these ideas about how science works came from? Where did you learn/hear about that (school, family/friends, media etc.)?

Appendix 3: Interview protocol (teachers)

1. I want to start by talking about the examples (items, cases) you use during your lessons to introduce/discuss a specific topic. How do you choose these examples you are going to present to your students? (present examples from my observations).
2. Still about that, one of the findings from my observations is that usually teachers do not expend a lot of time having in-depth discussions about these examples; that is, they usually move very quickly throughout the examples during the lessons. What do you think of that? Is that usually a reality for you?

   - If yes, why do you think that happens? Is it a personal choice (a personal view on what science teaching should be about) or are there other factors influencing your approach?
   - If no, how do you plan your lessons to ensure you will have these in-depth discussions with your students?

3. Do you think this lack of in-depth discussions about the examples can influence students' views about how the scientific community works, such as how scientists work and who they are?

   - Do you think learning about these things is relevant to your students? Why?
   - For you, what are the most important things for students to learn in your lessons (e.g. content, applications of science, how science works etc.)?

4. Still talking about this idea of how science works, do you think that some specific topics in the science curriculum are more open to this type of discussion than others? Could you give some examples from your own experience? (present examples from my observations).
5. Do you think there is any difference in relation to teaching about how science works in relation to sets and/or age groups (KS3 and KS4)? Could you give examples from your own experience? (present examples from my observations).
6. Another overall finding from my research is that teachers usually make a lot of connections between the topic they are teaching, other subjects, students' previous knowledge or personal interests, everyday life etc. That means that these science lessons are usually very open for students' questions and also that teachers are always asking their students questions as well. How important is this scenario for your practice? Why?

   – What you do say about making connections between the topic and other cultures (including your students' own backgrounds) or historical contexts? Is that relevant for your practice? Do you take this idea into account when thinking about your lesson? (present examples from my observations).

7. One of the questionnaires I applied to your students was connected to their knowledge about scientists and different countries' contributions to science. As an overall finding, there seems to be a large disconnection between remembering the names of scientists and actually remembering the work they have done and their origins (present my graph about scientists). Why do you think that happens?
8. Do you think the introduction of these discussions about scientists and their work (that is, History of Science) is relevant to your students? Why?

   – If yes, what do you feel the main obstacles for doing that are?

9. Another finding from this questionnaire is the lack of diversity in students' knowledge about scientists and countries in science, both in terms of the scientists they cited (gender, race, ethnicity) and the countries they considered as relevant to science in the past and nowadays (present my graphs about scientists and countries). Why do you think that happens?
10. Do you agree that we still have a problem with representation of scientists and cultures in school science? Why?

    – If yes, what do you think the main impacts of this scenario on students are?
    – Thinking again on my previous question about using examples from different cultures in your lessons, do you feel able to tackle this problem while planning and teaching your lessons (curriculum/time constraints, lack of materials etc.)? Why/How?

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