Teachers' Conceptions About the Genetic Determinism of Human Behaviour: A Survey in 23 Countries

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Abstract   This work analyses the answers to a questionnaire from 8,285 in-service and pre-service teachers from 23 countries, elaborated by the Biohead-Citizen research project, to investigate teachers' conceptions related to the genetic determinism of human behaviour. A principal components analysis is used to assess the main trends in all the interviewed teachers' conceptions. This illustrates that innatism is present in two distinct ways: in relation to individuals (e.g. genetic determinism to justify intellectual likeness between individuals such as twins) or in relation to groups of humans (e.g. genetic determinism to justify gender differences or the superiority of some human ethnic groups). A between-factor analysis discriminates between countries, showing very significant differences. There is more innatism among teachers' conceptions in African countries and Lebanon than in European countries, Brazil and Australia. Among the other controlled parameters, only two are significantly independent of the country: the level of training and the level of knowledge of biology. A co-inertia analysis shows a strong correlation between non-citizen attitudes towards and innatist conceptions of genetic determinism regarding human groups. We discuss these findings and their implications for education.

1 Introduction

1.1 The Biohead-Citizen Project

This study is rooted in the BIOHEAD-Citizen research project (Biology, Health and Environmental Education for Better Citizenship, 2004–2008, European Community CIT2-CT 2004-5006015). This project involved partners from eighteen countries chosen for their diversity: inside Europe (north to south, east to west) and outside Europe (North Africa,

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Senegal and Lebanon). Five other countries were then added, under the responsibility of P. Clément, to enlarge the sampling for a larger transnational comparative study: one in Europe (Denmark), two in Africa (Burkina Faso and Cameroon, to provide samples of non-Muslim African teachers) and two in other continents (Brazil and Australia). The participants associated with this project had competencies in both biology, health or environment and in human and social sciences, mainly in science education. The aim of this project was to analyse how aspects of citizenship can be promoted through biology, health and environmental education, taking into account the renewal of scientific knowledge as well as the social and affective dimensions linked to these topics.

This project was structured by two main axes: a critical analysis of curricula and school textbooks and an analysis of in-service and pre-service teachers' conceptions (including their systems of values as well as their scientific knowledge) in order to answer the following questions:

- Are there reductive simplifications in teaching issues related to our selected topics, like '1 gene → 1 character'; '1 microbe → 1 disease'? Do such teaching issues present or might they present notions of regulation, cycles, complexity? Are there implicit values in the curricula, syllabuses and school textbooks?
- What are the teachers' systems of values, including social dimensions, regarding nature, body and health, sexuality, biologic determinism, evolution? Do their values interact with their scientific knowledge? Are there differences among countries? Can such differences be associated with controlled parameters (gender, disciplines, religion, socio-economic context, recent history of the country, etc.)?

The theoretical background is the KVP model (Clément 2006, 2010, Fig. 1 below), in which conceptions are analysed as possible interactions between scientific knowledge (K), systems of values (V) and social practices (P), and the goal is to carry out:

- A comparative analysis of syllabuses and school textbooks among the countries. For each selected topic, one grid of analysis was constructed to be used by all the participating countries at all the school levels (primary and secondary schools, i.e. from 6- to 18-year-old students). Several papers were published and we mention here only some of them on each of the six topics of the project: environment (e.g. Caravita et al. 2008), health (e.g. Carvalho et al. 2008), sex education (e.g. Bernard et al. 2008), evolution (e.g. Quessada et al. 2008), the human brain (e.g. Clément et al. 2008) and human genetics (e.g. Castéra et al. 2008).
- A comparative analysis of the teachers' and future teachers' conceptions of the six topics. The questionnaire was mainly constructed by including questions from previously well-tested questionnaires on the selected topics followed by validation using a pilot test. Several papers were also published here, and we mention only some

Fig. 1 Conceptions (*C*) can be analysed as interactions among the three poles knowledge (K), values (V) and practices (P) (Clément 2006)
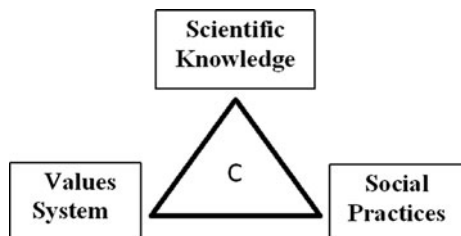
of them related to the environment (Munoz et al. 2009), evolution (Clément and Quessada 2009) and human genetics (Castéra and Clément 2010).

The present paper deals with the teachers' conceptions of human genetic determinism in more countries than the 18 included in the BIOHEAD-Citizen project. These conceptions are linked to social challenges, such as differences, but also equality of rights among all human beings, regardless of their gender or their ethnic group. Biology education must involve awareness to teach actualized scientific knowledge. Moreover, the goal of education is not restricted to the transmission of knowledge, but also includes skills and values (Delors 1996) such as the promotion of citizen human rights, e.g. the equality of all human beings. It is thus essential to analyse whether teachers are conceptualizing clearly the distinction between knowledge and values, and whether some possible interaction between knowledge and values can be identified and analysed in relation to different sociocultural contexts. This interaction can be an obstacle to the renewal of the taught scientific knowledge as well as sometimes facilitating it. That is the educational perspective of our work.

1.2 Genetic Determinism as a Belief

The 'nature versus nurture' debate is an old, traditional but outdated discussion. All biologists consider today that any phenotype emerges from the interaction between the genome (nature) and its environment (nurture). Working on this interaction is a new trend of biology, called 'epigenetics' (Wu and Morris 2001). Consequently, the traditional debate of genes 'or' environment, or '% of genes and % of environment' (which is possible only for an additive model 'genes + environment'), is outdated because there is an interaction between genes and environment. Jacquard (1972) used a metaphor, comparing the interaction between 'innate' and 'acquired' in human features with the interaction between cement and bricks in a wall: both are necessary and they interact. Meaney (2001) used another metaphor, explaining that asking which factor contributes more to the development of personality, nature or nurture, is akin to asking what contributes more to the area of a rectangle, the length or the width. The question of the relative importance of nature and nurture is irrelevant, because they are both necessary. The most interesting example to show the very high presence of genetic essentialism in our societies is the Human Genome Project (HGP). Presented, at the beginning, as the solution to the genetics roots of human features, including diseases such as cancers, Alzheimer's, diabetes, etc., researchers initially claimed that they were expecting to find 100,000–150,000 human genes, while we know today that our genome contains fewer than 23,000 genes. Researchers have recently admitted the very mixed results coming from the HGP:

> Hundreds of genetic variants have been linked to common diseases through genome-wide association studies, yet each confers only minimal disease risk. The findings thus far represent only the tip of the iceberg. (National Human Genome Research Institute 2010).

This shows that even for what can be considered as simple features (such as diseases), genetic determinism is not sufficient to explain the complexity of human phenotypes. Only the multiple interactions between genome, environment and organism can give an overview of the biological complexity ('the triple helix' of Lewontin 2000). Trying to oppose nature and nurture is a nonsense because both are 100 % necessary (Jacquard & Kahn 2001).

Nevertheless, at least before the middle of the twentieth century, nature was opposed to nurture and was often considered as stronger than nurture. This prevalence of nature

(innatism) appeared frequently in the common thinking and culminated in colonialism and then with the Nazis' ideology. During this period, the research into genetics was growing and was structured in France in Institutes of 'Genetics and Eugenics' or in America with the American Eugenics Society (Aubert-Marson 2005). These kinds of institutes have certainly disappeared, but the ideology that we could understand the whole human being from its genes was still very present at the end of the twentieth century (e.g. the Human Genome Project, criticized by Song 2003). Gericke and Hagberg (2007), as well as Smith and Adkison (2010), analysed the historical progression of the genetic determinism models, showing that these models had difficulties in integrating the influence of the environment. Indeed, several scientists tried to correlate complex behaviours with some particular sequences in genomes, such as in the journal *Science* in which Hamer et al. (1993) claimed to have found DNA sequences that influenced the male sexual orientation (the 'gene of homosexuality' was taken up by the media). In 1999, Rice et al. published contradictory data in the same journal, showing no linkage with the particular sequence found before: Hamer et al. overestimated the genetic determinism. In addition, according to Nelkin and Lindee (1995), the imprinting of innatism in western societies can be found in 'mass culture': in TV shows, movies, journals, etc. The most common way used by this 'mass culture' to explain genetic determinism was to reduce one phenotype (such as behaviour) to one gene. That could only be explained by the ultra-simplification of a scientific fact, but these authors also suggested a parallel between DNA and soul:

> Such spiritual imagery sets the tone for popular accounts of DNA, fuelling narratives of genetic essentialism and giving mystical powers to a molecular structure. Indeed, DNA had assumed a cultural meaning similar to that of the Biblical soul. (Nelkin and Lindee 1995, p. 40)

They suggested that innatism could be more than a misunderstanding or simplification of science but could be anchored in deep beliefs. Other authors, writing on biology or on the epistemology of biology, developed the idea that genes took the place of God in explaining the determinism of human behaviours and performances. They saw the 'genetic programme' as being a kind of predestination created by God: everything that happened was written in advance (Kupiec and Sonigo 2000; Forissier and Clément 2003). For these authors, the common understanding of genetic determinism is rooted in a social religious culture of predeterminism. At the end of the twentieth century, this awareness encouraged some scientists to denounce the problem of an innatist society (e.g., Atlan 1999 in France, Lewontin et al. 1984 or Nelkin and Lindee 1995 in the U.S.).

In France, the media has often discussed this problem, with many controversies about genetic determinism. Maybe one of the most famous was the debate between the philosopher M. Onfray and the future President of the French Republic, N. Sarkozy, who claimed genetic determinism of human behaviours such as smoking, juvenile violence or suicide (Philosophie Magazine 2007).

Finally, well-known researchers in genetics (such as Lewontin 2000 or Jacquard and Kahn 2001) and philosophers (in the line of Jean-Paul Sartre and Simone de Beauvoir for instance) alert us to the fact that genetic determinism explanations can be used as a justification for social fatalism, with political or religious issues.

1.3 Innatism, a Many-Faceted Belief

Several authors have developed critical analyses of innatism (for instance Lewontin et al. 1984; Nelkin and Lindee 1995; Atlan 1999; Jacquard and Kahn 2001). Brun and Maurel (2005, p. 14) proposed a synthesis by distinguishing four forms of innatism:

(1)   The first one claims that there would be inherited biological differences in mental abilities between individuals within each human group.

(2)   The second postulates such differences between racial groups.

(3)   The third claims that social structures and behaviours (identifiable by the diversity of cultures and personal attitudes) would reflect the weight of genetic factors. Indeed, sociobiology (as Wilson 1978) postulates a genetic selection of the main cultural and social human features.

(4)   The fourth form of innatism considers the belief that mental gender differences would be genetically determined.

Psychologists such as Keller (2005) in Germany or Dambrun et al. (2009) in France have shown innatism among university students' conceptions, justifying racist or sexist attitudes. More precisely, Keller (2005) showed that when a group of people read a pro-genetic determinism article (indicating the importance of genes for humans) before completing an intolerant attitudes test, the answers are significantly more intolerant than those of a group who read a neutral article. For Keller, beliefs in strong genetic determinism engender intolerant attitudes. Moreover, in a recent work, Ranger and Keller (2011) proposed a complementary approach in order to clarify the conceptions about determinism considering not only the belief in genetic determinism (BGD) but also the belief in social determinism (BSD). In this way, they showed a correlation between BSD and intolerant attitudes when prejudices have been activated experimentally. The reductionism linked to BSD is probably rooted in some works of sociology or social psychology, while the reductionism linked to BGD generally claims to be justified by research in biology. Working on didactics of biology, our work is, firstly, mainly focused on BGD.

1.4 What are Conceptions?

Conceptions are central to this research. Giordan and De Vecchi (1987, p. 79) defined conceptions as 'a coordinated set of ideas and coherent explanatory images, that learners use for reasoning in context of problem-solving'.

Clément (2006, 2010) proposed analysing conceptions as the possible interaction between three poles (Fig. 1):

- Scientific knowledge (K): knowledge published and identified as scientific by the scientific community at a precise moment: today, but sometimes several years earlier.
- Values (V): 'what we use for our judgement'. Values justify opinions, ideologies or beliefs, but also science (e.g. the rejection of any fraud is a value). Innatism, as the belief in the great importance of genetic inheritance, or as the reduction of a sociocultural feature to a mere biological basis, is an interaction between some scientific knowledge (even if outdated) about genetic determinism and a value such as fatalism.
- Social practices (P): this pole represents all individual or collective social practices, whether professional, religious, political or in other domains. For instance, fatalism is a value sustaining conservative political positions (political practice).

For instance, the conception of a person who has already learned that genes do not determine a macrophenotype directly, but are in interaction with their environment, will differ from the conception of a person who does not know that: the influence of K on conceptions about genetic determinism can be strong. Alternatively, a person who is a fatalist, thinking that everything has already been written in advance, will easily agree with genetic determinism: the values can also influence strongly conceptions about genetic

determinism. The practices of a researcher in genetics are also different if they wish to test a genetic or an epigenetic influence. Social practices (such as the goals of the school and of any education) will differ if they are or are not rooted in a strong belief in genetic determinism regarding students' performances.

1.5 Situated Conceptions, Conceptions and Social Representations

According to Clément (1994), the researcher can only analyse the 'situated conceptions' of a person, i.e. the conceptions mobilized by a person when placed in a precise situation. Researchers consider for instance a response to a question (written or oral), or a behaviour or achievement, in relation to its specific context. The situated conceptions depend on the way in which the researchers collect the information. To gain an idea of a conception of a person relating to a precise topic, it is necessary to place that person in different situations. This enables the mobilization of several facets of his/her conceptions: several situated conceptions. It is from the combination of these various situated conceptions that the researcher can infer hypotheses about the conception of a person related to a specific topic (Fig. 2).

For instance, in the present work, we will use several situations to try to analyse conceptions of genetic determinism: some dealing with identical twins, some with human clones, some with predeterminism of a feature from the parents' genes, etc.

Social representations (Moscovici 1984; Jodelet 1998), called collective representations by Durkheim (1889), can be considered as conceptions shared by the individuals belonging to a social group (Clément 2010). One of the goals of this study is to explore the main collective conceptions (social representations) regarding genetic determinism in several countries. The comparison is based on an intercultural approach to identification that is defined by Hofstede (1984) as *'the collective programming of the mind which distinguishes the members of one group or category of people from another' (p. 5)*. In the same way,
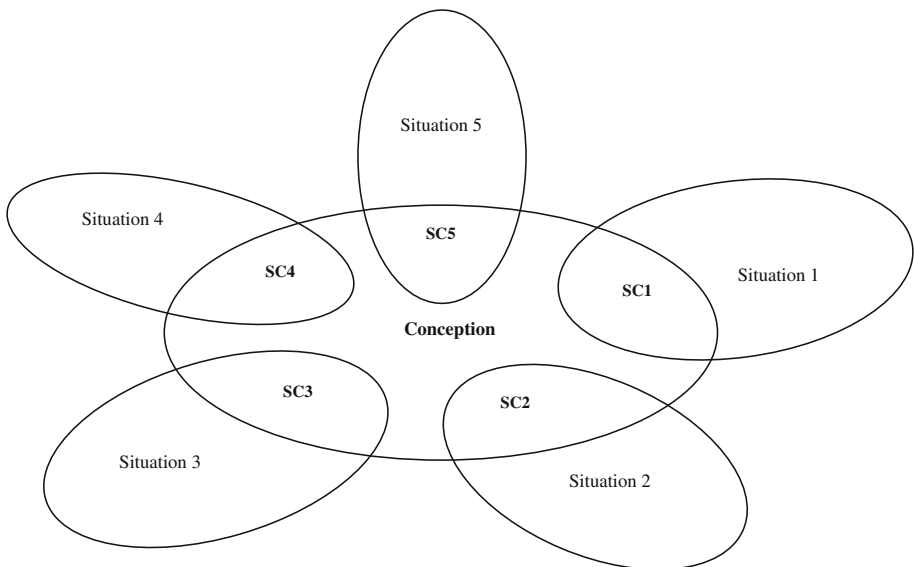
Fig. 2 Links between conception and situated conception (SC1 to SC5 here), according to Clément (1994) and Clément (2010) (*SC* situated conceptions)

Spencer-Oatey (2000, p. 4) explained intercultural research more precisely with the following definition of the cultural dimensions:

> a fuzzy set of attitudes, beliefs, behavioural norms, and basic assumptions and values that are shared by a group of people, and that influence each member's behaviour and his/her interpretation of 'meaning' of other people's behaviour.

The intercultural comparison developed in the project BIOHEAD-Citizen is based on these assumptions in order to understand the diversity of social representations, which also means the diversity of interactions between science and society. We explore here teachers' conceptions about the genetic determinism of humans' behaviours in 23 countries.

2 Hypotheses and Research Questions

This study is based on the following research questions:

- What are the different conceptions about genetic determinism among our total sample of teachers in 23 countries? Until now, no research has been performed from a large intercultural perspective to analyse teachers' conceptions related to genetic determinism.
- Are these different conceptions correlated with one or some of the controlled parameters (country, taught discipline, level of training, religion, gender …)?
- Is the eventual teachers' innatism related to convictions of intolerant attitudes?
- From analysing biology textbooks in 16 of the 23 countries studied in the present work, Castéra et al. (2008) found important differences among the countries. As a consequence, we predict that there are at least some differences among the 23 countries, but we are also expecting differences among other parameters across all these countries, based on the following hypotheses:
- The belief in predestination may be linked to conceptions overestimating the importance of genetic determinism, but it can differ from one religion to another, or can be linked only to the degree of belief in God and practising religion.
- The teachers' level of knowledge in biology should also influence the analysed conceptions: teachers with a diploma in biology could be more aware that human behaviour and performance are also built by epigenesis and not only by genes. However, the epigenetic processes, as well as cerebral epigenesis, are not yet taught in most of the countries (Castéra et al. 2008; Clément et al. 2008): as a consequence, the eventual difference between biology teachers and other teachers must be evaluated.
- As found by Keller (2005) and Dambrun et al. (2009), we predict a correlation between 'intolerant attitudes' (such as sexism or racism) and conceptions overevaluating the importance of genetic determinism.

3 Methods

In order to answer these research questions, a precise methodology was adopted by all the teams involved in the BIOHEAD-Citizen Project and in the following research.

3.1 Procedure

We took two full years to design the BIOHEAD-Citizen questionnaire collectively (Clément and Carvalho 2007). Starting with a bibliography for selecting some already-

validated questions, we added others related to our hypotheses, using interviews and then a long pilot test. This pilot test was translated into each national language using several complementary processes: parallel independent translations, from which was built a consensual translation, this then being retro-translated and compared with the initial formulation (the reference questionnaire was in English). In several countries, the questionnaire was filled in twice by the same students, with 1 month of delay, to analyse the reliability of their answers: when answers were not reliable, they were eliminated. The data from at least 50 pre-service teachers, in most countries, were then analysed, and only the questions differentiating the teachers' answers were utilized in the final questionnaire.

The process for collecting the completed questionnaires was very similar from one country to another. Usually pre-service teachers filled in the questionnaires during a training course and in-service teachers in their school or during training workshops on topics different from those of our investigation. In all cases, the 10-page questionnaire was answered in the presence of the researcher, who guaranteed that the whole process was totally anonymous and immediately gathered the completed questionnaires. In each country, the answers were entered into an Excel file, and all the data were centralized in the Didactic Laboratory of University Lyon 1 (France) for comparative analyses.

3.2 Questionnaire

This anonymous questionnaire included 144 questions dealing with the 6 topics of the BIOHEAD-Citizen project, including questions on personal information, in particular gender, age, the teacher's subject and several other questions related to religious, political, social and economic opinions. The full questionnaire took approximately 30–40 min to complete. The exact processes of construction and validation of the instruments are described in Carvalho and Clément (2007).

For this research, we consider 16 questions about genetics, mainly related to the genetic determinism of behaviour and intellectual performance (Table 1), to analyse the possible interactions between the teachers' knowledge and their values. The answer to some questions is mainly oriented by the teacher's knowledge, or by interaction between his/her knowledge and his/her values. We also use some questions mainly related to values: the teachers' attitudes towards foreigners or towards poor people, or about the rights of homosexuals and gender equality (Table 2). All these questions constitute the analysed variables. Another set of questions is related to teachers' personal information (age, gender, etc.) and social practices: their religion, level of belief in God and of practising religion, level of training (number of years after secondary school), subject taught, etc. These questions are used as instrumental variables (e.g. to define the compared groups).

The responses to all the questions about genetics are based on a Likert scale on which each teacher was asked to tick one of four boxes, ranging between 'I agree' and 'I don't agree'. The majority of the questions concern genetic/biological determinism of human behaviour. These questions can be grouped into four different categories:

(1) Genetic determinism of personal or individual features: questions about clones and twins (A3, A6, A19, A24, A43 and A53).
(2) Genetic/biological differences related to gender (A9, A14, A21, A25, A36, A38 and A46).
(3) Genetic differences among ethnic groups (A35).
(4) Two questions about more general knowledge of genetics (A27, A31: pole K in Fig. 1), although recognizing that question A27 can also be influenced by innatism.

Table 1 The 16 questions related to biological (mainly genetic) determinism (their ranking throughout the whole questionnaire is stochastic)

A3.	If clones of Einstein could be obtained, they all would be very intelligent.	I agree				I don't agree
A6.	Due to identical genes, identical twins have identical immune responses to transplants from another person.	I agree				I don't agree
A9.	Women are less intelligent than men because their brains are smaller than men's brains.	I agree				I don't agree
A14.	Thanks to their physical features, men perform better in athletics than women.	I agree				I don't agree
A19.	Due to identical genes, identical twins have identical brains and, therefore, identical behaviour and ways of thinking.	I agree				I don't agree
A21.	Biologically, women can be as intelligent as men.	I agree				I don't agree
A24.	If clones of Mozart could be obtained, they all would be excellent musicians.	I agree				I don't agree
A25.	It is for biological reasons that women cannot hold positions of high responsibility as men can.	I agree				I don't agree
A27.	The human genome contains more genes than the genome of any other living being.	I agree				I don't agree
A31.	When a couple has already had two girls, the chances that their third child will be a boy are higher.	I agree				I don't agree
A35.	Ethnic groups are genetically different and that is why some are superior to others.	I agree				I don't agree
A36.	Men might be more able to think logically than women, because men might have different brain bilateral symmetry.	I agree				I don't agree
A38.	It is for biological reasons that women more often than men take care of housekeeping.	I agree				I don't agree
A43.	In identical twins, one can be right-handed and the other left-handed.	I agree				I don't agree
A46.	Biologically, men cannot be as sensitive and emotional as women.	I agree				I don't agree
A53.	Due to identical genes, identical twins have identical immune responses to micro organisms.	I agree				I don't agree

Table 2 Questions measuring attitudes towards groups of individuals

A2.	In a modern society, men and women should have equal rights.	I agree				I don't agree
A30.	It is important that there are as many women as men in Parliament.	I agree				I don't agree
A26.	There are too many foreigners in my country: the government should limit immigration.	I agree				I don't agree
A41.	Homosexual couples should have the same rights as heterosexual couples.	I agree				I don't agree
A15.	A priority of the government must be to guarantee resources for health protection of the poor.	I agree				I don't agree
A52.	It is acceptable that poor people do not have access to the same health care quality as rich people.	I agree				I don't agree

The answers to the questions of the three first groups are based on scientific knowledge interacting with values (poles K and V in Fig. 1). They are also related to the different facets of innatism summarized by Brun and Maurel (2005), but the facet related to

sociobiology is missing (questions about sociobiology were in an optional part of the questionnaire, not used in all 23 countries and consequently not used here).

Zimbardo and Gerrig (1999, p. 745) defined an attitude 'as a positive or negative evaluation of people, objects, event, activities, ideas, or just about anything in your environment'. Here, we assess the attitudes towards different groups of people: foreigners, homosexuals, the opposite gender or poor people. The Likert scale used here was initially created for the purpose of assessing this kind of attitude (Likert 1932).

3.3 Samples

The questionnaire was completed by a balance of in-service teachers (i.e. currently active) and pre-service teachers (i.e. adults in their last year of teacher training), in both primary and secondary schools in the 23 countries. In each country, 6 categories of samples were defined: in-service primary school teachers (inP), in-service secondary school biology teachers (inB), in-service secondary school language teachers (inL), pre-service primary school teachers (preP), pre-service secondary school biology teachers (preB) and pre-service secondary school language teachers (preL). In each country, about 50 teachers in each category (only 30 in the smallest countries, such as Malta and Estonia) completed the questionnaire, with a mean of 300 per country (and more in some countries where complementary hypotheses were tested). A total of 8,285 teachers completed the questionnaire; see Table 3 for the size of the samples in each country.

3.4 Data Analyses

3.4.1 Validity and Reliability

Firstly, we analysed the results of the pilot test, involving a longer questionnaire than the final one. In four countries (France, Lebanon, Germany and Portugal), we applied the same pilot test questionnaire twice to the same population of pre-service teachers, after at least 1 month. It was totally anonymous and each student had to memorize his/her nickname used then for analysing the reliability of their answer to each question. In this way, every question on the pilot questionnaire with less than 70 % reliability was deleted from the final questionnaire, used in this paper. This was the case for all the open questions and the questions with a ranking. We kept mainly questions based on a Likert scale or on a choice between two or four items. We conducted several types of multivariate analysis, before finally deciding to use the software 'R' and the analyses presented below. We published a few of the data and analyses from the pilot test (e.g. Clément et al. 2006). In these analyses, we also decided to suppress questions when they were not differentiating the teachers' conceptions, and also when they were too redundant. A challenging problem was the translation of the questionnaire into each national language, and we exposed above how it was performed in each country: independent translations, then a retro-translation of the synthetic initial translation.

Using the final questionnaire, a principal component analysis (PCA) was applied to the questions used in this paper in order to assess the internal validity of the scale (see paragraph 4.1). This PCA confirms the way in which the questionnaire was constructed: there are different views of innatism (justifying performances between individuals or between groups of individuals).

Table 3 Teachers' samples in each country

Countries	Number of teachers
Algeria	223
Australia	201
Brazil	402
Burkina Faso	296
Cameroon	373
Cyprus	322
Denmark	259
Estonia	182
Finland	306
France	732
Germany	365
Great Britain	154
Hungary	334
Italy	559
Lebanon	722
Lithuania	316
Malta	198
Morocco	330
Poland	311
Portugal	350
Romania	273
Senegal	324
Tunisia	753

3.5 Statistical Analyses

All the computations were performed using the statistical software R (Ihaka and Gentleman 1996) with the multivariate analysis package ade4. More precisely, we used four different methods:

- Principal component analysis or PCA (Lebart et al. 1995) to analyse the general structure of the answers.
- Between analyses (Dolédec and Chessel 1989) to discriminate between groups of individuals (different countries, biology teachers and non-biology teachers, different religions, etc.) in order to analyse which conceptions differentiate the most between these groups. A Monte-Carlo permutation test (Romesburg 1985) implemented in the ade4 libraries was then used to test the statistical significance of the instrumental variables' analyses (to ascertain whether the difference between groups is significant or not).
- Sometimes, differences between groups can be a single consequence of another difference. For instance, a gender difference can result from the greater number of males in the biology teachers' group than in the language teachers' group. Using the principal component analysis of the orthogonal instrumental variables (PCAVOI), it is possible to suppress the effect of one variable (Sabatier et al. 1989). For instance, we

suppressed the 'effect of biology/not biology teachers' to determine whether the gender difference persists or not.

- Co-inertia analysis (Dray et al. 2003) is used to compare two sets of questions—for instance, those related to genetics and attitudes—and to determine the possible correlations between them.

These kinds of statistical methods are often used in ecology (Escoufier 1987; Dolédec and Chessel 1989) in order to obtain a general overview of the repartition of species, which is contingent on a number of physical parameters. However, these kinds of methods are also frequently used in sociology (Busca and Toutain 2009) and are suitable for analysing our data (Munoz et al. 2009).

4 Results and Discussion

4.1 The Main Trends in Teachers' Conceptions

Each response from of a teacher expresses his/her situated conception related to the topic of the question, but the coherence of the answers to several questions dealing with the topic 'genetic determinism' expresses his/her conceptions related to that topic more. Moreover, several coherences can be identified among all the teachers, each one expressing a trend that we call a collective conception (a social representation as defined by Moscovici 1984). The goal of the principal component analysis is to identify the general trends of answers among the teachers of our sample, the most discriminative questions and how they are inter-correlated. In other words, we can identify opposite conceptions within our total sample.

The histogram showing the part of the variance explained by each component (Fig. 3c) illustrates that the first component (horizontal axis C1 in Fig. 3a) is the most important for differentiating the responses of teachers, explaining more than 20 % of the total variance (in the absence of any coherence of answers, each component would be, for 16 questions, about 6 %). The second component (C2) explains more than 10 % of the variance, and according to the histogram, the other components can be assimilated as background noise. So, the interpretation of the two first components explains the main part of the teachers' conceptions according to their responses.

Each question is represented, in the correlation circle (Fig. 3a), by a vector ending with the question number (A3, A6, etc.). The more a question contributes to the variance, the longer its corresponding vector. The table (in Fig. 3b) helps readers to interpret the correlation circle with the exact coordinates of the vector in the correlation circle.

Two groups of questions emerge from the correlation circle:

- The first group represents the conceptions related to genetic determinism of human groups (gender and ethnicity), because it is structured by the answers to questions A35, A25, A38, A9, A46, A36, A31, A27, A14 and A21 (negative correlation). These questions concern the possible innate differences between human groups as gender groups or ethnic groups.
- The second group represents the similarities or differences between individuals (due to genes) without consideration of the 'human groups' (gender or ethnicity), because it is structured by the answers to questions A24, A6, A3, A53, A19 and A43 (negative correlation). These questions concern clones or twins.
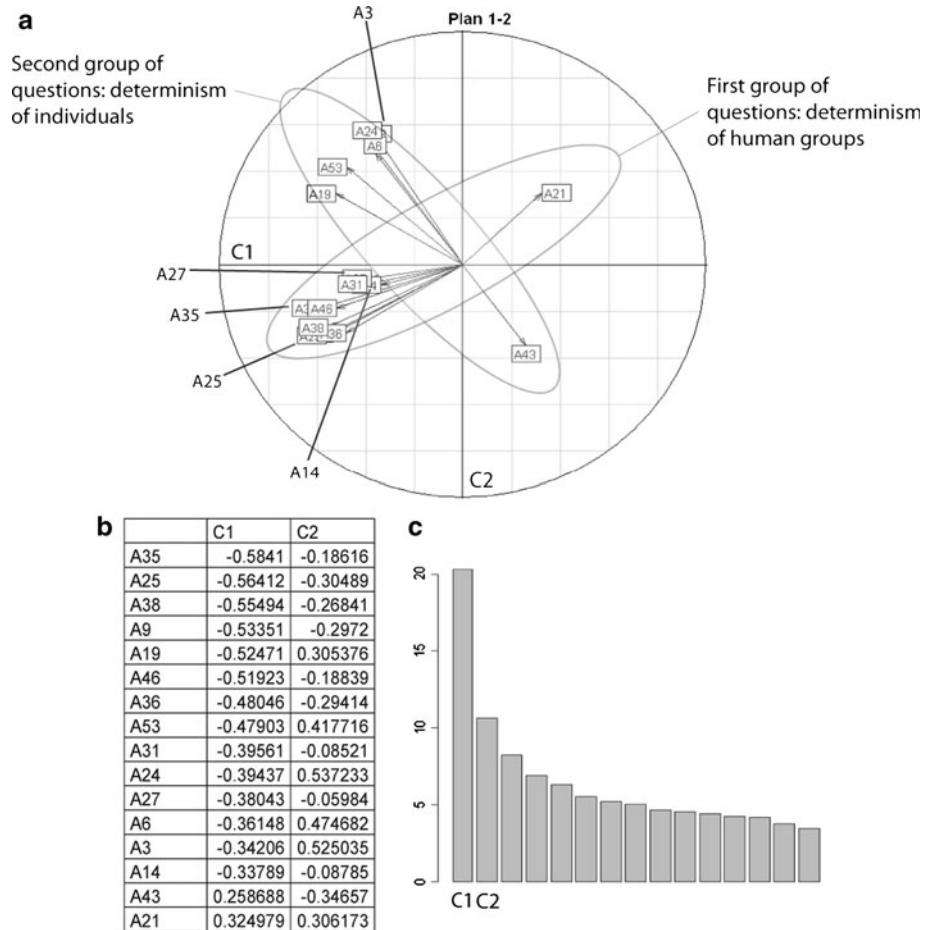
Fig. 3 Principal component analysis (PCA) of the responses from 8,285 in-service and pre-service teachers to the 16 variables on genetics. **a** The correlation circle shows that the differences between the teachers' conceptions come from two independent axes: *C1* and *C2*. **b** The table of coordinates of the variables for the first components *C1* and *C2*. **c** The *histogram* of the proportion of variance for each component: the first two are the most informative (*C1* = 20 % and *C2* = 10 % of the total variance)

According to the PCA, the conceptions of teachers are shown by the two axes of the correlation circle. C1 can be interpreted as the axis of general innatism; both groups of questions are well represented on the C1 axis (6 questions in the first group and 2 questions in the second group have a value between |0.59| and |0.40| on C1; see Fig. 3b). The C2 axis can be interpreted as the axis of individual innatism (only 4 questions, all from the second group, are between |0.54| and |0.40|). In this total sample (coming from 23 countries), most teachers are opposed based on their beliefs to general genetic determinism of differences (individual, ethnic or gender: component C1), and for some teachers, there is no correlation between their beliefs in individual or collective genetic determinism (component C2).

We wish to point out that questions A31 and A27, linked to basic knowledge about genetics (the number of genes in the human genome and the laws of probability), make a small contribution to C1 and almost nothing to C2. So, the answers to these two questions are not correlated with the answers to the questions defining the components C1 and C2.

The most important oppositions between teachers' conceptions are defined by the questions including values with a clear interaction between their knowledge and their values (the poles K and V in Fig. 1). For instance, the most sexist values are justified by the outdated knowledge that it would be biological justification for the higher status of men (A25) or for housekeeping by women (A38) while the less sexist conceptions do not agree with these justifications. The biological justification is seen as the size or the lateralization of the brain in questions A9 and A36. This opposition also relates to the genetic justification of the superiority of some ethnic groups (A35) and is also related to the identity of twins: the biological justification here is the outdated idea of common identity of the brains (question A19) or of the immune systems (question A53) of identical twins, due to their identical genes.

Nevertheless, these last two questions about twins, as well as the two questions related to clones (of Einstein: A3 and of Mozart: A24), define component 2 (the vertical axis in Fig. 3), which is independent of component 1. This means that, for some teachers, the innatism linked to the conviction of individual genetic determinism among twins or clones can be juxtaposed with an absence of innatism linked to egalitarian values concerning the gender or ethnic groups. While Devine (1989) mentioned a conflict between stereotypes and recent beliefs, we prefer to interpret this apparent contradiction as a juxtaposition of situated conceptions (Fig. 2) that are not yet in conflict. We agree with the model of Lepore and Brown (1997) when they explain that it is not an inhibition of the part of a conception.

4.2 Are These Conceptions Social Representations?

When a conception characterizes a group of actors, it can be called a social representation (Moscovici 1984; Clément 2010). We thus now try to determine whether the identified conceptions can be specific to social contexts or groups by testing whether they correlate with one or some of the controlled parameters characterizing each teacher. We then analyse whether these eventual correlations are independent of each other or not.

4.2.1 Strong Differences Among Countries

A between-class analysis of the country groups (Fig. 4) shows that the conceptions of teachers are very different from one country to another.

The histogram showing the percentage of variance of each component (Fig. 4a) shows that the first component (D1) is the most important (D1). This component (D1) subsumes almost all the information (68 % of the variance). The other components can be considered as background noise and need not be taken into account. The correlation circle of the 16 variables on the plane defined by the two first components (Fig. 4b, e giving the exact coordinates of each question in the circle of correlations) shows that D1 is mainly defined by questions about differences between human groups (A35, A38 and A25) but also by two questions related to twins (A19, A53). There is opposition between innatism (groups and individuals) and non-innatism among countries. On the left in D1 (Fig. 4d) are the countries with a more innatist conception of human behaviours or performances and on the right are countries with less innatist conceptions. The most important innatism is observed
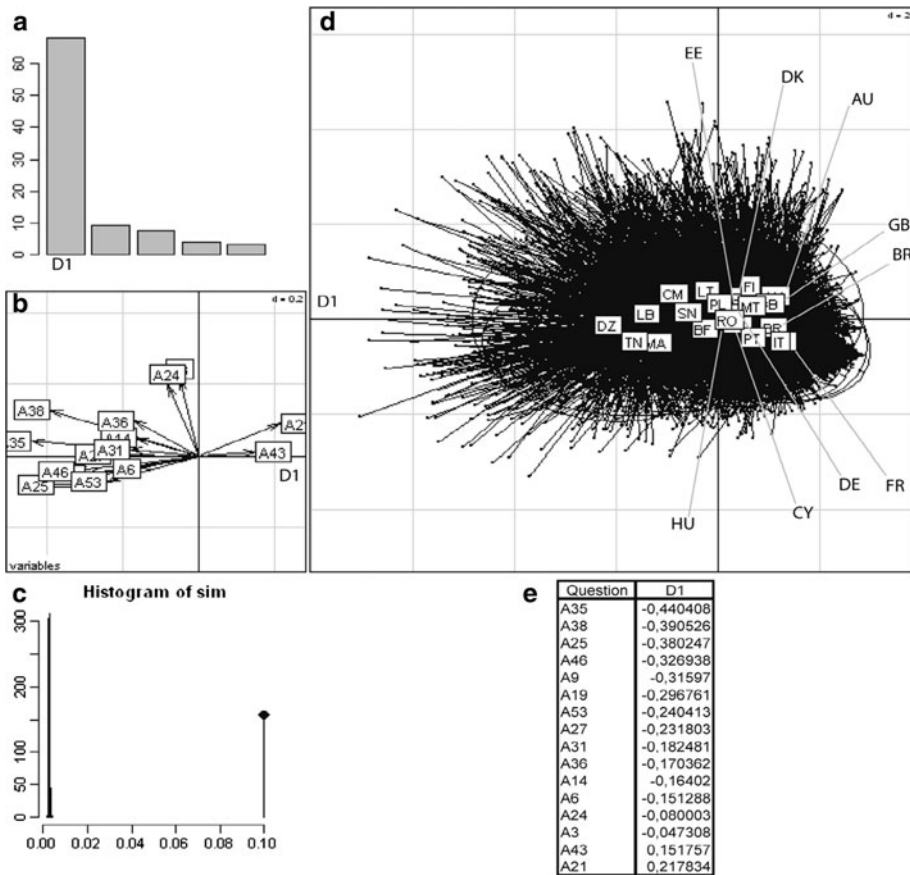
Fig. 4 Between-class analysis differentiating between the 23 countries. From *left* (innatist conceptions) to *right* (less innatist conceptions) of the *horizontal axis D1*: DZ = Algeria, TN = Tunisia, LB = Lebanon, CM = Cameroon, MA = Morocco, SN = Senegal, BF = Burkina Faso, LT = Lithuania, PL = Poland, RO = Romania, HU = Hungary, CY = Cyprus, EE = Estonia, DK = Denmark, DE = Germany, PT = Portugal, MT = Malta, FI = Finland, GB = Great Britain, BR = Brazil, AU = Australia, IT = Italy, FR = France. See the text for explanations of (**a**) (**b**), (**c**), (**d**) and (**e**)

in Africa and Lebanon. The caption for Fig. 4 indicates the ranking of countries according to their conceptions about genetic determinism (strong innatism to less innatism).

The randomization test (Monte Carlo, Fig. 4c) shows that the observed distribution (the trait on the right) is entirely outside the histogram built from 1000 essays by chance (on the left). The differences among the 23 countries are strongly significant ($p < 0.001$). This test assigns a new nationality to each individual randomly and the variance is calculated between these newly formed groups. The operation is repeated 1000 times and all the calculated variances are shown by the bar plot (on the left). The trait on the right of the bar plot is the variance of our sample. The difference between the variance of our sample and the variance resulting from random dispersions shows that the difference observed between countries is not random.

Question A35 (ethnic groups are genetically different and that is why some are superior to other) is the most discriminating question for countries ($\chi^2 = 2346$, $df = 66$, $p < 2.2e$-

16). Figure 5 shows the percentage of teachers who, in each country, agree or disagree with the affirmation that can be considered as expressing racist positions: "ethnic groups are genetically different and that is why some are superior to others". The percentages fluctuate between 97 % of teachers totally or rather disagreeing in France and only 38 % in Lebanon. Even in some European countries, such as Denmark, Lithuania and Poland, between 17 and 34 % of teachers agree or rather agree with 'Ethnic groups are genetically different and that is why some are superior to others'.

Question A25 ('It is for biological reasons that women cannot hold responsible positions as high as men'; Fig. 6) indicates supposed genetic or biological determinism of social performances for women and men. The responses to this question show that the differences among countries are significant ($\chi^2 = 1648.192$, $df = 66$, $p < 2.2e\text{-}16$) with more or less the same differences among countries as for the precedent question on ethnic groups.

The same significant differences among countries are observed for the two questions dealing with gender differences of brains: A9 ('Women are less intelligent than men are because their brains are smaller') and A36 ('Men might be more able to think logically than women, because men might have a different brain bilateral symmetry').
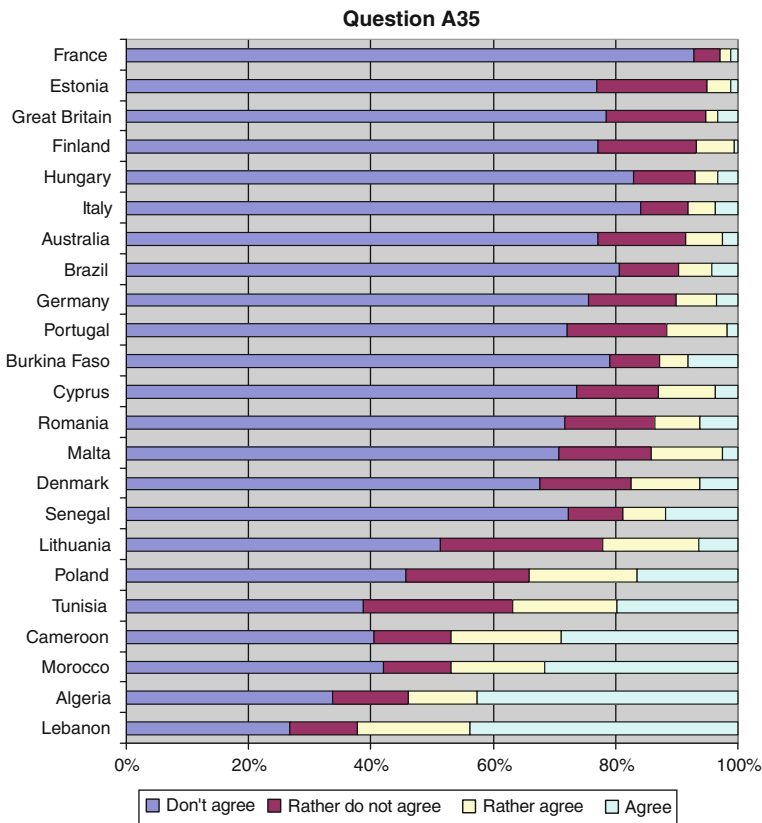
Fig. 5 *Histogram* of countries according to the affirmation A35: 'Ethnic groups are genetically different and that is why some are superior to others'
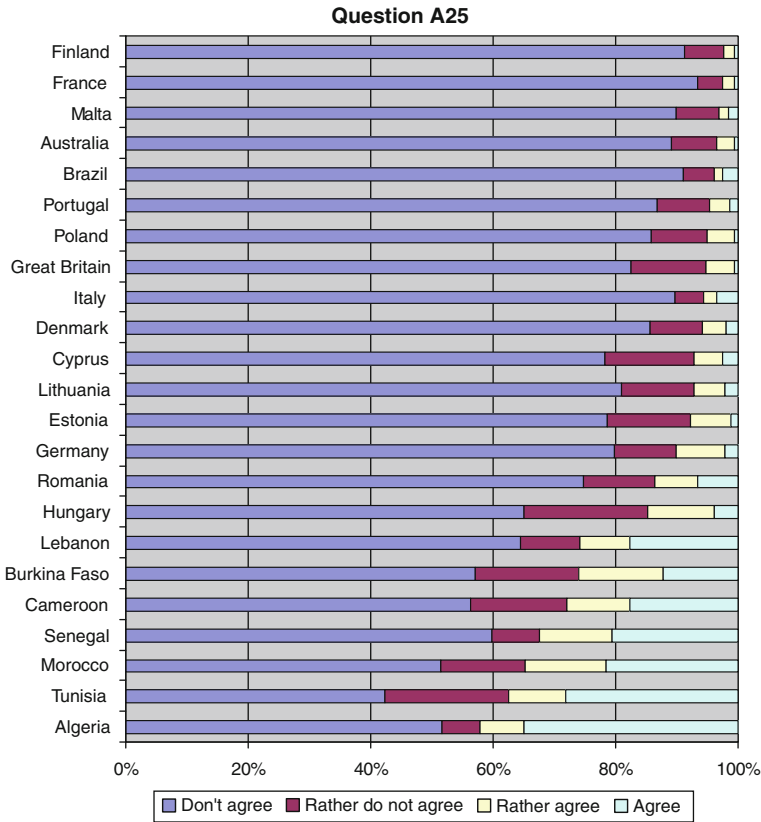
Fig. 6 *Histogram* of the responses by countries to A25: 'It is for biological reasons that women cannot hold responsible positions as high as men'

The justification of biological reasons for intellectual superiority in men has been claimed since the end of the nineteenth century, beginning with Broca's work based on craniology, then in the 1970s by Witelson based on socio-biology and later by different studies in neurobiology. Gould (1981) demonstrated that the claim by Broca was not scientifically rooted (reanalysing Broca's data) and was in fact ideological. Clément (2001) and Vidal and Benoit-Browaeys (2005) undertook the same kind of critical analysis of the publications of neurobiologists. It is accepted today that the size or lateralization of the human brain is not correlated with being more or less intelligent. Nevertheless, this outdated idea is still accepted by a large number of teachers in some countries (Fig. 6), again showing a clear correlation between their knowledge and their values, probably linked to their social practices at home (the three poles K, V and P in Fig. 1).

4.2.2 Are There Differences Linked to Religions?

Our hypothesis was the existence of a correlation between innatism in teachers' conceptions and their practised religion. To test this we undertook different analyses.

In undertaking a between-religion analysis to compare the teachers' conceptions from one religion to another, as already undertaken for countries (Fig. 4), we effectively found

significant differences. Nevertheless, these differences can be taken to be a single conse-
quence of the country effect, because the religions differ greatly from one country to
another. For instance, almost all the Muslims in our sample are from African countries. As
a consequence, a difference between Christian and Muslim teachers' conceptions can
correspond with the difference already described between African and other countries.

To solve this problem, we used a complementary type of multivariate analysis, PCA-
VOI, which allows the suppression of the effect of one variable (Sabatier et al. 1989). This
mathematical process is used to suppress an effect before undertaking a between-variable
analysis, e.g. suppressing the effect of the countries. Thus, it is possible to test whether the
significance of a variable (e.g. the religions) is independent of the suppressed variable or
not.

As a consequence, we suppressed the variance between countries in order to determine
whether the residual variance between the religions is still significant.

The randomization test (Monte Carlo, Fig. 7) shows that the observed distribution is
inside the histogram built from 1,000 stochastic essays: the observed distribution is not
different from a random distribution. The practised religion does not correlate with par-
ticular conceptions about genetic determinism, independent of the effect of the country.
On the contrary, when suppressing the variance coming from religions, we still found
significant differences among the countries. The conclusion is that the effect of religion is
not independent of the country effect, which cannot be reduced to the religion effect.

Each teacher indicated his/her religion (including the possibility to tick 'agnostic',
'atheist' or 'I don't wish to answer') and also his/her degree of belief in God and of
practising religion, using a scale of five boxes ranging between 'I believe in God' and 'I
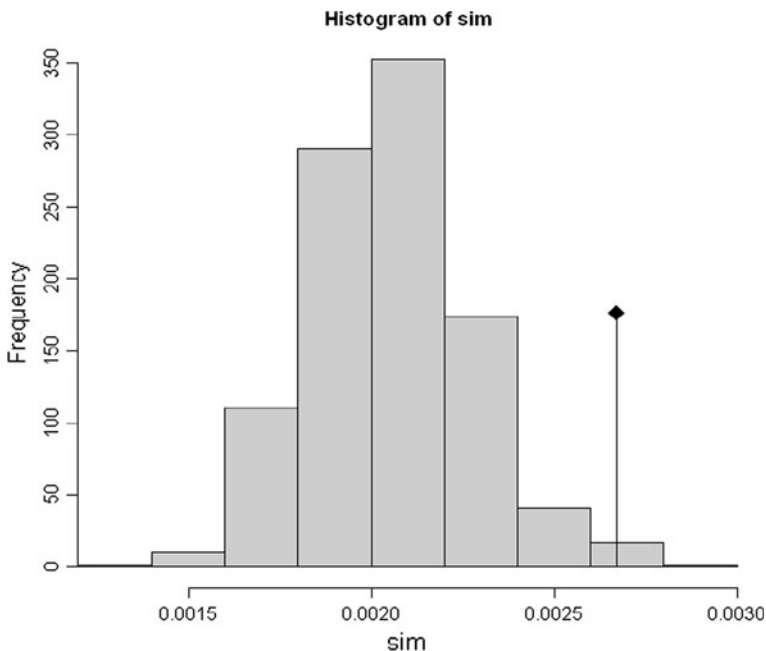
Fig. 7 The Monte Carlo permutation test, indicating the non-significant results among groups of religions
(in our sample: Catholics, Protestants, Orthodoxies, Shiites, Sunnites, Druzes, Agnostics/Atheits, other
religions)
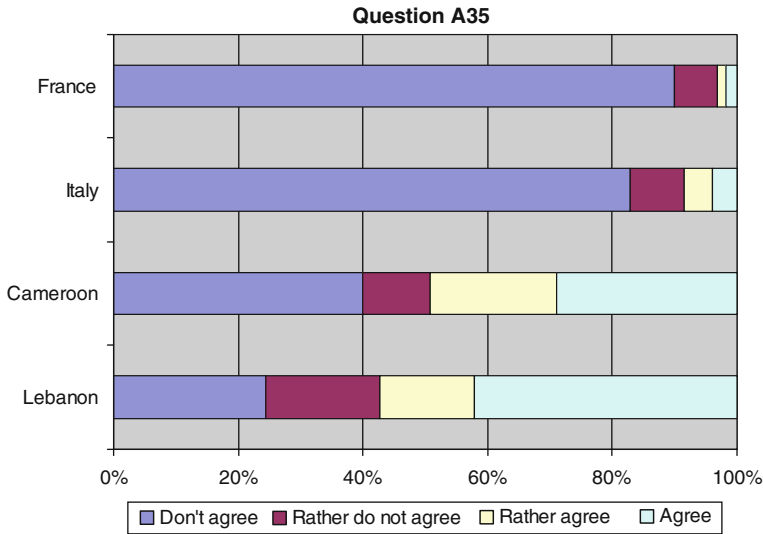
Fig. 8 Responses of Catholic teachers in France, Italy, Cameroon and Lebanon to the question A35 'Ethnic groups are genetically different and that is why some are superior to others' (number of French Catholic teachers = 279, Italian Catholics = 440, Cameroonian Catholics = 173, Lebanese Catholics = 152)

don't believe'; 'I practice religion' and 'I don't practice'. For the responses to these two last parameters, we undertook the same analyses as those just described above for the religions. We obtained the same kind of result: a significant difference, which disappears when suppressing the country effect. However, the country effect is still significant when suppressing the effect of the degree of belief in God or the effect of practising religion.

As a consequence, we cannot say that there is no correlation between belief in genetic determinism and belief in God or practising religion, but that this correlation is mainly part of the sociocultural context of each country.

As an illustration, we compared the conceptions of teachers belonging to the same religion but living in different countries, for instance the responses to question A35 by only Catholic teachers living in France, Italy, Lebanon or Cameroon (Fig. 8): the differences are very significant ($\chi^2 = 362.102$, $df = 9$, $p < 2.2e\text{-}16$). We also observed significant differences for the responses to other questions such as A25, A36, A38 and A19.

4.2.3 A Difference Linked to Knowledge of Biology

To ascertain whether the level of knowledge can influence conceptions about genetic determinism, a comparison between teachers (pre- and in-service) of biology and teachers of the country language (pre- and in-service) is assessed (after suppressing the country effect with PCAVOI): the outcomes show that the Monte Carlo test is significant ($p < 0.001$) and that questions A31 and A27 explain these significant differences. That is not surprising, because they are the two questions that are the most related to biological knowledge. When the questions include some opinions about genetic determinism, they do not differentiate between biology teachers and non-biology teachers: the level in biology does not influence the beliefs in innatism.

4.2.4 Influence of the Level of Training

Teachers were categorized depending on the number of years they had studied at university (regardless of whether they studied biology, language or another subject), to form three groups: N1 = 1 year at university, N2 = 2 or 3 years and N3 = 4 years or more. The difference between the three groups is very significant. Even after a PCAVOI suppressing the country effect, a between-study analysis according to these three groups, completed by the Monte Carlo test, showed a significant difference between the three levels of training. The lowest one showed a higher level of innatism: the number of genes being more important for humans compared with other species (A27), some human ethnic groups being superior to others due to their genes (A35) or for biological reasons women taking care of housekeeping more often than men (A38). So, the lower the level of training, the more teachers believe in innatism, independent of the country. This effect is very important, giving encouragement to calls for an increase in the level of teacher training, but not only in biology.

4.2.5 Co-inertia Analysis: Correlation Between Innatism and Non-Tolerant Attitudes

The idea of co-inertia is the comparison of the structure of a dot cloud (our sample of teachers) with two sets of variables (genetics and attitudes), using two different PCAs. In other words, it is possible to display the similarities (or dissimilarities) of teachers' responses to two different topics: in this case, genetic determinism and more or less tolerant attitudes.

The existence of a strong significant co-structure for the two sets of variables is confirmed using a Monte Carlo permutation test (Fig. 9b). The first component explains 85 % of the variance of both PCAs (Fig. 9a). The analysis of Fig. 9c, d shows the meaning of this co-structure. The most weighted questions (Fig. 9c) are A25, A38, A35, A46 and A9, while in Fig. 9d, the most weighted questions are A41 ('Homosexual couples should have the same rights as heterosexual couples'), A2 ('In a modern society, men and women should have equal rights') and A30 ('It is important that there are as many women as men in Parliament').

The vectors related to these questions tend to point out the tendency that when teachers formulate innatist conceptions for human groups, they also formulate intolerant attitudes related to the rights of women or of homosexuals, and vice versa. Questions on individual innatism are less important (see Fig. 9c showing the small vectors for questions A24, A6, A3, A53, A19 and A43), so an actual correlation between individual innatism (related to human twins or clones) and intolerant attitudes is not demonstrated. Nevertheless, as Keller (2005) and Dambrun et al. (2009) pointed out, we found a significant correlation between intolerant attitudes (for Dambrun et al.: 'anti-egalitarianism') and innatism-related human groups (differences among gender or among ethnic groups).

As a complementary approach, multiple regression analysis was applied in order to evaluate the influences of the independent variables 'genetic determinism' (IV1) and 'country' (IV2) on the dependent variable: intolerant attitudes (DV). According to the value of the multiple correlations (R), only IV1 (genetic determinism) contributes significantly ($R = 0.348$; $p < 0.001$) to explaining DV (intolerant attitudes). Nevertheless, IV2 (countries) and the interaction between IV1 and IV2 are not significant (respectively $p = 0.158$ and $p = 0.052$). This kind of analysis confirms that the variable 'genetic determinism' explains the most important part of the intolerant variation, as shown in our Fig. 9, but without differentiating the two groups of genetic determinism emerging from
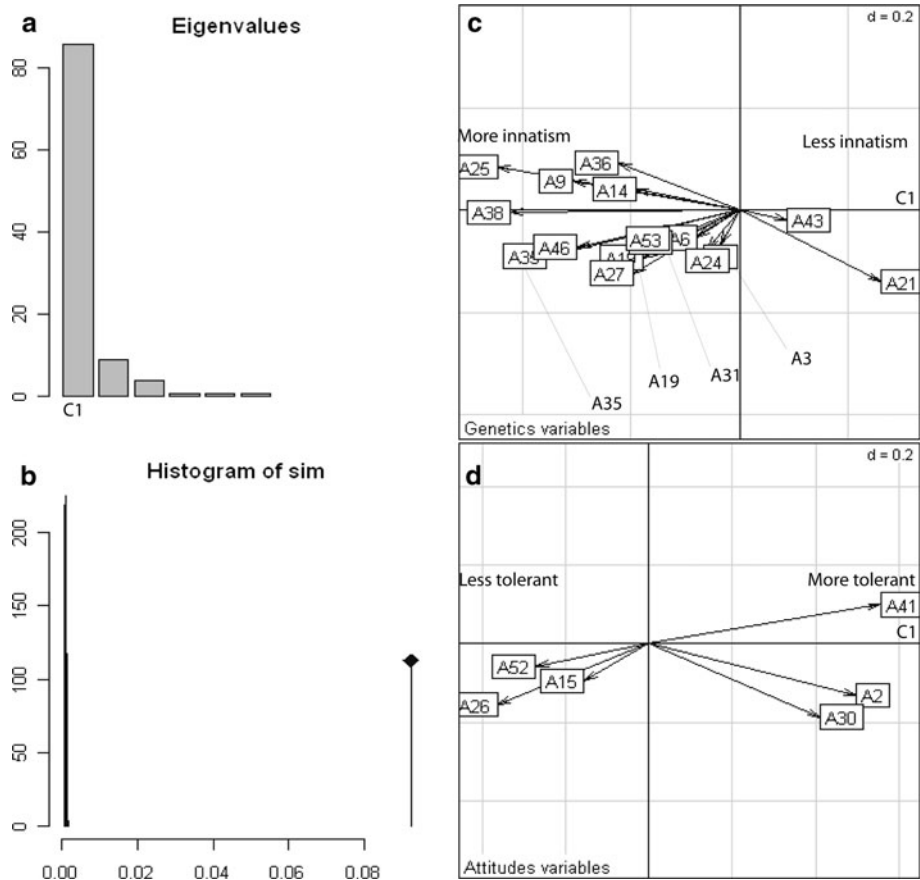
Fig. 9 Co-inertia analysis: **a** histogram of eigenvalues; **b** Monte Carlo test; **c** correlation *circle* of genetics variables; **d** correlation circle of attitude variables

our analyses. This multiple regression analysis is not able to put into evidence the differences among countries related to intolerant attitudes, because the item groups such as 'intolerant attitudes' (Table 2) are heterogeneous. When conducting a between analysis differentiating the 23 countries from only the 6 variables 'intolerant attitudes' (Fig. 10), the difference among countries is very significant and mainly due to axis 1 for the questions A41 (homosexuals' rights), A2 and A30 (gender equality). The more tolerant countries are to the left of this axis, and the less tolerant ones to the right, with a ranking very similar to the ranking observed in Fig. 4 for the variable 'genetic determinism'.

Finally, when carrying out another between analysis discriminating countries by using the 22 questions (genetic determinism + intolerant attitudes), the results confirm the very significant differences among countries and the correlation showed by the co-inertia analysis (Fig. 9): some intolerant attitudes (related to the rights of females and homosexuals, pole V = values in Fig. 1) are strongly correlated with some conceptions of genetic determinism, those justifying by biological arguments the differences among genders or ethnic groups, corresponding to an interaction between scientific knowledge (K) and values (V).
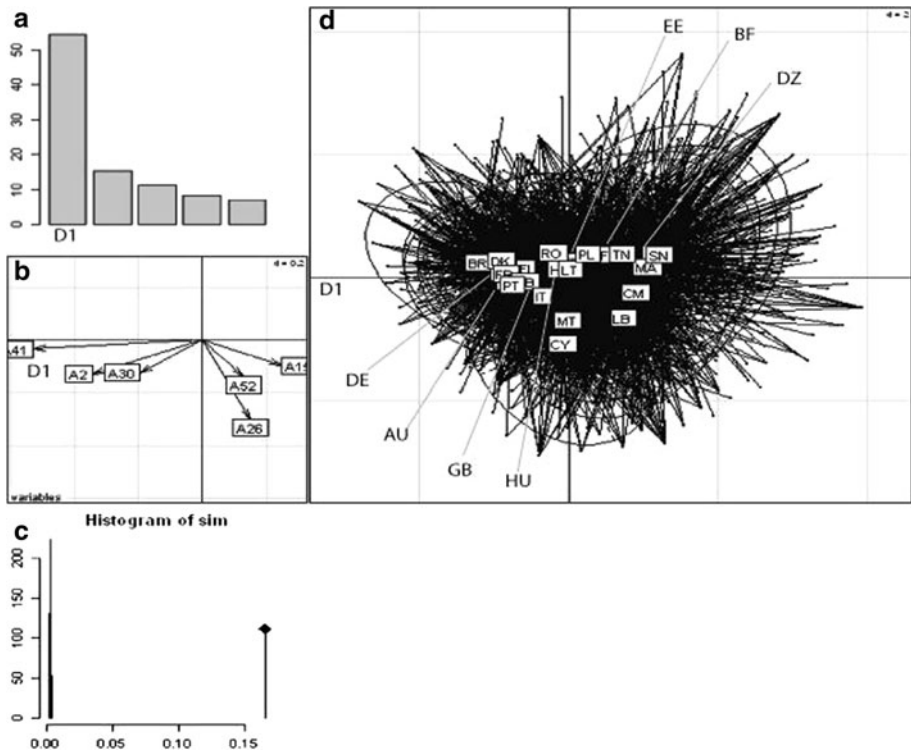
Fig. 10 Between-class analysis differentiating between the 23 countries. From the *left* (more tolerant) to the *right* (less tolerant) of the *horizontal axis* (**a**: *histogram* of variance; **b**: correlation *circle*; **c**: Monte Carlo test; **d**: reparation of countries)

5 Conclusion

Our research firstly investigated the different conceptions about genetic determinism from our total sample of teachers in 23 countries. The results showed that conceptions about genetic determinism cannot be reduced to a simple dichotomy between more innatism and less innatism. When teachers are located more on the innatism pole, we can distinguish two categories of innatism:

- The first one justifies for biological reasons the differences or similarities between human groups (gender or ethnic).
- Another trend justifies for biological reasons the differences and similarities between individuals (of the same group, such as twins or clones).

Our third research question was: is innatism related to intolerant attitudes? The outcomes showed correlations between intolerant attitudes and innatism. However, only the innatism related to human groups is correlated with some intolerant attitudes (see co-inertia analysis, Figs. 9 and 10). This means that on one hand some teachers believe in innatism but with only a strong influence of genes to differentiate individuals and they refuse to justify gender or ethnic differences by genetics. On the other hand, other teachers at the same time accept innatism explaining individual but also collective differences, e.g. related

to gender and ethnic groups, and show intolerant attitudes related to rights linked to gender or homosexuality.

The second research question tried to identify the parameters correlated with innatism. The analysed data show that innatism related to groups (ethnic or gender) is the main difference among countries (Fig. 4) as well as some intolerant attitudes (Fig. 10). The 23 countries differ from their specific sociocultural context, including religion as well as the level of believing in God or of practising religion. In the majority of European countries, as well as in Australia and Brazil, teachers' innatism linked to some intolerant attitudes is less important while in other European countries (such as in Poland or Lithuania), the number of teachers strongly believing in genetic determinism of sociocultural human features is higher. In the African countries of our sample, as well as in Lebanon, more than half of the teachers believe in innatism (individual and collective innatism). These differences in social representations between countries are probably linked to several parameters, including economical, political, geographical and historical dimensions, and are also linked to the way in which the 'mass media' deal with the topic of genetic determinism. In each country, more studies could be developed in order to analyse this last parameter. For instance, in France, the low level of innatism among teachers is probably linked to the history of France, including the strong media coverage of scientists and philosophers formulating ideas about the dangers of this ideology in society.

The level of teachers' training also influences their conceptions, mainly related to genetic determinism about groups, with innatism decreasing when the level of teacher training increases. This result is particularly important, showing from this first international survey (until now, no international survey of this size has been undertaken concerning this topic) that a more citizenship-focused education can be linked, in any country, to an increase in the level of qualification of teachers, for primary as well as for secondary school teachers, and for language or biology teachers.

Improving the way in which biology is taught is also very important. Several researchers (Roth 2004; Leach et al. 2005; Grace 2010, etc.) have already noticed that science education is an important topic for (democratic) citizenship. Marks (2009) argued that a lack of genetic literacy leads to an inability to participate fully in social life and potentially a lack of support for new genetic technologies. The role of education is to give keys to citizens for their decision-making. However, according to our research, we think that genetics education can also lead to better tolerance, which is also a pillar of citizenship. Thus, it is suggested that 'genetic determinism' should be included and discussed in biology teachers' training, with coverage of epistemological approaches including social and ethical dimensions, and with the analysis of the possible interaction between knowledge, values and social practices (KVP: Fig. 1). Explaining how science can be used to justify ideology can help teachers and students become aware of their own conceptions. As shown by our results, biology teachers do not differ from other teachers, meaning that knowledge of biology does not influence their opinion about genetic determinism and innatism. During teaching, students' values and social practices are more difficult to change than their scientific knowledge. Nevertheless, Kochkar (2007) showed that if recent knowledge such as epigenetic processes is included in students' training, innatism can decrease in the population tested. A multi-dimensional approach to considerations of the determinism of human features, including their behaviour and intellectual performances, should help teachers to become less focused on outdated stereotypes of innatism. Training biology teachers could link their biological knowledge to historical, epistemological, psychological and social dimensions. Dambrun and Taylor (2005) already concluded that an understanding of the differences between human groups is possible 'towards contextual

components'. That is an area for urgent improvement of the citizenship dimension at school.

References

Atlan, H. (1999). *'La Fin du 'Tout Génétique' (The end of 'all-genetics')*. Paris: INRA.

Aubert-Marson, D. (2005). 'Les Politiques Eugénistes aux Etats-Unis dans la Première Moitié du XXe siècle' (Eugenic Policies in the United States in the First Half of the Twentieth Century). *Medecine/Science, 21*, 320–323. doi:10.1051/medsci/2005213320.

Bernard, S., Clément, P., Carvalho, G., Alves, G., Berger, D., Thiaw, M.-S., et al. (2008). Sexual transmitted diseases and control of reproduction in biology textbooks. A comparative analysis in 16 countries. *Science Education International, 19*(2), 185–208.

Brun, B., & Maurel, M. C. (2005). 'Introduction à l'Histoire de la Controverse "Inné/Acquis"' (Introduction to the history of the controversy 'nature/nurture'). In M. C. Maurel & B. Brun (Eds.), *L'Inné et l'Acquis. Nouvelles Approches Epistémologiques* (pp. 7–46). Presses Universitaires de Provence, Aix en Provence.

Busca, D., & Toutain, S. (2009). *'Analyse Factorielle Simple en Sociologie' (Factorial analysis in sociology)*. Bruxelles: De Boeck Université.

Caravita, S., Valente, A., Luzi, D., Pace, P., Khalil, I., Valanides, N., et al. (2008). Construction and validation of textbook analysis grids for ecology and environmental education. *Science Education International Journal, 19*(2), 97–116.

Carvalho, G. S. & Clement, P. (2007). 'Construction and validation of the instruments to compare teachers' conceptions and school textbooks of 19 Countries: The European Biohead-Citizen Project'. In *Actes du Congrès international AREF 2007*, 28 August–1 September, Strasbourg. Available from: http://repositorium.sdum.uminho.pt/bitstream/1822/7418/1/Biohead%20project.pdf.

Carvalho, G.-S., Dantas, C., Rauma, A.-L., Luzi, D., Ruggieri, R., Geier, C., et al. (2008). Comparing health education approaches in textbooks of 16 countries. *Sciences Education International, 19*(2), 133–146.

Castéra, J., & Clément, P. (2010). Interaction entre Connaissances Scientifiques et Valeurs dans les Conceptions d'Enseignants Français sur le Déterminisme Génétique de Comportements Humains' (Interaction between Scientific Knowledge and Values in the Conception of French Teachers on the Genetic Determinism of Human Behavior). *Recherches en Didactique des Sciences et des Technologies, 1*, 241–264.

Castéra, J., Clément, P., Abrougui, M., Sarapuu, T., Turcinaviciene, J., Aggoram, B., et al. (2008). Genetic determinism in school textbooks: A comparative study conducted among 16 countries. *Science Education International, 19*(2), 163–184.

Clément, P. (1994). 'Représentations, Conceptions, Connaissances' (Representations, Conceptions, Knowledge), In A. Giordan, Y. Girault, & P. Clément (Eds.), *Conceptions et connaissances* (pp. 15–45). Berne: Peter Lang.

Clément, P. (2001). Using Complex Images in the Popularization of Science: Scientific or Ideological Agenda? In J. F. Rouet, J. Levonen, & A. Biardeau (Eds.), *Multimedia learning: Cognitive and instructional issues* (pp. 87–98). London: Pergamon (Elsevier Science).

Clément, P. (2006). Didactic transposition and the KVP model: Conceptions as interactions between scientific knowledge, values and social practices. In *Proceedings of summer school ESERA* (pp. 9–18). IEC, Univ. Minho (Portugal).

Clément, P. (2010). 'Conceptions, représentations sociales et modèle KVP' (Conceptions, social representations and KVP model), *Skholê* (Univ. De Provence, IUFM) 16, 55–70.

Clément, P. & Carvalho, G. (2007). 'Biology, health and environmental education for better citizenship: teachers' conceptions and textbook analysis in 19 Countries. In *Proceedings WCCES XIII* (*World Council of Comparative Education Societies*) (p. 15). Sarajevo, CD-Rom.

Clément, P., Carvalho, G., Abrougui, M., Khalil, I., Thiaw, M. S., Ndiaye, V., et al. (2006). Differences in values associated to biology, health and environmental questions among France, Portugal, Hungary, Senegal, Lebanon and Tunisia. In S. Yoong et al. (Eds.), *IOSTE XII Meeting*, *Proceedings XII IOSTE Conference, Science and Technology Education in the Service of Humankind* (pp. 149–151). Universiti Sains Malaysia.

Clément, P., Mouelhi, L., Kochkar, M., Valanides, N., Nisiforou, O., Thiaw, M. S., et al. (2008). Do the images of neuronal pathways in the human central nervous system show feed-back? A comparative study in fifteen countries. *Science Education International, 19*(2), 117–132.

Clément, P., & Quessada, M. P. (2009). Creationist beliefs in Europe. *Science, 324*(26), 1644.

Dambrun, M., Kamiejski, R., Haddadi, N., & Duarte, S. (2009). Why does social dominance orientation decrease with university exposure to the social sciences? the impact of institutional socialization and the mediating role of "Geneticism". *European Journal of Social Psychology, 39*(1), 88–100. doi: 10.1002/ejsp.498.

Dambrun, M., & Taylor, D. M. (2005). '"Race" sex and social class differences in cognitive ability: Towards a contextual rather than genetic explanation. *Current Research in Social Psychology, 10*, 188–202.

Delors, J. (1996). Learning the treasure within. In *Report to UNESCO of the international commission on education for the twenty-first century*. Paris: UNESCO.

Devine, P. G. (1989). Stereotypes and prejudice: Their automatic and controlled components. *Journal of Personality & Social Psychology, 56*, 5–18. Available at: https://mywebspace.wisc.edu/wtcox/web/trishpubs_files/Devine%20%281989%29.pdf?uniq=-c4okl9. Accessed Feb 22, 2011.

Dolédec, S. & Chessel, D. (1989). 'Rythmes Saisonniers et Composantes Stationnelles en Milieu Aquatique II—Prise en Compte et Elimination d'Effets dans un Tableau Faunistique' (Seasonal Rhythms and Aquatic Stational Components II—Recognition and Elimination of Effects in a Faunistic Table), *Acta OEcologica, OEcologia Generalis* 10, 207–232. Available at: http://pbil.univ-lyon1.fr/R_old/articles/arti060.pdf. Accessed 22 Feb 2011.

Dray, S., Chessel, D., & Thioulouse, J. (2003). Co-inertia analysis and the linking of the ecological data tables. *Ecology, 84*(11), 3078–3089. doi:10.1890/03-0178.

Durkheim, E. (1889). 'Représentations Individuelles et Représentations Collectives', *Revue de Métaphysique et de Morale*, volume VI. Available at: http://classiques.uqac.ca/classiques/Durkheim_emile/Socio_et_philo/ch_1_representations/representations.pdf. Accessed 20 Feb 2012.

Escoufier, Y. (1987). The Duality Diagram: A Means of Better Practical Applications. In P. Legendre & L. Legendre (Eds.), *Development in numerical ecology* (pp. 139–156). Berlin: Springer.

Forissier, T., & Clément, P. (2003). Teaching "biological identity" as genome/environmental interactions. *Journal of Biological Education, 37*(2), 85–91. doi:10(1080/00219266),2003,9655857.

Gericke, N. M., & Hagberg, M. (2007). Definition of historical models of gene function and their relation to students' understanding of genetics. *Science & Education, 16*, 849–881. doi:10.1007/s11191-006-9064-4.

Giordan, A., & De Vecchi, G. (1987). *'Les Origines du Savoir: des Conceptions des Apprenants aux Concepts Scientifiques'* (The origins of knowledge: From the learners' conceptions to science concept),. Neuchâtel-Paris: Delachaux & Niestlé.

Gould, S. J. (1981). *The mismeasure of man*. New York: W.W. Norton & Co.

Grace, M. (2010). Science for Citizenship. In J. Frost (Ed.), *Learning to teach science in the secondary school* (3rd ed., pp. 218–232). London: Routledge.

Hamer, D. H., Hu, S., Magnuson, V. L., Hu, N., & Pattatucci, A. M. (1993). A linkage between DNA markers on the X chromosome and male sexual orientation. *Science, 261*, 321–327. doi:10.1126/science.8332896.

Hofstede, G. (1984). National Cultures and Corporate Cultures. In L. A. Samovar & R. E. Porter (Eds.), *Communication between cultures*. CA: Wadsworth, Belmont.

Ihaka, R., & Gentleman, R. (1996). R: A language for data analysis and graphics. *Journal of Computational and Graphical Statistics, 5*, 299–314. doi:10.2307/1390807.

Jacquard, A. (1972). *'Eloge de la Différence' (In praise of difference)*. Paris: Le Seuil.

Jacquard, A., & Kahn, A. (2001). *'L'Avenir n'est Pas Ecrit' (The future is not written)*. Paris: Bayard.

Jodelet, D. (1998). Représentation Sociale: Phénomènes, Concept et Théorie. In S. Moscovici (Ed.), *Psychologie Sociale (1st edition: 1984)* (pp. 361–382). Paris: PUF fondamental.

Keller, J. (2005). In genes we trust: The biological component of psychological essentialism and its relationships to mechanisms of motivated social cognition. *Journal of Personality and Social Psychology, 88*(4), 686–702. doi:10.1037/0022-3514.88.4.686.

Kochkar, M. (2007). '*Les Déterminismes Biologiques. Analyse des Conceptions et des Changements Conceptuels Consécutifs à un Enseignement sur l'Epigenèse Cérébrale chez des Enseignants et des Apprenants Tunisiens*' (Biological Determinism. Analysis of Conceptions and Conceptual Changes Resulting from Education on Cerebral Epigenesis for Tunisian Teachers and Learners), Thèse Doctorat Université Lyon 1 & ISEFC—Université de Tunis.

Kupiec, J.-J., & Sonigo, P. (2000). *'Ni Dieu, Ni Gène' (Neither God, Nor Gene)*. Paris: Seuil.

Leach, M., Scoones, I., & Wynne, B. (2005). *Science and citizens: Globalization and the challenge of engagement*. London and New York: Zed Press.

Lebart, L., Morineau, A., & Piron, M. (1995). *'Statistique Exploratoire Multidimensionnelle' (Exploratory multivariate statistics) (3rd edition: 2000)*. Paris: Dunod.

Lepore, L., & Brown, R. (1997). Category and stereotype activation: Is prejudice inevitable? *Journal of Personality and Social Psychology, 72*(2), 275–287.

Lewontin, R. (2000). *The triple helix: Gene, organism, environment*. Cambridge, MA: Harvard University Press.

Lewontin, R. C., Rose, S., & Kamin, L. J. (1984). *Not in our genes: Biology, ideology and human nature*. New York: Pantheon.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 1–55.

Marks, N. J. (2009). 'Public understanding of genetics: The deficit model', *eLS*, doi: 10.1002/9780470015902.a0005862.

Meaney, M. J. (2001). Nature, nurture and the disunity of knowledge. *Annals of the New York Academy of Sciences, 935*, 50–61. doi:10.1111/j.1749-6632.2001.tb03470.x.

Moscovici, S. (1984). The Phenomenon of Social Representations. In R. M. Farr & S. Moscovici (Eds.), *Social representations* (pp. 3–69). Cambridge: Cambridge University Press.

Munoz, F., Bogner, F., Clément, P., & Carvalho, G. S. (2009). Teachers' conceptions of nature and environment in 16 countries. *Journal of Environmental Psychology, 29*(4), 407–413.

National Human Genome Research Institute. (2010). '*Finding the missing heritability of complex diseases*.' Available at: http://www.genome.gov/27534229. Accessed 16 Jan 2012.

Nelkin, D., & Lindee, M. S. (1995). *The DNA mystique: The gene as a cultural icon*. New York: Freeman.

Philosophie Magazine. (2007). '*Dialogue: Nicolas Sarkozy et Michel Onfray—Confidences Entre Ennemis*' (Dialogue: Nicolas Sarkozy and Michel Onfray—Confidences between Enemies). Available at: http://www.philomag.com/article,dialogue,nicolas-sarkozy-et-michel-onfray-confidences-entre-ennemis,288.php. Accessed 22 Feb 2011.

Quessada, M. P., Clément, P., Oerke, B., & Valente, A. (2008). Human evolution in science textbooks: A survey in eighteen countries. *Science Education International, 19*(2), 147–162.

Ranger, U., & Keller, J. (2011). Essentialism goes social: belief in social determinism as a component of psychological essentialism. *Journal of Personality and Social Psychology, 100*(6), 1056–1078.

Rice, G., Anderson, C., Risch, N., & Ebers, G. (1999). 'Male homosexuality: Absence of linkage to microsatellite markers at Xq28. *Science, 284*, 665–667. doi:10.1126/science.284.5414.665.

Romesburg, H. C. (1985). Exploring, confirming, and randomization tests. *Computers & Geosciences, 11*(1), 19–37.

Roth, W. (2004). Educating for citizenship: Reappraising the role of science education. *Canadian Journal of Science, Mathematics and Technology Education, 4*(2), 149–168.

Sabatier, R., Lebreton, J. D., & Chessel, D. (1989). 'Principal Component Analysis with Instrumental Variables as a Tool for Modelling Composition Data. In R. Coppi & S. Bolasco (Eds.), *Multiway data analysis* (pp. 341–352). North-Holland: Elsevier Science Publishers B.V.

Smith, M. U., & Adkison, L. R. (2010). Updating the model definition of the gene in the modern genomic era with implications for instruction. *Science & Education, 19*(1), 1–20. doi:10.1007/s11191-008-9161-7.

Song, R. (2003). *The human genome project as soteriological project, In brave New World?: Theology, ethics and the human genome* (pp. 164–184). London: T&T Clark.

Spencer-Oatey, H. (2000). '*Culturally speaking: Managing rapport through talk across cultures*', Continuum, London.

Vidal, C., & Benoit-Browaeys, D. (2005). *'Cerveau, Sexe et Pouvoir' (Brain, sex and power).* Paris: Éditions Belin.

Wilson, E. O. (1978). *On human nature*. Cambridge, MA: Harvard University Press.

Wu, C.-T., & Morris, J. R. (2001). Genes, Genetics, and Epigenetics: A Correspondence. *Science, 293*, 1103–1105.

Zimbardo, P. G., & Gerrig, R. J. (1999). *Psychology and life* (15th ed.). New York: Longman.