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Integrating Bioethics in Sciences' curricula using values in science and socio-scientific issues

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Abstract

The main objective of the present work is selection of ethical issues that should be addressed with first year undergraduate and K-12 students.

Since K-12 Sciences' curriculum, in Portugal, does not include bioethics content in any discipline explicitly, teachers need to make an effort to include it. Some online materials are available to use in high school classes and will be discussed.

My proposal combines inquiry learning-teaching methods with the aim of promoting the discussion of bioethics issues in accordance to UNESCO Bioethics Core Curriculum already adopted by twenty universities throughout the world (Darwish 2015). Some of the issues that are addressed are: ecology and environment ethics, infectious diseases and vaccination, water for all, intellectual property, genomes and patents, biotechnological advances (genetic modified organisms and synthesis of genomes), future generations, climate changes and natural resources, biomedical advances and human rights, authorship and contributions in scientific publications, and biobanks.

In conclusion, this study may constitute an example to facilitate the implementation, by K-12 teachers, of active inquiry strategies, using features of science such as values and socio-scientific issues, and focused on the discussion of concrete ethical issues facing humanity. It also constitutes a proposal of integrating Bioethics in undergraduate sciences' curricula.

Keywords

Bioethics, socio-scientific issues, values in science, inquiry, K-12, undergraduate.

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1. Introduction

The development seen in the last decades in Biology has caused individuals to question the consequences, benefits and possible impacts of molecular biology, medicine, genetics and biotechnology at the individual/citizen level and in society. Therefore the promotion of scientific literacy is essential and it is known that science education today is the most important factor to promote it. And since some level of understanding of bioethical issues is essential for science literacy, these issues should be included in the K-12 curriculum, as well as at the undergraduate level for all science students.

Using bioethical issues in the classroom promotes the development of a specific type of questioning, argumentation of different perspectives and, in some cases, proposed solutions (Keskin 2013). My proposal constitutes one version of inquiry-based learning using dilemmas, with ill-structured problems and open-ended questions. In a class based on dilemmas scientific argumentation is essential, however including bioethical questions in the classroom will develop other useful skills and prepare students to become citizens who make decisions, such as public policy decisions, for example the ones related with allocating public resources, using scientific data, from different sources, and multiple bioethical views (Gutierez 2015).

This learning proposal considers that students can understand the complex nature of doing science focusing in some Features of Science (Matthews 2012) such as values in science and socio-scientific issues, and therefore the need of a bioethics reflexion during any scientific activity. Since K-12 Sciences' curriculum, in Portugal, does not include bioethics content in any discipline explicitly (except one learning objective on 9th grade's curriculum, *, in Table 1), science teachers need to make an effort to include it. Recently a Portuguese project "Education for Values and Bioethics" addressed some of the known gaps in the middle school curriculum (Nunes et al. 2015).

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For undergraduate students, my proposal combines inquiry learning methods with the aim of promoting the discussion of bioethics issues in accordance to UNESCO Bioethics Core Curriculum already adopted by twenty universities throughout the world (Darwish 2015) in a single discipline common to all science minors of a faculty or department of sciences. Some of the themes that are addressed in this proposal are: ecology and environment ethics, infectious diseases and vaccination, water for all, intellectual property, genomes and patents, biotechnological advances (genetic modified organisms and synthesis of genomes), future generations, climate changes, exploitation of natural resources, biomedical advances and human rights, authorship and contributions in scientific publications, biobanks and DNA databases.

In summary, this study may constitute an example to facilitate the implementation, by K-12 teachers, of active inquiry strategies, using features of science such as values in science and socio-scientific issues, and focused on the discussion of concrete ethical issues facing humanity. It also constitutes a proposal of integrating Bioethics in undergraduate sciences' curricula.

2. Proposed methodology

2.1. Teaching-learning argumentation

In K-12 classes, science teachers' focus – regarding bioethics - should be to teach students how to compose a good argument, that includes reasons, facts, evidence to support it and persuasive language, in accordance with other authors, such as in the IDEAS project (In: https://www.beep.ac.uk/content/284.0.html). I propose the use of inquiry learning-teaching methods to practice argumentation, which will contribute to develop critical thinking skills (Chowning et al. 2012) and should also promote the respect for different views of others.

College students should know how to compose arguments and I propose the introduction of a curricular discipline of Bioethics, for first year undergraduate students enrolled in any faculty or department of sciences, that should focus in promoting the critical thinking of relevant themes and development of decision-making skills.

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2.2. Learning Features of Science: Socio-Scientific issues (SSI) and Values in Science

Features of Science, that include Nature of Science topics, constitute an important theme in science education (Matthews 2012) that allows students to understand the complexity of science. In this proposal we focused on two Features of Science - Socio-Scientific issues (SSI) and Values in Science - and also on the use of inquiry-based learning strategy.

2.2.1. Socio-Scientific Issues (SSI)

The learning-teaching strategy using Socio-Scientific issues (SSI) is similar to the strategy of Science-Technology-Society (STS), however SSI includes argumentation and reasoning skills about the benefits and detriments of each issue. Therefore, learning Bioethics can be done using collaborative work focusing on SSI and promoting students' claims and justifications (Osborne 2010).

SSI provide a real-world context for Bioethics discussions mainly by including biological advances and the relationship between science and society, which may help K-12 students to engage with the theme, and make decisions on the impact of science, as others described (Gutierez, 2015).

2.2.2. Values in Science

Some views of science consider that it is based only on facts and is value-free, however recent sociological views of science proposed a science framework including the relation of science-technology-society, the SSI, and science methods, e.g. values in science (Allchin 1999).

Citizens in order to be able to discuss scientific themes, need to learn about the values in science. The use of episodes of History of Science to teach these values is suggested, such as the one of Pasteur and his "germ theory of disease". The main Values in Science, or the epistemic values expressed by Science, are (Allchin 1999; Serageldin 2011): clearness, honesty, collaboratively, acknowledgment of authorship, skepticism, creativity, reliability, testability, accuracy, precision, simplicity, repeatability, novelty, universalism, organized skepticism, interventional experiments and controlled observation.

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3. Contents: selecting themes and integration in curricula's themes

3.1. K-12 students

All students should learn by the end of K-12 education, in Natural Sciences and Biology disciplines, how to articulate our responsibilities towards nature and future generations when focusing in socio-scientific issues such as biotechnology (O'Mathúna 2007) and use of natural resources. Biotechnology, mainly by genetic engineering, can ensure the production of saline water-, drought-, herbicidal-resistant plants, as well as producing plants with vitamins-enhanced content (Zimmermann and Hurrell 2002). While the production of herbicide-resistant plants will benefit agriculture, this will not benefit neither the consumers or the future generations by polluting the soil, and therefore it constitutes a conflict. The production of saline water- and drought-resistant plants will be important for present and future generations living in locations with these conditions, such as in Africa. Another molecular biology technological advance is related with a novel scientific area named Synthetic Biology and artificial life: the first synthetic cell was made in 2010 (Gibson et al. 2010) and the artificial bacteria with minimal genome (Syn 3.0) was obtained recently (Hutchison et al. 2016); these two examples are good to promote discussion in the classroom if there should be a limitation to science work, and if so who should decide.

Another important issue is vaccination: should it be mandatory for all students? And if so, benefits against infectious diseases and potential risks should be learned during K-12 education in Natural Sciences (at middle school level) and Biology (at high school, for example 12th grade).

Intellectual property, including authorship, is a core issue of ethics and bioethics and should constitute one of the themes of K-12 education since students are frequently asked to perform collaborative work, such as finding digital resources to answer questions or information about a theme proposed by the teacher. K-12 students should know how to cite the work of others as well as defining the authorship of the group's work and the adequate use of creative commons denominations (*In:* https://creativecommons.org).

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Other issues to be discussed are ecology and environmental ethics, such as natural resources that includes biodiversity and species protection against extinction and geodiversity and non-renewable, in our lifetime, geological resources, such as oil and charcoal. Another natural resource is water, that is important for all life forms, and is considered a human right (*In:* http://waterforall.org). The protection of biodiversity issue also includes the discussion about the risks of introduction of invasive species, genetic modified and synthetic organisms and biobanks, for example of germplasm. The discussion of the respect for future generations rights includes all the alterations made in natural ecosystems and the ones done at a global level, such as climatic changes.

The advantages and disadvantages of DNA databases can be addressed with a role playing activity dividing students in two groups using either for or against claims of asking all citizens to provide DNA for a database; this activity can address another objective of learning to be tolerant to views of others.

Some biomedical issues should also be addressed with K-12 students as mentioned by other authors "Education for health" (Nunes et al. 2015), and such as informed consent and biomedical tests.

The proposal of SSI to be included in each curriculum's theme is presented on Table 1.

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Table 1. Overview of science topics and the corresponding SSI to be included in K-12 education.

Discipline (grade)	Science topic in the curriculum	Bioethics theme – proposal of SSI to be included in the curriculum
Natural Sciences (Middle School)	Sustentability on Earth (7th and 8th grades)	Protecting geodiversity and geological processes Protecting biodiversity and biosphere Climate changes; water as a right Future generations
	Scientific and technological development (8th grade)	Biotechnology and synthetic biology Intelectual property and patents
	Individual and public health (9th grade)	Vaccination
	Reproductive system (9th grade)	IVF human cloning
	Genetics, its applications and bioethical issues* (9th grade)	Genetic tests; DNA databases Consent; privacy; confidentiality Transgenic food
Biology & Geology (10th and 11th grade), Biology (12th grade) and Geology (12th grade) (High School)	Human interventation on Earth's subsystems (10th grade)	Future generations and sustainable development Water as a right Exploitation versus preservation of natural resources
	Hidrographic basins (11th grade)	
	Sustainable exploitation of geological resources (11th grade)	
	Reproduction (Biology - 12th grade)	IVF human cloning
	Genetic heritage (Biology - 12th grade)	Intellectual property and patents
	Food production & sustainability (Biology - 12th grade)	Biotechnology and transgenic food
	Immune system (Biology - 12th grade)	Vaccination
	Preservation of environment (Biology - 12th grade)	Sustainable development
	Water exploration (Geology - 12th)	Water as a right

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On Table 1, one can see some repetition of themes comparing middle and high school curricula, however since the 9th grade is the last common year for all students these topics should be mainly approached by the end of middle school. Therefore, for the students choosing Biology & Geology (10th and 11th grades), Biology (12th grade) and Geology (12th grade) the SSI themes should be explored with more detail and complexity.

Bioethics principles, such as respect for persons, beneficence/nonmaleficence and justice (Chowning et al. 2012; UNESCO 2011) should be included in 7th grade.

In order to learn about values in science I propose the use of the historical episode of Louis Pasteur and his "germ theory of disease".

3.2. Science undergraduates in a Bioethics discipline

This proposal includes inquiry-based learning in a Bioethics discipline to be created in the first year of each BSc.

Learning the Values in Science may help to decide between two competing hypotheses for the best to include in a group report or as self-reasoning; and the use of the historical episode of Louis Pasteur and his "germ theory of disease" is also recommended as a theme of discussion with increased detail.

Intellectual property, patents and authorship are themes that should be discussed by undergraduates, allowing learning the benefits and bad consequences of each. Controversial issues that should be addressed are associated with patenting of biotechnological inventions, genome and DNA tests. The "patentability" of the human genome is not possible since 2013 by a decision of the Supreme Court of USA that established that DNA is not patentable (Zaragoza 2015). The discussion of genetic tests (for example, for diseases) and DNA databases (for example in the search of missing persons and any crime scene), should include consent, privacy and confidentiality.

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The three companies that have more patents related with food production are: Monsanto, USA, Dupont, USA, and Syngenta, Switzerland. Recently, Syngenta obtained the patent of natural pepper, that were obtained by farmers' breeding activity, without genetic engineering, in the last millions of years. And recently the European Patent Office revoked Monsanto patent on melons (*In:* http://no-patents-on-seeds.org). It is important to discuss arguments for and against, such as the costs – for the farmer – of seeds obtained by genetic engineering with patent will be higher and in some cases it makes impossible to use it; however, only transgenic plants survive in soil-containing herbicides, such as glyphosate.

The protection of biodiversity issue also includes the discussion about the risks of introduction of invasive species and genetic modified and synthetic organisms. The discussion of the respect for future generations rights includes all the alterations made in natural ecosystems and at a global level, such as climatic changes.

The use of animals in medical experiments is also important to discuss facing both the benefits to humans and the welfare of the animals.

Databases obtained by DNA profiling are also controversial with benefits in searching for missing persons and as a proof for forensics analyses of any crime scene.

Another issue that should be addressed is the "Right2water" - an initiative of European citizens - that constitutes the first petition with more than 1.5 million signatures, by citizens of all countries of the European Union, that demanded the water and the sanitation as a human right and water as a public good.

In the Bioethics discipline for all the BSc courses it should also be learned how does an ethics committee work since any of the science professionals may be asked to integrate one.

The curriculum should be different between different BSc courses on the deontological issues, since rights and duties are different for each future professional, such as, for example, a biologist and an astronomer, so this module/lesson should be taught by different science professionals. Medical bioethics contents should be included in another discipline

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that should constitute an option for senior biology students, that is not in the scope of this paper.

Learning about the values in science and some examples of misconduct (Turrens 2005) are important topics to be addressed so that science professionals are

´able to analyze a research paper and evaluate its relevance.

4. Discussion and future perspectives

Since Bioethics can have different meanings for different authors, and is still under discussion within its field (Irrazábal 2015), I decided to focus on the contents and on a methodology that can be used in classes to prepare students to make decisions as citizens, as consumers, and as scientists. Others have introduced some of these topics as a discipline named "Introduction to Bioscience Ethics" (Van Roy and Pollard, 2002). In Portugal bioethics is not required to be included in the curriculum for many biology undergraduate studies.

This proposal consists of ill-structured problems about each theme that should motivate students to research about the theme, in small groups, and present, to the class, different arguments and views. An Inquiry-based learning strategy should be used, such as problem-based learning used by others with success (Van Roy and Pollard 2002).

According to other authors integrating socio-scientific issues constitute an approach that enhance the bioethical decision-making of high school students (Gutierez 2015). The main objectives of this proposal is that students, at each level, from middle school to undergraduate studies, understand the most important controversies in bioethics and acquire tools to analyze, in the future, bioethical arguments. This strategy may also increase motivation in students and their engagement with science themes, and prepares students with reasoning and justification skills as described by others (Chowning et al.2012).

Bioethics issues are included in science literacy since global issues, such as, for example, climatic changes, vaccination and the use of nuclear energy, should be discussed by all

citizens, at a regional and a global level, and only upon reaching a bioethical consensus the scientific advances should be either applied or not (Van Roy and Pollard 2002).

It is important that future scientists in their activity when facing an ethical decision take in consideration respect for others, minimization of harms and maximization of benefits, fairness and authenticity, and these principles can be learned when facing several bioethical themes in class (Loike et al. 2013).

Others have shown positive results by students of different BSc that were able to engage in all themes (Loike et al. 2013; Van Roy and Pollard 2002).

Bioethics as a discipline in all BSc – in the first undergraduate year - in a faculty or department of sciences will prepare students as scientists able to distinguish scientific and bioethical questions, as well as able to address both and to conduct responsible research. This paper constitutes a proposal of what can be established in the future in the Faculty of Sciences, and may constitute an example for other departments or faculties, as well as for high school teachers to be able to include the themes in the curriculum.

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The views expressed in this paper are the author's own and do not necessarily reflect the present view of Faculdade de Ciências, Universidade do Porto.

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