UNIVERSITAT ROVIRA I VIRGILI

BIOTECHNOLOGY LITERACY OF FUTURE TEACHERS: A NEW EDUCATIONAL APPROACH.

Marina Casanoves de la Hoz

Dipòsit Legal: T 57-2016

Marina Casanoves de la Hoz

Biotechnology literacy of future teachers: A new educational approach

DOCTORAL THESIS

Supervised by Dr. Ángel-Pio González Soto

and Dr. Maria Teresa Novo Molinero

Pedagogy Department

Universitat Rovira i Virgili

Tarragona

2015

UNIVERSITAT ROVIRA I VIRGILI
DEPARTAMENT DE PEDAGOGIA

Carretera de Valls, s/n
43007 Tarragona
Tel.: +34 977 55 80 77
Fax: +34 977 55 80 78
e-mail: sdpeda@urv.cat
web: http://pedagogia.fcep.urv.cat

Els sotasignats, Dr. Ángel-Pio González Soto, Director de l'Institut de Ciències de l'Educació de la Universitat Rovira i Virgili i la Dra. Maria Teresa Novo Molinero, professor agregat del Departament de Bioquímica i Biotecnologia de la Universitat Rovira i Virgili.

FAN CONSTAR que aquest treball, titulat **"Biotechnology literacy of future teachers: A new educational approach"** que presenta Marina Casanoves de la Hoz per a l'obtenció del títol de Doctor, ha estat realitzat sota la nostra direcció al Departament de Pedagogia d'aquesta universitat i que acompleix els requeriments per poder optar a Menció Internacional.

Tarragona, 8 d'octubre de 2015

Dr. Ángel-Pio González Soto — Dra. Maria Teresa Novo Molinero

DECLARATION

I hereby declare that this is entirely my own work and that it has not been submitted as an exercise for the award of a degree at this or any other University. I agree that the Library may lend or copy this dissertation on request.

Tarragona, 8 d'octubre de 2015

Marina Casanoves de la Hoz

Als meus pares, a l'Arnau i al Roger.

"Education is the most powerful weapon which you can use to change the world."
Nelson Mandela

ACKNOWLEDGEMENTS

Me gustaría agradecer al Dr. Ángel-Pio González y a la Dra. Maite Novo por la oportunidad que me han ofrecido y por su valiosa guía y ayuda durante toda la realización de esta tesis.

Agrair a la Cristina, a l'Ángel, al Zoel i al Juan perquè des de la vostra vessant científica, m'heu permès introduir dins el món de la recerca des d'una visió més amplia. També a la Sílvia, l'Helena i la Laia per la vostra col·laboració en diferents etapes de la meva recerca. Gràcies a tots per les vostres aportacions des dels mons de la psicologia, química, enginyeria, informàtica, entre d'altres. M'heu ajudat a veure la investigació de diferents maneres i a utilitzar diferents recursos que desconeixia.

A todos mis compañeros del grupo FORTE y del Departamento de Pedagogía de la Facultat de Ciències de l'Educació i Psicologia de la URV. A mis compañeras Anna, Ana Inés, Ximena, Gloria, Rosa, Eliana por su apoyo, ayuda y compañía en el día a día.

Across this four years of research I have meet some international professors that have helped me to reinforce my research and to continue improving every day in my work. I would like to thank Niklas Gericke and Annelie Boden for their help before, during and after my stage in Karlstad University (Sweden). I would like to express gratitude to Teresa, Stina, Lea and Daniel because they have gave me a warm reception in Sweden. Tack så mycket. Thanks to John Barnett from University of Western Ontario (Canada) for his help and for following our research in Canada. Merci beaucoup au professeur Laurent Dubois de la Université de Genève parce que il m'est accueilli dans la université pendant quelques jours et pour sa collaboration pendant ma recherche.

Finalment m'agradaria agrair a tots els amics que m'han donat el seu suport incondicional. I especialment a la meva familia i al Roger pel seu suport durant aquesta etapa tant important i enriquidora.

PUBLICATIONS

- González, A., **Casanoves, M**., Barnett, J., Novo, M. (2013). Biotechnology literacy: Much more than a gene story. *International Journal of Science in Society* Vol.4 Issue 2 pp. 27-35.
- Salvadó, Z., **Casanoves, M**., Novo, M. (2013). Building bridges between biotech and society through STSE education. *International Journal of Deliberative Mechanisms in Science* Vol.2 No.1 July 2013 pp. 62-74.
- Novo, M. T., **Casanoves, M**., Garcia-Vallvé, S., Pujadas, G., Mulero, M., & Valls, C. (2015). How do Detergents Work? A Qualitative Assay to Measure Amylase Activity. *Journal of Biological Education*, 1-10.
- **Casanoves, M**., González, A., Salvadó, Z., Haro, J. and Novo, M. Knowledge and Attitudes towards Biotechnology of Elementary Education pre-service Teachers: The First Spanish Experience. *International Journal of Science Education* (Submitted on september 2014, first revision sent on February 2015, second revision sent on August 2015)
- **Casanoves, M**., Salvadó, Z., González, A., Valls, C. and Novo, M. Learning genetics through a scientific inquiry game. *Journal of Biological Education* (Accepted for publication on October 2015).

PAPERS TO BE SUBMITTED

- **Casanoves M**., Haro J., Salvadó Z., Gericke N. and Novo M. A comparison across Europe: Swedish and Spanish pre-service teachers' knowledge and attitudes towards Biotechnology.
- **Casanoves, M**., Solé, A., Salvadó, Z., Valls, C.and Novo, M. Assessment of a scientific inquiry game about genetics for pre-service teachers: a comparison between students from Sweden and Spain.

CONFERENCE CONTRIBUTIONS

- **Casanoves, M.**, Salvadó, Z., Novo, M., Jiménez, J.M. y González A.P. (2014). Estudio sobre los conocimientos y las actitudes en biotecnología de les futuros profesores. *III Congreso de Docentes de Ciencias (Biología, Geología, Física y Química)*, Madrid.
- **Casanoves, M.**; Salvadó, Z.; Garcia, A.; Ramírez, N.; Haro, J.; González, A.P. y Novo, M. (2014). Alfabetización medioambiental de los futuros profesores. *Congreso Internacional de Docencia Universitaria e Innovación (CIDUI). <Modelos flexibles de formación: Una respuesta a las necesidades actuales>*, Tarragona.
- **Casanoves, M.**; Salvadó, Z.; Haro, J.; Jiménez, J.M.; González, A.P. y Novo, M. (2014). Knowledge and attitudes towards biotechnology of elementary education pre-service teachers in Spain. *ECER <The Past, Present and Future of Educational Research in Europe>*, Porto.

TABLE OF CONTENTS

ABSTRACT

Over the past decades, there has been a revolution in the field of biology research and, more concretely, in biotechnology and genetic fields. This scientific development has led to a huge gap between what scientific comunity studies and what citizens know. In order to involve society in the decision-making process about scientific policies, we need well-informed citizens who are able to make thoughtful decisions based on scientific conclusions combined with ethical and moral considerations. The forefront to educate new generations is teaching. Teachers play a critical and central role in the education system and they are therefore an influential collective because they become teachers of the next generation.

The purpose of this thesis is to explore knowledge and attitudes towards biotechnology of pre-service teachers from a Northern (Sweden) and Southern (Spain) European countries. After that it is developed a new educational activity in order to make future teachers literate of biotechnology.

First, it was created a new questionnaire in order to analyse the knowledge, and attitudes of pre-service teachers. Data is analysed in a quantitative method. The results show that pre-service teachers from Spain and Sweden are interested in biotechnology topics and this research has also shown that their knowledge about basics genetics is lower than expected. Due to these first results, a new Problem-Based Learning (PBL) educational material has been developed. The aim of this educational material is to increase pre-service teacher's knowledge about genetics topics. A pre and post-test was created in order to validate the efficacy of this new educational tool, then data is analysed in a quantitative and qualitative approach. Finally, a significanlty increase of student's knowledge is proved with taking part of the learning activity. Moreover, most of the students involved in the activity expressed that they were feeling engaged to this educational dynamic.

RESUMEN

En las ultimas décadas, se ha producido una revolución en el campo de la investigación en biología y más concretamente de la genética y la biotecnología. Este desarrollo científico ha dejado una grieta entre los estudios de la comunidad científica y los conocimientos de los ciudadanos. Para involucrar a la sociedad en los procesos de toma de decisiones sobre la legislación científica, se necesitan ciudadanos informados y capaces de tomar decisiones razonadas basadas en conclusiones científicas y a la vez con consideraciones éticas y morales. Los profesores juegan un rol crítico y central en el sistema educativo ya que son el colectivo con influencia en la próxima generación.

El objetivo de esta tesis es explorar el conocimiento y las actitudes en biotecnología de los estudiantes de magisterio de un país Nórdico (Suecia) y un país del Sur (España) de Europa. En base a estos resultados, se ha desarrollado una nueva actividad educativa para alfabetizar biotecnológicamente a los futuros profesores.

Primeramente se ha creado un nuevo cuestionario para poder analizar cuáles son los conocimientos y las actitudes de los estudiantes de magisterio. Los datos se han analizado de forma cuantitativa. Los resultados muestran que los estudiantes de magisterio en España y Suecia están interesados en temas de biotecnología aunque sus conocimientos en genética básica están por debajo de los esperados. A partir de estos primeros resultados, se ha desarrollado una nueva actividad educativa basada en Aprendizaje Basado en Problemas (ABP), el objetivo de la qual es incrementar el conocimiento de los futuros profesores sobre temas de genética básica. Un cuestionario previo y uno de final han sido creados para validar la eficacia de la nueva herramienta educativa. A continuación, los datos han sido analizados tanto cualitativa como cuantitativamente. Finalmente, después de realizar la actividad se ha demostrado una mejora significativa del conocimiento y una fuerte implicación de los estudiantes en la realización de la actividad.

RESUM

En les últimes dècades, s'ha produït una revolució en el camp de la investigació en biologia, concretament en genètica i biotecnologia. Aquest desenvolupament científic ha deixat una fissura entre els estudis de la comunitat científica i el coneixement dels ciutadans. Per tal d'involucrar a la societat en els processos de presa de decisions sobre la legislació científica, es necessiten ciutadans informats, que siguin capaços de prendre decisions raonades basades en conclusions científiques tenint en compte les consideracions ètiques i morals. Els professors juguen un rol crític i central en el sistema educatiu i són el col·lectiu amb influència en la propera generació.

L'objectiu d'aquesta tesi és explorar el coneixement i les actituds en biotecnologia dels estudiants de magisteri d'un país Nòrdic (Suècia) i un país del Sud (Espanya) d'Europa. A partir dels resultats obtinguts, s'ha desenvolupat una nova activitat educativa per alfabetitzar biotecnològicament als futurs professors.

Primerament s'ha creat un nou qüestionari per analitzar quins són els coneixements i les actituds dels estudiants de magisteri. Les dades s'han analitzat de manera quantitativa. Els resultats mostren que els estudiants de magisteri d'Espanya i Suècia estan interessats en temes de biotecnologia encara que els seus coneixements en genètica bàsica estan per sota dels esperats. A partir d'aquests primers resultats, s'ha desenvolupat una nova activitat basada en Aprenentatge Basat en Problemes (ABP), l'objectiu de la qual és d'incrementar el coneixement dels futurs professors sobre temes de genètica bàsica. Un qüestionari previ i un de final han estat creats per tal de validar l'eficiència de la nova eina educativa. Un cop obtingudes les dades, han estat analitzades tant qualitativa com quantitativament. Finalment, després de participar en l'activitat s'ha demostrat una millora significativa del coneixement dels estudiant i una forta implicació en l'activitat.

INTRODUCTION

1. Science in society

Currently, Europe faces a moment of transformation. Due to this it has appeared a new strategy named Europe 2020 to put forward priorities to help us come out stronger from the crisis. In deeper detail, Europe 2020 program focus on the development of economy based on knowledge and innovation. For this purpose this strategy promotes that all Member States of European Union have to ensure a sufficient supply of science, math and engineering graduates and to target school curricula on creativity, innovation and entrepreneurship (Communication from the Commission, 2010). Therefore, Europe 2020 promotes the scientific and technological literacy of future students; in this field biotechnology has a huge importance. Meanwhile, on the latest Eurobarometer survey of the life science and biotechnology (Gaskell *et al.*, 2010), based on representative samples from 32 European countries, points to a new era in the relations between science and society. The survey shows that 53% of Europeans are optimistic about biotechnology. Genetic modified food and animal cloning for food products are still the weakness fields of biotechnology. Support to Genetic Modified Food, production and consumption is decreasing across many of the EU Member States (Gaskell *et al.*, 2010).

Many public concerns can be attributed to a lack of understanding of the scientific and science principles, and the processes and applications of biotechnology (Alberts & Labov, 2003). The underlying notion is that the development of knowledge and the mental habits will allow people to become more responsible citizens, better able to create informed opinions, even while living in societies that are becoming increasingly complex and even more dependent on science and technology. In order to make better personal and social choices as members of the society, people would like to be informed about science and technology (Usak *et al.*, 2009)

In this 21st century, science education should become a bridge between science itself, technology and the social and environmental context in which both science and technology operate. Following from this position, much research in science education worldwide promotes, as an important goal for science teaching, the scientific and technological literacy of entire populations (Dimopoulos & Koulaidis, 2003; Jenkins, 1997; Miller, 1998; Zoller, 2012). The starting point is that science education plays a central role in the promotion of scientific literacy (Bingle & Gaskell, 1994; Driver *et al.*, 1996; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003). The school should give to students a solid foundation, scientific reasoning, and knowledge of where and how to test resources (Sorgo & Ambrozis-Dolinsek, 2009). The key position in education goes to the teachers, and we can recognize them as a link between science and society, since they transfer to students not only knowledge but personal views and opinions as well (Sorgo & Ambrozis-Dolinsek, 2009).

1.1 Different research fields in a same way

The 80s were the golden years to appreciate the beginning of two events which had lots of significance for the public's evolving engagement with science and technology. First of them was the birth of the Public Understanding of Science (PUoS) a movement which promoted public knowledge of science and the second one was a widespread reassessment of the content and goals of school science teaching which implies a curricular reform called "Scientific Literacy" or "Science for all" (Turner, 2008).

1.1.1 Public Understanding of Science (PUoS)

The Public Understanding of Science (PUoS) movement was born in the United Kingdom when Royal Society Report was published (Bodmer, 1985). PUoS was closely associated with the promotion of an informed, democratic society as much as it was with the promotion of science as a "public good". The scientific understanding is not merely a matter of scientific literacy; it also embraces issues of trust in scientist, doctors, and sources of information (Turney, 1996a). The project of educating the public faces various difficulties because there is plenty of evidence that past efforts to educate the wider public about science have made virtually no difference, at least in terms of relatively crude indices of "scientific literacy" (Shamos, 1995). Sometimes science education is seen as being quite separate from the promotion of public understanding of science, for this reason, Turney (1996a) said "Most people see the bulk of scientific knowledge as simply irrelevant to their needs and interests, and they are probably right".

New scientific advances, such as the Human Genome Project or the identification of the "obesity gene" among others, have provoked increasing demands on scientists' ability to explain new scientific findings in ways that people can easily understand (Turney, 1996b). Also it was shown in some qualitative studies whether the topic affects citizens in their health or safety, most of the adults affected showed little curiosity about the relevant scientific explanations and asked few questions by their own interest (Michael, 1992). Sometimes we think that a limited understanding of scientific topics will suffice for the general public's involvement in policies on these issues but in most of the cases deeper understanding is often necessary simply to understand the scientific phenomenon and in addition, public controversies often invoke knowledge claims that involve deeper and broader knowledge to validate. So this fact poses theoretical and educational challenges for researchers and teachers in their attempts to explain and improve the general public's understanding and use of science information (Bromme & Goldman, 2014).

There are at least two main reasons for hoping that these scientific findings can be met. First, it is known that the public is interested in biological and medical research as shown in the results of the last major national survey of attitudes towards and understanding of science in UK (Durant *et al*., 1992). The second reason is that the social science research that has been done in the past 30 years offers a basis for a more helpful analysis of the difficulties in improving public understanding of science (Turney, 1996b).

Regarding this interest of public understanding of science some authors proposed many different approaches. One approach is oriented to improve knowledge and understanding sciences whereas another approach is oriented to communication and aims to focus on attitudes about science and trust in scientists (Bromme & Goldman, 2014). Also Solomon and Thomas (1999) claims about the huge amount of approaches for acquiring scientific literacy and attitudes, some approaches concentrate on content, some others on cultural appreciation, some on utility, some on democratic participation, and some are epistemological finally others confined to living with risk.

The target of PUoS movement is to analyse "what people will use" so the prior requirement is to explore what adults perceive to be their needs for scientific knowledge in relation to concerns which they have defined and prioritized themselves, and also motivate them to learn science.

For that reason, Solomon and Thomas (1999) focused on these three headings: "What sort of science content should we include?", "What is the appropriate motivation to study science?", "What kind of learning promotes the acquisition of appropriate knowledge?". This movement is based on educate citizens all lifelong, for this reason it is important to be aware that all levels of education process are important such as school, vocational training and adult informal learning.

1.1.2 "Scientific literacy" or "Science for all"

Modern science research has been increasing last decades. It is important to remark the underlying agreement between both scientists and the rest of society. It is clear that scientists themselves have never been immune from such social influences. The concept of scientific literacy has always been hard to define. Roberts (2007) distinguished between two trends in all that aggregation of definitions that refer to scientific literacy in terms of either the content of science or its sociocultural context. New advances of modern science research have triggered to new ethical, social, environmental and philosophical questions. This new questions will have to be faced by a scientific literate population.

In order to see if citizens are informed and they apply their scientific knowledge in their real life situations, Shen (1975) identified three categories of scientific literacy: practical, civic, and cultural.

- Practical scientific literacy is knowledge that can be used by individuals to cope with life's everyday problems.
- Civic scientific literacy comprises the knowledge, skills, attitudes, and values necessary for making decisions on matters.

- Cultural scientific literacy includes knowledge of the major ideas and theories of science and the sociocultural and intellectual environment in which they were produced.

The work of the science education research community for the past 40 years was to analyse which is the interest of science and students attitudes towards science and of whole population. It was found that the decline in the interest of young people in pursuing scientific careers (Smithers & Robinson, 1988). Combined with research indicating widespread scientific ignorance in the general populace (Durant & Bauer, 1997; Durant *et al.,* 1989; Miller *et al.,* 1997) and an increasing recognition of the importance and economic utility of scientific knowledge and its cultural significance, the falling numbers choosing to pursue the study of science has become a matter of considerable social concern and debate. "Science for all" focused on keeping engaged young generations, and focused on new curricula and agendas taking into account ethical, social, environmental and other interdisciplinary questions related to science.

To produce changes in science curriculum, agencies or groups that can have some effects on this new agenda can be categorized and can be analysed to explore which effects have each group. There are at least 4 types of agencies (Table 1). It is important to combine the changes of these four agencies in order to change science education curriculum to the right way.

Table 1: The agencies which change the science curriculum. (INSET = in-service training) (Source: after Aikenhead 1989).

Agents	***Location of change***			
	Policy documents	Advice and INSET	Classroom teaching	Pupil learning
Government	Most	Some	None	None
Research	Little	Most	Little	None
Curriculum developers	None	Little	Most	Some
Teachers	None	None	Most	Most

Research on Relevance

In order to engage people into science knowledge they need to feel that science is relevant for their daily-lives.

But relevance is certainly an ambiguous term. Mayoh and Knutton (1997) characterized it as having two dimensions: First is "Relevant to whom? Pupils, parents, employers, politicians, teachers?" and the second is "Relevant to what? Everyday life, employment, further and higher education, being a citizen, leisure, students' existing ideas, being a 'scientist'?"

Research into humanistic curriculum policies is reviewed according to seven types of relevance, a scheme developed in part from Fensham's (2000) views about who decides what is relevant. This research into humanistic curriculum is studied in further detail in order to apply the relevance in science curriculum.

On this research it was found seven heuristic categories which are more detailed right after, but first take a look of a summary of these 7 categories on Table 2.

Let's focus on each of these categories.

1. Wish-They-Knew Science

This type of relevance is typically embraced by academic scientists, education officials, and many science educators when asked, what knowledge is of most worth? (Walberg, 1991). Even when teachers choose everyday context to teach science, their ideas of a relevant everyday context are often at odds with most students' views (Campbell *et al.*, 1994).

2. Need-to-Know Science

This kind of relevance is defined by the lay public who has faced a real life decision related to science. Citizen science and knowledge about science and scientists turns out to have greater practical value than conventional science. This archetypal science content is not often usable in everyday situations, and most students encounter extreme difficulty when they attempt to learn canonical science (Aikenhead, 2006).

Table 2: Research on Relevance (Aikenhead, 2006, p. 32).

Type of Relevance	Who Decides What Is Relevant?
Wish-They-Knew Science	Academic scientists, education officials, many science teachers.
Need-to-Know Science	The general public who have faced and resolved real-life problems/decisions related to science and technology.
Functional Science	People in science-based occupations.
Enticed-to-know Science	The media and internet sites.
Have-Cause-to-know Science	Experts who have interacted with the general public on real-life issues.
Personal-Curiosity Science	Students themselves.
Science-as-Culture	Interpreters of culture who can determine what aspects of science comprise features of a local, national and global culture.

3. Functional Science

Functional science is deemed relevant primarily by people with occupations or careers in science-based industries and professions. Coles (1998) surveyed higher education specialists in science and he found that the most valued qualifications were generic thinking skills and mathematical capabilities. Key characteristics of functional science include mathematical capabilities, thinking skills, personal attributes related to acquiring science content and personal skills required to communicate science content. So knowing specific canonical science is a low priority. Duggan and Gott's (2002) data suggested that procedural understanding was essential across most science-related occupations.

Functional science, however, can be found in progressive vocational science programs, although when vocational school teachers are concerned only with the narrow objective of vocational technology, vocational science loses its humanistic perspective.

4. Enticed-to-know Science

This is science content encountered in the mass media and the internet positive or negative in its images of science, and sensational and sometimes dishonest owing to the media's quest to entice a reader or viewer to pay closer attention.

An example of enticed-to-know science is the "event-centred learning" approach to humanistic school science researched in Brazil and the United Kingdom (Watts *et al.,* 1997).

5. Have-Cause-to-know Science

Societal experts are better situated than academic scientists to decide what knowledge is worth knowing in today's changing scientific and technological world. Researchers acknowledged the fact that decisions often rely more on applying values than on applying science content. Fensham (2002) envisioned a have-cause-to-know science curriculum policy unfolding in three phases:

A. Selected societal experts systematically determine features of society endemic to an informed citizenry.
B. Academic scientists specify science content associated with the features of society.
C. Science educators develop a school science curriculum.

6. Personal-Curiosity Science

When students themselves decided on the topics for school science, relevance takes on a personal meaning (Reiss, 2000). In order to understand or to know which topics are relevant, some authors have developed new different surveys. Surveys of student interests have typically accompanied the evaluation of humanistic science pilot materials.

7. Science-as-Culture

The main goal of Science-as-Culture is the enculturation of students into scientific disciplines. So it is much more than just a pop culture (Solomon, 1998). As a category to need-to-know, functional, enticed-to-know, have-cause-to-know, and personal-curiosity science. Its relevance resides in a student's community culture and in a student's home and peer cultures (Costa, 1995; McKinley, 2005). Research into science-as-culture reveals useful ideas for a humanistic science policy, particularly for the enculturation of students into their local, national and global communities.

2. Biotechnology: A field in science literacy

2.1 What Biotechnology is?

21st century is the one which is speeding up biotechnology. In the near and distant future it is expected from biotechnology to solve most problems facing humanity today such as diseases, lack of food and treat waste among others.

First use of the term biotechnology was on 1910. Since then the definition of the term has been changed several times. Nowadays the definition still attracts many debates. The Organisation for Economic Cooperation and Development OECD (2015) defined this concept as (Woodward, 2009):

"Biotechnology is the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, good and services."

Table 3: The field of Biotechnology includes pure biological sciences and also technological applications.

Pure biological sciences		Technological applications
Biochemistry	Physiology	Computer Science (Bioinformatics)
Cell Biology	Immunology	Bioprocess engineering
Embriology	Enzymology	Biorobotics
Genetics	Medicine	Chemical engineering
Microbiology	Agronomy	Enviromental protection engineering
Molecular biology	Nutrition	

There are three essential elements about what biotechnology involves (Table 3). First, biotechnology involves the use of living organisms which include plants, microbes, animals as well as human beings. Secondly, biotechnology involves parts of organisms or components within the organisms that can be used in isolation from the organism itself, and include pieces of DNA, enzymes or internal cell organelles. Thirdly, biotechnology involves specific processes of techniques for making or modifying living organisms or parts of them so, it may include genetic engineering as well as genetic medication.

2.2 The History of Biotechnology

The History of Biotechnology begins on the Neolithic and nowadays is changing fast. In order to distinguish all most remarkable steps of the history of biotechnology it was divided in two different periods. First period is classical biotechnology which starts on the Neolithic revolution and the second period is called contemporary biotechnology which begins at the end of XX century.

2.2.1 Classical biotechnology

Nowadays most people believe that biotechnology is very modern, but considering the strict definition of its use of living organisms to produce products and services in fact biotechnology is one of the oldest scientific processes used by humans, with deep historical roots (Pele & Campeanu, 2012). The history of Biotechnology begins on the Neolithic Revolution. In that period Agriculture became the dominant way of producing food. For food production, the earliest farmers selected and bred the best suited crops, having the highest yields, to produce enough food to support a growing population. Throughout the history of agriculture, farmers have inadvertently altered the genetics of their crops through introducing them to new environments and breeding them with other plants. In this period they also kept most beautiful animal for breeding, rather than consuming them without discrimination, in that point appeared these unconscious artificial selection by farmers.

The use of microorganisms in the food processing is lost in the darkness of time. Bread, cheese, wine and beer were reached long ago by various processes of fermentation. Written sources provided evidence that Sumerians and Babylonians produced beer thousands years before Christ. Egyptians prepared this using leaven bread with 4000 years before Christ while in the Middle East wine was produced (Pele & Campeanu, 2012). It has appeared Archaeological evidence in the Caucasus and the northern edge of the Middle East shows that on the late Neolithic or early Chalcolithic it was the earliest-known production of wine. Wine is produced by a fermentation process. Fermentation is biotechnology in which desirable microorganisms are used in the production of value-added products of commercial importance. The making of wines and beers uses this biotechnology under controlled conditions. Alcoholic beverages have been produced for centuries in various societies. Ancient biotechnology is not represented only by drinks or bakery products obtained with the aid of microorganisms but also by large number of prepared foods such as fermented milk products (Pattison, 1903).

2.2.2 Contemporary biotechnology

The last revolution in biotechnology began in the late 1970s with the discovery and application of genetic technology and recombinant DNA. There were two key events that have come to be seen as scientific breakthroughs beginning the era that would unite genetics with biotechnology. One was the 1953 discovery of the structure of DNA, by Watson and Crick, and the other was the 1973 discovery by Cohen and Boyer of a recombinant DNA technique by which a section of DNA was cut from the plasmid of an *Escherichia coli* bacterium and transferred into the DNA of another.

The origins of biotechnology culminated with the birth of genetic engineering ((Grace, Biotechnology Unzipped, p. 155) "Applications of Biotech..."). This "genetic engineering" has had a profound impact on all areas of traditional biotechnology with a major involvement especially in medicine and agriculture, specially for problems impossible to solve by traditional methods (Pele & Campeanu, 2012). Modern biotechnology is used in almost all areas of life, agriculture, bioremediation, light industry, chemical industry, food processing, health, food security and social security, energy production, etc (Bud, 1994).

Biotechnology is a new science at the border between several booming sciences which provide dynamism and creativity out of the ordinary, but in addition Biotechnology results its remarkable capacity for specific technological applications to contribute to the increasing quality of life (Pele & Campeanu, 2012).

In recent years, biotechnology can be grouped into four major groups depending on the application (Pele & Campeanu, 2012):

- Red biotechnology is biotechnology applied to health by means to obtain medicines and vaccines, methods of diagnosis and control, among others.
- Green biotechnology is biotechnologies applied in agriculture which cover biotechnology for increased production or the production of resistant plants to different conditions.
- White or grey biotechnology which represents industrial and environmental biotechnologies.
- Blue biotechnology is a term used for marine and aquatic applications.

Bioinformatics is an interdisciplinary field which plays an important role place in all categories of biotechnology.

2.3 Biotechnology literacy

The fast development of modern biotechnology and genetic engineering has led to a huge gap between what the scientific community understands to be the risk and benefits and what is understood by the society (European Commission, 2010b).

In 2010, the European Commission launched the Europe 2020 Strategy to put forward some strategies in order to help the nations of the European Union (EU) to come out stronger economically from the current crisis and to prepare their economies for the next decade's challenges (European Commission, 2010a). In this context European Commission prepared a bioeconomy strategy for Europe in which biotechnology has seen as one of the major driving force in the creation of better health and welfare for European citizens (European Commission, 2012).

Biotechnology education becomes necessary due to the increasing usage of biotechnological products which are used in industrial areas and economy, increasing number of needed technical workers, and the social and moral concerns that are reflected to the society (Darçin & Güven, 2008). The various benefits of biotechnology suggest the need for students, teachers and citizens at large to be scientifically literate so that they can appreciate how biotechnology is impacting their lives and societies (Chabalengula *et al.*, 2011).

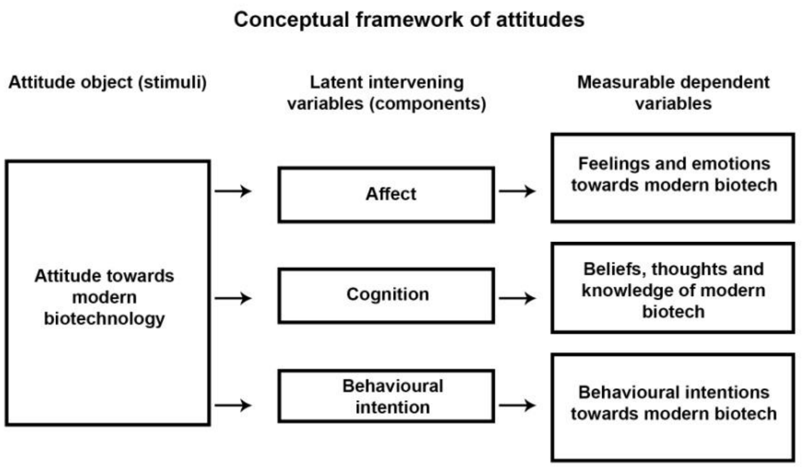
2.3.1 Knowledge and attitudes towards biotechnology

In the information jungle, where both trustworthy and corrupt sources are instantly available, we believe that schools should take their share of responsibility for educating young people about biotechnology (Sorgo & Ambrozis-Dolinsek, 2009). It should be the responsibility of the schools to inform students about scientific and technical aspects of biotechnology, with the benefits and disadvantages related to biotechnology, and thus to enable them to cope with such technology and form their own attitudes towards biotechnology (Sorgo & Ambrozis-Dolinsek, 2009). Therefore, the role of science curriculum is to prepare students to be citizens with basic knowledge about genetic engineering (Prokop *et al.*, 2007). In recent decades, DNA technologies were perceived to be very similar to hazards such as nuclear energy, radioactive waste, electromagnetic fields, and other technologies that use rays or chemical substances (Savadori *et al.,* 2004). Ethical and moral issues play a significant role in formation of attitude towards application of modern biotechnology (Sáez *et al.,* 2007).

Attitude is a manner of thinking, feeling, or behaving that reflects a state of mind or disposition. Many Psychologists (Eagly & Chaigen, 1993) have proposed that attitudes have three components. The cognitive component refers to knowledge about objects, the beliefs. The affective component includes feelings about the object, and its assessment is performed using psychological indices. The behavioural component pertains to the ways people act toward the object (Figure 1).

In general terms attitudes toward biotechnology in school-age students and also pre-service teachers have been relatively less investigate in comparison with adult consumers. This is, however, a crucial stage of research in this area because this may reveal in sufficiency of science curricula or school textbooks that are an important source of information on this topic (Martínez-Gracia *et al.*, 2003). The attitudes of science teachers and pre-service science teachers are very important for the biotechnology education studies to be successful (Darçin & Güven, 2008).

Figure 1: Conceptual framework of attitudes (adapted from Klop, 2008).



3. Reforms agendas

During last decades the debate over primary school and high school curricular reform has appeared in different countries. But, how do these reforms are implemented? In particular, in this thesis examines the two main reform agendas.

The first one called Nature of Science (NoS) which focuses on scientific method and the second one is Science, Technology and Society (STS), which it is based on the integration of two broad academic fields: first, the interactions of science and scientists with social issues and second, the social interactions of scientists and their communal, epistemic, and ontological values internal to the scientific community. Hodson (2003) incorporates the environment aspect as another important field to be included in STS reform so nowadays this reform agenda is called Science, Technology, Society and Environment (STSE).

3.1. Nature of Science (NoS)

This specific reform agenda most commonly refers to the values and assumptions inherent to the development of science knowledge (Lederman & Zeidler, 1987). In the early 1900s the nature of science objective was expressed in terms of increased emphasis on the scientific method (Hurd, 1960); in the 1960s the objective was linked to the advocated emphasis on scientific process and inquiry (Welch, 1979); and most recently it has included a critical component of scientific literacy (American Association for the Advancement of Science (AAAS), 1989).

Research related to the NoS can be conveniently divided into four interrelated, but distinct, lines of research:

a) Assessment of student conceptions of the nature of science.
b) Development, use, and assessment of curricula designed to "improve" student conceptions of the nature of science.
c) Assessment of, and attempts to improve teachers' conceptions of the nature of science.

d) Identification of the relationship among teachers' conceptions, classroom practice, and students' conceptions.

3.2. Science, Technology, Society (STS) and Environment (STSE)

In the mid 40s was founded the National Science Teachers Association (NSTA), which is the largest organization in the world promoting excellence and innovation in science teaching. Science technology and society was a field of study which was in a continuous and fast expansion in educational institutions of all educational levels and countries all over the globe (such as United States of America, Canada, Occidental Europe, Australia, New Zealand and South America). STS appeared in Colleges in 70s (Cutcliffe, 1987). Some university programs taught history and philosophy of science that eschewed sociological perspectives on science. Others embraced sociology, economics, and politics, and gave themselves the label STS (Aikenhead, 2006 p.16). Then in 80s it expanded to High School levels.

The most important associations based on STS field are the AAAS which their "Project 2061" began its work in 1985 and also the European Association for the Study of Science and Technology (EASST) which was founded in 1981. The last 30 years those occidental societies worked to improve the scientific literacy of students and of general population (AAAS, 1989). Afterwards it appeared other associations in oriental societies. The Japanese Society for Science and Technology Studies (JSSTS) was founded in 2001 and the Asia-Pacific Science, Technology and Society Network (APSTSN) formed in 2008.

A conceptual framework for STS was achieved through the integration of two broad academic fields: first, the interactions of science and scientists with social issues and institutions external to the scientific community and second, the social interactions of scientists and their communal, epistemic, and ontological values internal to the scientific community (Ziman, 1984).

There is a substantial agreement that the most important aspects of scientific literacy are those that impinge on everyday life (Champage & Lovitts, 1989), in particular those which develop the knowledge and skills needed to make decisions and solve problems where science, technology, and society interface (Brickhouse *et al*., 1989).

A recent STS model, the STS (E), proposed by (Hodson, 2003) incorporates environment (E) and comprises 4 elements:

- learning science and technology
- learning about science and technology
- doing science and technology
- engaging in socio-political action

STS Education goals

Some individuals and organizations have issued general statements which are difficult to translate into curricula yet provide a general orientation for curriculum development. STS studies at secondary school levels have been available since 1988 (Solomon, 1998). The Science through Science, Technology and Society Project on 1985, funded by the National Science Foundation, developed the following eight criteria as a set of guidelines for instructional materials evaluation in STS.

1. The relations of technological or scientific developments to societal relevant issues are made clearly, early, and in compelling ways to capture attention.
2. The mutual influences of technology, science, and society on each other are clearly presented.
3. The material develops learners' understanding of themselves as interdependent members of society and society as a responsible agent within the ecosystem of nature.
4. The material presents a balance of differing viewpoints about the issues and options without necessarily striving to hide the author's perspective.
5. The material helps learners to venture beyond the specific subject matter to broader considerations of science, technology, and society, which include a treatment of personal and societal values.
6. The material engages students in developing problem-solving and decision-making skills.

7. The material encourages learners to become involved in a societal or personal course of action after weighing the tradeoffs among values and effects drawn from various scenarios or alternative options.
8. The material uses this STS linkage to foster learners' confidence in handling and understanding at least one science area, and/or handling and using some quantification as a basis for judgments in the STS area.

Some STS models and examples

In 1970 British education started to promote STS teaching in universities and polytechnics. It produced teaching materials which linked science with economics. In 1978 appeared one of the first school STS courses called SISCON-in-Schools. This one focused more on the human and fallible nature of science theories, quality of life in the first and third worlds, and social effects of new technologies.

In Canada at the beginning of 70s appeared a STS course notable for its advanced thinking. In Science, Aikendhead (2006) produced a series of classroom materials for teaching the philosophical and social aspects of science.

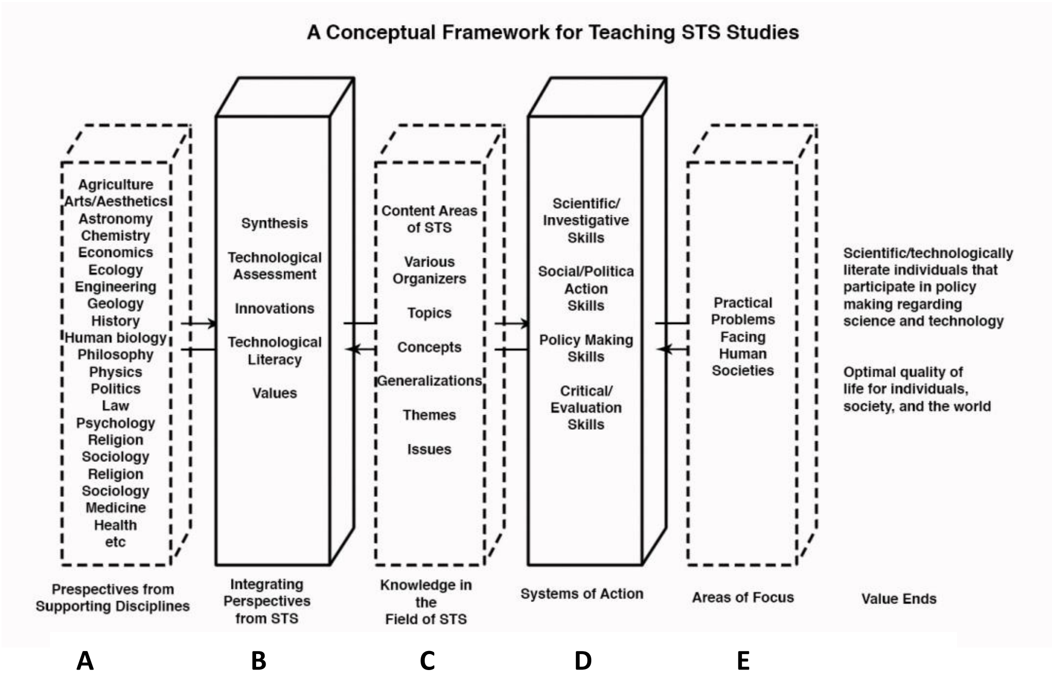
Holland had a special national need for STS in the 1970s which ensured that their new school courses had a matching objective. The University of Utrecht developed PLON project (Eijkelhof & Verhangen 1985; Eijkelhof & Linjnse, 1988). The project has produced over twenty modules dealing with physics and society for Dutch students from ages twelve to sixteen.

In Spain, STS dimension was not included in official pre-university syllabuses until recently with the Education Act of 2006 and its curricular development. STS content knowledge was not compulsory for Spanish science teachers, and consequently teachers have not been concerned about these issues until recently (Vazquez-Alonso *et al*., 2013). Faculties of education have not systematically trained science teachers in STS content or about the appropriate pedagogical content knowledge to teach the topic (Bencze *et al*., 2006; Lederman *et al*., 2001).

A conceptual Framework for Teaching STS Studies

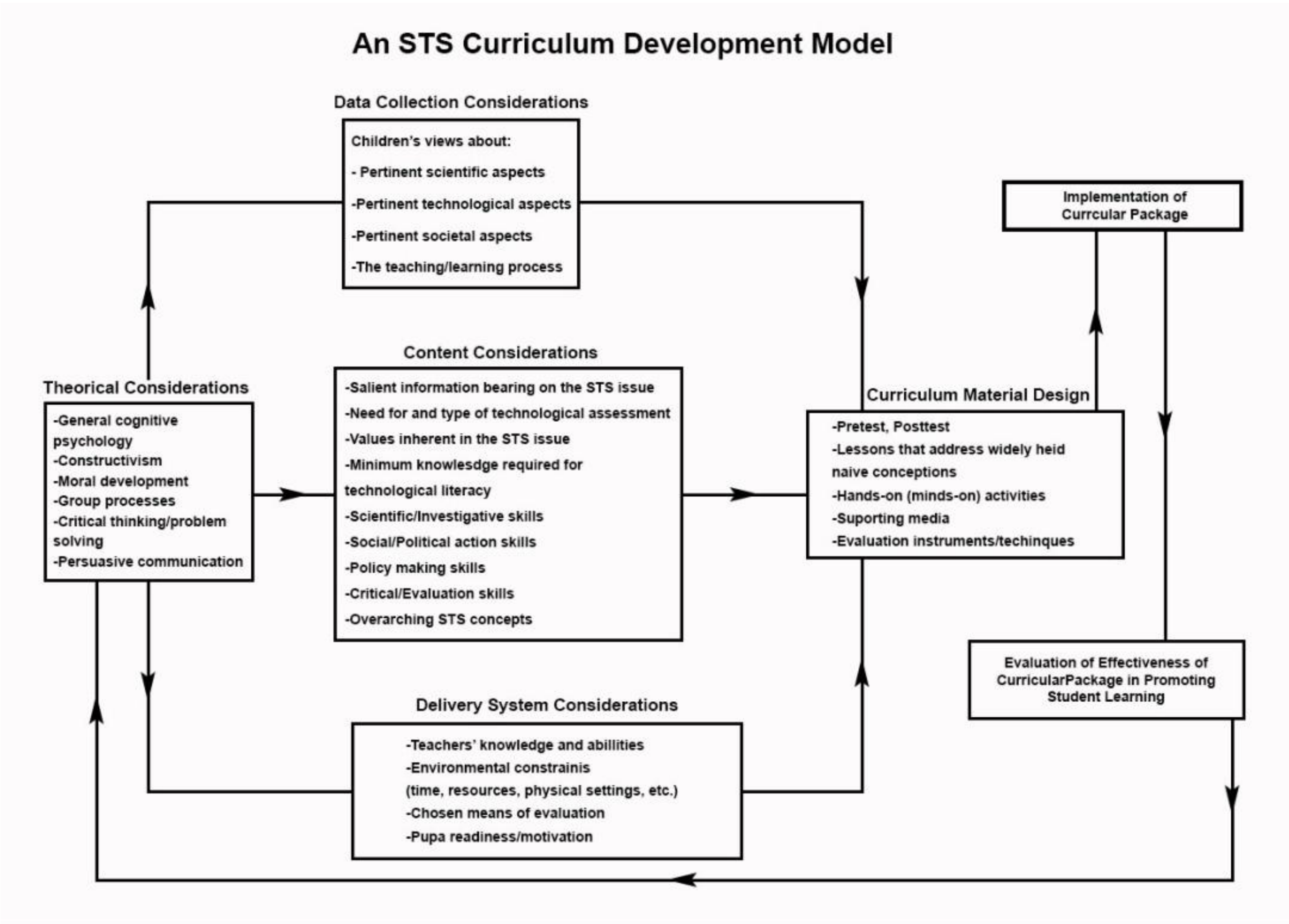
MacCleave-Frazier & Murray (1984) have developed a conceptual framework for teaching home economics. This framework has been substantially revised for STS education and rendered more interactive than the original authors intended in their model (Figure 2).

Figura 2: A conceptual Framework for teaching STS studies (adapted from Cheek 1992, p. 132).



The dynamic aspects of the model are reinforced by the use of arrows proceeding in either direction. A quality STS education approach may be expected to include an emphasis upon the items within panels B and D. These two panels are processes that mediate between the other panels. Panels A, C and E can be interchanged while panels B and D remain static (Figure 2). The framework might be a useful heuristic device to assist an STS educator in conceptualizing and sequencing STS instruction. In order for this framework to be effective, however, we must interrelate it with constructivist psychology.

Figura 3: An STS curriculum development model (adapted from Cheek 1992, p. 142).



An STS Curriculum Development Model

An STS curriculum development Model is created based on the Driver and Oldham (1986) model (Figure 3).

Four major components contribute to the design of curriculum materials in this model: theory, data collection, delivery-system considerations, and STS-related content.

Any given STS issue, of necessity, involves facets of these theoretical research areas. Research would then suggest appropriate considerations that would guide data collection, delivery system considerations, and selection of content. Then it is important that the team can assemble appropriate instruments and techniques to collect primary data. Theory and research should shape decisions regarding the delivery-system component of curriculum materials design. Attention on the delivery system must consider pupils' readiness and motivation so that materials can be constructed that are likely to find a hearing and engage students in an effective manner.

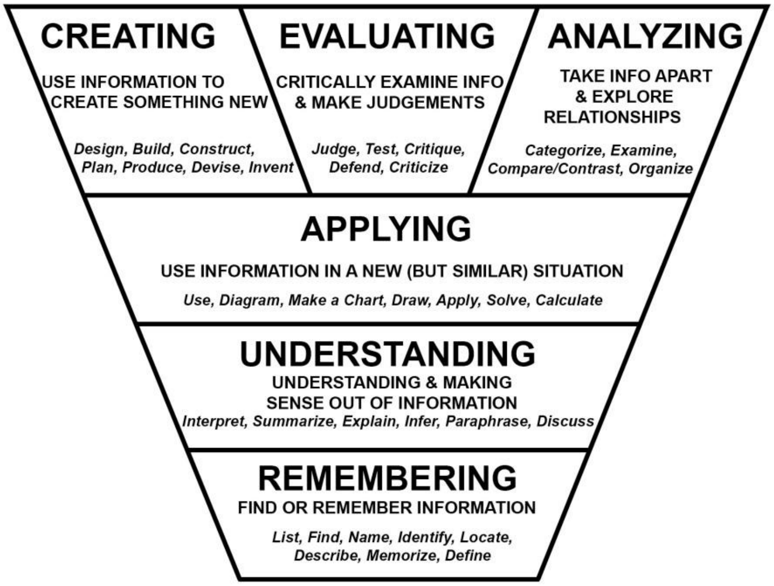
The data collection, delivery system, and content components should then be brought simultaneously to bear upon the design of the curriculum materials. These materials should include such items as pre- and post-tests, lessons that address widely held naive conceptions regarding aspects of the STS issue under review, supporting media, and evaluation instruments and techniques. A feedback loop back to the theory component reminds us that theoretical and research-based considerations should be kept in mind.

Higher order thinking skills (HOTS) or higher order cognitive skills (HOCS)

STS education does not only encourage scientific literacy in a societal perspective (Pedretti & Hodson, 1995), but it also aims at improving student's higher order thinking skills (Dori & Tal, 2000). The students should construct a deep conceptual understanding of any scientific topic.

Higher order thinking skills is a concept of education reform based on Bloom's (1956) learning taxonomies. This term may also be used to delineate cognitive activities that are beyond the stage of understanding and lower level application according to Bloom's taxonomy (Bloom, 1956) (Figure 4). The hierarchies of educational goals are implied by Bloom's work, these specify cognitive levels are clear, succinct, and still useful (Zohar & Dori, 2003).

Figure 4: Categories in the cognitive domain of Bloom's Taxonomy.

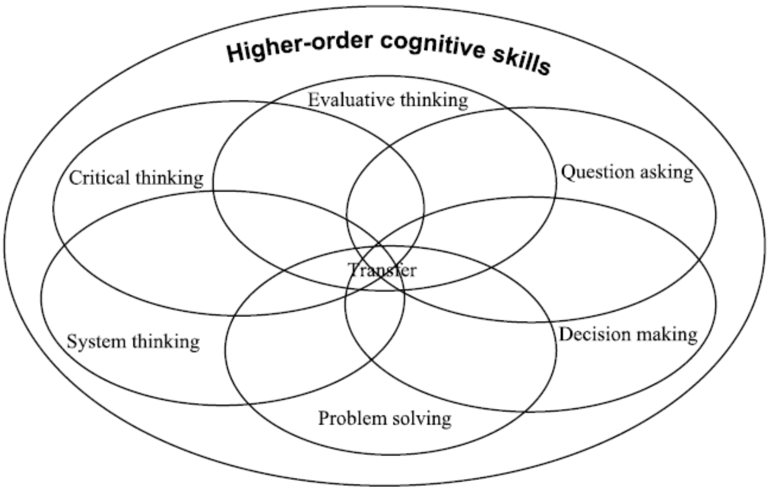


Higher order thinking is situated in the broader context of higher order learning with the five "essential learning" listed as: communicating, personal futures, social responsibility, world futures and thinking (Forster, 2004).

In more detail Zoller 1993, 2000 and Zoller and Pushkin, 2007 worked deeper on this reform in science education. They specified more on "essential learning" as Higher order Cognitive skills which is composed of various overlapping and integrated forms of cognitive capabilities, such as critical thinking, system thinking, question asking, evaluative thinking, decision making and problem solving for transfer (Zoller, 1993, 2000; Zoller & Pushkin, 2007) (Figure 5).

Zoller and Tsaparlis (1997) also explains the difference between these items and Lower Order Cognitive Skills items (LOCS) which are based on knowledge questions that require simple recall of information or a simple application of known theory or knowledge to familiar situations.

Figure 5: The guiding conceptual model of HOCS in the context of science education (source after Levy-Nahum *et al.*, 2010).



In order to put this model on practice Lyle and Robinson (2001) proposed to incorporate cognitive activities that involve knowledge and skills which found to be effective to develop students' critical thinking and problem solving skills. In addition to this Zoller and Tsaparlis (1997), defined HOCS items as quantitative problems or qualitative conceptual questions of the examinations, unfamiliar to the student, that require for their solution more than knowledge and application of known algorithms.

4. Educational paradigms

In the early part of the 20th century, education focused on the acquisition of basic literacy skills: reading, writing and calculating (Zohar & Dori, 2003). The main role of teachers was perceived as that of transmitting information to students (Bransford *et al.*, 1999). Thinking and reasoning became not the heart of education, but hoped-for summits that most students never reached (Resnick & Klopfer, 1989). During last decades, some authors declare that students could be able to find and use the knowledge effectively not only memorizing.

Being able to use knowledge to solve new types of problems means that one must understand that knowledge. Understanding is seen as being constructed while learners engage in thinking and inquiry in context that make sense to them (Zohar & Dori, 2003).

Almost every country on Earth, at the moment, is reforming public education. All are trying to shift their way of learning. As Kyle (1996) said, "Education must be transformed from the passive, technical, and apolitical orientation that is reflective of most students' school based experiences to an active, critical and politicized life-long endeavour that transcends the boundaries of classrooms and schools". This transformation of learning will imply to change the way of student will work (Biggs, 2003; Marton *et al.,* 1993), and is not just the mere acquisition of facts. The education and the curriculum it is clear that have to be changed. Another element of the learning process is the teacher. Regarding this Sutherland *et al.,* (2010) said that, in order to make the transition from student to teacher, pre-service teachers need to not only acquire a complex set of knowledge and skills and understandings of pedagogical practices, but they also need to create and recreate their image of themselves as members of a professional community.

4.1. Constructivism

The theory of knowledge called constructivism had been appeared over the past century. The theory started in a physiologic context and after it had extent to other disciplines such as sociology, education and history of science. Focused on the education context it is important to be conscious that constructivism is a way of emphasizing the importance of meaningful, authentic activities that help the learner to construct understandings and develop skills relevant to solving problems (Wilson, 1996).

Constructivism involves two principles according to (Von Glasersfeld, 1989), a noted constructivist theorist: First principle is that knowledge is not passively received but actively built up by the cognizing subject. This principle has long been recognized within philosophy and education. And the second principle said that the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. This involves acceptance of the view that knowledge of objective reality is not possible by human reasoning.

Depending on the author we can talk about three kinds of constructivism as Carretero (2000) have summarized:

1. Learning as an individual process. Piaget, Ausubel and the cognitive psychology said that the human being learning is made in alone way without the intervention of the social context.
2. Learning as an interaction between the social context and the individual. This kind of constructivism is in half way of Piaget and Vigotsky's contributions. This learning promotes the information exchange between students of different levels. That promotes a change of students' schemas in order to generate learning process.
3. Learning as a result of the social context. This is the Vigotsky's thinking. He said that the learning process is not an individual process but it is a social process.

Following this theory, the aim of education should be to independently attain understanding through active involvement in real, meaningful activity, and not the reproduction of available knowledge that has already been constructed (Piaget, 1973). Learning is described as something that is "done by people - not to them" (Race, 2007, p.26).

During last decades, the problem with traditional didactic teaching methods, resulting in memorisation and replication, is that the delivery of correct responses is possible without real learning having to take place (Piaget, 1973). Usually, course material can be viewed simply as a collection of abstract concepts, with the only motivation for learning coming from the need to pass an examination (Kember *et al.,* 2008). The ability to think generatively about new issues, or problems, in a subject area cannot be developed by concentrating on merely remembering facts relating to the topic (Bruner, 1960). As some authors suggested, schools are in need of racial change. This change is called learning-by-doing. Over the years, the movement to give law students hands-on experience has matured from hapazars and starry-eyed to demanding and thoughtful. It is at least as reflective and self-analytical as it tries to teach its students to be (DeBendedictis, 1990). It is known that life requires us to do, more that it requires us to know in order to function (Schank *et al.,* 1999).

4.2 Constructivist learning approaches

During last decades it has appeared different constructivist educational approaches which has been called by various names such as, discovery learning (Bruner, 1961); problem-based learning (PBL) (Barrows & Tamblyn, 1987), inquiry learning (Rutherford, 1964), experiential learning (Kolb & Fry, 1975) and constructivist learning (Jonassen, 1991). The philosophy of these learning approaches finds its antecedents in constructivist learning theories, such as the work of Piaget, Dewey, Vygotsky, and Freire, among others.

The focus of any constructivist learning environment is the question or issue, the case, the problem, or the project that students attempt to solve. This is the main difference between constructivists learning in comparison to “conventional learning” which is that the problem, question or project drives de learning process. During this process students learn content in order to solve the problem, rather than solving the problem as an application of learning.

The main targets of these approaches are two. First to challenge students to solve real problems, based on the assumption that having learners to construct their own solutions will lead to a more effective learning experience. Second, it is assumed that knowledge can be best acquired through experience based on the procedures of the discipline (Kirschner *et al.,* 2006).

In particular the educational approaches that are explained in this thesis are Inquiry learning (IL), Problem based learning (PBL), and Project based learning (PBL).

In IL, students learn content as well as discipline-specific reasoning skills and practices by collaboratively engaging investigations (Hmelo-Silver *et al.,* 2007). In Problem based learning, students learn content, strategies, and self-directed learning skills through collaboratively solving problems. In Project based learning, the learning process is organized around projects.

To create constructivist classrooms in which students learn through investigation, solving problems or based in projects, requires basic changes in the rules of the game for science classrooms – new curricula and tools must be accompanied by new teaching approaches and an explicit attention to shifting students' attitudes toward science and science learning (Reiser *et al.,* 2001). Nowadays numerous studies support replacing "cookbook" learning methods (students only follow step-by-step the procedures) with student initiative activities (Hart *et al.,* 2000). Class members are no longer content to sit passively through a lecture or laboratory activity; rather today's students need to be engulfed in it (Lord & Orkwiszewski, 2006).

4.2.1 Inquiry learning (IL)

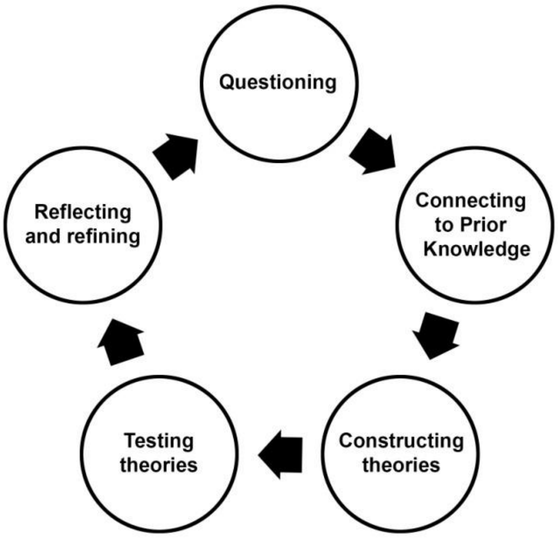
The power of an inquiry-based approach to teaching and learning is its potential to increase intellectual engagement and foster deep understanding through the development of a hands-on, minds-on and 'research-based disposition' towards teaching and learning (Stephenson, undated).

The Inquiry concept is defined as seeking for truth, information, or knowledge by questioning. This process is innate in human beings because individuals carry on the process of inquiry from the time they are born until they die. Inquiry learning is based on this process.

Specific learning processes during inquiry-learning include: (Bell *et al.,* 2010) (Figure 6)

- Questioning: Creating questions of their own
- Connecting to prior knowledge: Obtaining supporting evidence to answer the question or questions
- Constructing theories: Explaining the evidence collected
- Testing theories: Connecting the explanation to the knowledge obtained from the investigative process
- Reflecting and refining: Creating an argument and justification for the explanation

Figure 6: Five steps of learning processes during inquiry-learning.



The main key step is to articulate a vision of scientific inquiry for students. While there is much interest in involving students in "authentic" scientific reasoning, designing environments for learning requires an articulation of the aspects of scientific practice to establish as goals for students, and consideration of how to integrate those practices within the practices of classrooms (Reiser *et al.,* 2001).

Active learning suggests students are physically participating in the lesson, inquiry learning requires that they are also mentally participating in it (Enger & Yager, 2001). Rettig and Canady (1996) reported that in schools where active learning methods prevail, the students demonstrated "significantly higher achievement as measured by the National Assessment of Educational Progress".

Inquiry is an umbrella term that covers a number of other approaches to teaching and learning. Teaching practices that utilize a disposition of inquiry learning include: (Stephenson, undated)

- problem-based learning: learning that starts with an ill-structured problem or case-study
- project-based learning: students create a project or presentation as a demonstration of their understanding
- design-based learning: learning through the working design of a solution to a complex problem

4.2.1.1 Problem-Based Learning (PBL)

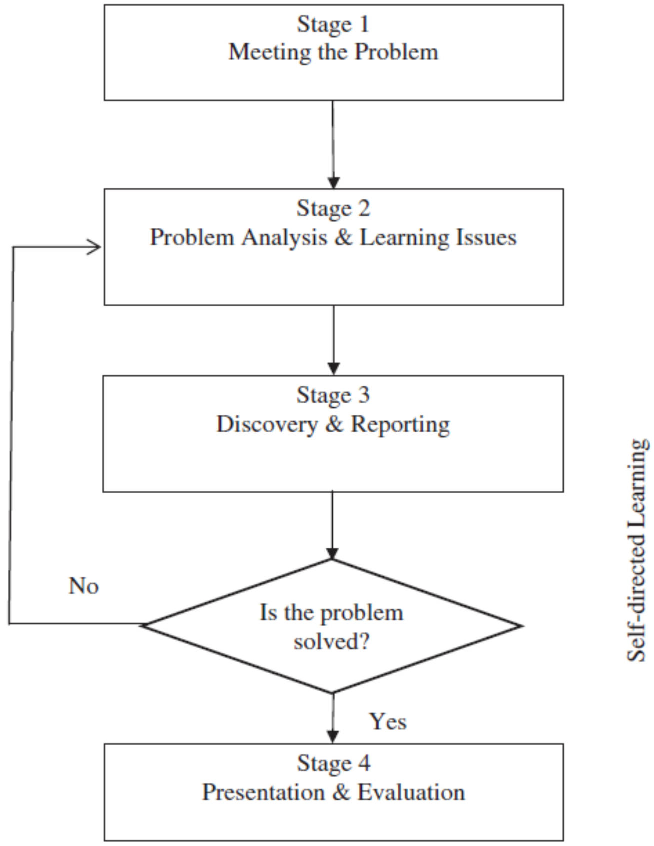
The original problem-based learning model was developed for use with medical students in Canada (Barrows, 1992). Medical students are introduced to a diagnostic problem. Using a database of information and test data about this patient and guided by a facilitator who plays the role of a coach, students are led to construct a diagnosis by generating hypotheses, collecting information relevant to their ideas and evaluating their hypotheses (Thomas, 2000). PBL model has been developed and implemented in an increasing number of other subject-matter domains such as business, education, psychology, economics, architecture, law, engineering, social work (Barrows, 1996) and also has been extended to mathematics, science and at the elementary and secondary level (Stepien & Gallagher, 1993). PBL is a pedagogical approach whereby authentic problems are the focal points for learning (Boud & Feletti, 1996). Solving unstructured real-world problems in a PBL environment engages learners in thinking processes such as exploring perspectives, questioning assumptions, looking for connections and synthesising information. The elements of PBL allow for flexible adaptation of guidance, making this instructional approach potentially more compatible with the manner in which our cognitive structures are organized than the direct guided instructional approach (Kirschner *et al.*, 2006). On this kind of activity there is not one specific correct answer or predetermined outcome (Barrows & Tamblyn, 1987). Quintessential here is not finding problems that bear some correspondence to school problems or activities in scientific laboratories but finding authentic problems that are truly problematic to students (Lave, 1992).

The effective learning is related to the cognitive load which refers to the total amount of mental effort being used in the working memory. Cognitive Load Theory (CLT) was developed out of the study of problem solving in the late 1980s (Sweller, 1988). CLT distinguishes between three categories of cognitive load: intrinsic, extraneous, and germane.

- Intrinsic cognitive load is the inherent level of difficulty associated with a specific instructional topic.
- Extraneous cognitive load is generated by the manner in which information is presented to learners and is under the control of instructional designers (Chandler & Sweller, 1991).
- Germane cognitive load is that load devoted to the processing, construction and automation of schemas.

The use of real-world scenarios through the implementation of a PBL methodology may help to establish and reinforce what Hodgson refers to as the experience of intrinsic-relevance for the students, supporting them to not only develop their own understanding of new concepts in terms of their prior learning and experience, but also make use of that knowledge and skills (Hodgson, 1997). PBL has been demonstrated to develop the cognitive functions of pre-service teachers, including their thinking skills, problem-solving skills, analytical skills, information-processing skills and self-directed learning skills (Etherington, 2011; Koray *et al.*, 2008; McPhee, 2002) (Figure 7).

Figure 7: PBL cycle for typical course (source after Chua *et al.*, 2014).



PBL curricula comprise the following elements: (a) Students are assembled in small groups; (b) these groups receive training in group collaboration skills prior to the instruction; (c) their learning task is to explain phenomena described in the problem in terms of its underlying principles or mechanism; (d) they do this by initially discussing the problem at hand, activating whatever prior knowledge is available to each of them; (e) a tutor is present to facilitate the learning; (f) the tutor does this by using a tutor instruction consisting of relevant information, questions, etc., provided by the problem designer; and (g) resources for self-directed study by the students such as books, articles, or other media (Schmidt *et al.*, 2007).

Tutor role

A PBL tutorial could be conducted in several ways but in all cases there exist two main characteristics. First characteristic is the Tutor role which is to facilitate the proceedings and ensure that the group achieves appropriate learning objectives in line with those set by the curriculum design team (Wood, 2003). For the tutor role Savin-Baden (2003) suggested that the often unarticulated aim of teachers who use PBL approaches is to develop in their students 'criticality' - emotional, intellectual and practical independence. Other authors Finkle and Torp (1995) described the tutor's role as 'cognitive coaching', something quite different from the more typical 'content coaching'. Second characteristic is that the activity is performed in groups. Groups learning facilities promote the acquisition of several desirable attributes such as communication skills, teamwork, problem solving, independent responsibility for learning, sharing information and respect for others (Wood, 2003).

Training collaboration skills

An instructional technique or technology could be used to train students in a systematic procedure. A seven-step procedure is suggested to analyse a problem at hand and to translate this problem into a set of learning issues for individual study (Schmidt *et al.*, 2007). The first step is de clarification of terms and concepts. In the second step, a definition of the problem is generated. The third step is based on a brainstorm. The fourth step is based on the explanations produced in the brainstorm that are subsequently systematized and scrutinized in view of the information available. The questions that came to the fore during the third and fourth step form the issues for individual learning, and a list of these issues is the product of the fifth step. In sixth step student study the available resources. Finally during seventh step, the students share findings, review and critically discuss the literature, solve remaining problems, and synthesize what has been learned.

It is believed that the more complex task, the more efficient it will become for individuals to cooperate with other individuals in a fashion that the load is shared (Ohtsubo, 2005).

Assessment of PBL

In the design of problem-based instruction, simple-to-complex whole task sequences are used such that students start with the easiest problem and progressively proceed to more complex or expert-like problems (Schmidt *et al.*, 2007). This is a progressive way to improve learners' knowledge and problem solving skills. In this process students know how to PBL approach works and at the same time they feel comfortable during the learning process (Table 4).

In order to assess a PBL activity, tutors could give feedback or use formative or summative assessment procedures. It is although helpful to consider assessment of the group as a whole because the award of a group mark encourages students to achieve the generic goals (Wood, 2003).

Table 4: Advantages and disadvantages of PBL methodology (source after Wood, 2003).

Advantages and disadvantages of PBL

Advantages of PBL	Disadvantages of PBL
Student centred PBL—It fosters active learning, improved understanding, and retention and development of lifelong learning skills	*Tutors who can't "teach"*—Tutors enjoy passing on their own knowledge and understanding so may find PBL facilitation difficult and frustrating
Generic competencies—PBL allows students to develop generic skills and attitudes desirable in their future practice	*Human resources*—More staff have to take part in the tutoring process
Integration—PBL facilitates an integrated core curriculum	*Other resources*—Large numbers of students need access to the same library and computer resources simultaneously
Motivation—PBL is fun for students and tutors, and the process requires all students to be engaged in the learning process	*Role models*—Students may be deprived access to a particular inspirational teacher who in a traditional curriculum would deliver lectures to a large group
"Deep" learning—PBL fosters deep learning (students interact with learning materials, relate concepts to everyday activities, and improve their understanding)	*Information overload*—Students may be unsure how much self directed study to do and what information is relevant and useful
Constructivist approach—Students activate prior knowledge and build on existing conceptual knowledge frameworks	

4.2.1.2 Project-Based Learning

Project-based learning (PBL) is a model that organizes learning around. Projects are defined as complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations (Jones *et al.*, 1997; Thomas, 1999). There is a longstanding tradition in schools for doing projects and incorporating hands-on activities, developing interdisciplinary themes, conducting field trips, and implementing laboratory investigations (Thomas, 2000). It is important to know and see the distinctions made between a traditional classroom instruction and a project-based learning.

To capture the uniqueness of project-based learning it was important to see if the learning process follows five criteria which are centrality, driving question, constructive investigations, autonomy and realism (Thomas, 2000).

- PBL projects are central, not peripheral to the curriculum, so that means that the projects are the curriculum, students encounter and learn the central concepts of the discipline via the project.
- PBL projects are focused on questions or problems that "drive" students to encounter the central concepts and principles of a discipline. This is usually done with a question or a problem.
- Projects involve students in a constructive investigation. Investigations may be design, decision-making, problem-finding, problem-solving, discovery, or model-building processes. The central activities of the project must involve the transformation and construction of knowledge of students (Bereiter & Scardamalia, 1999).
- Projects are students-driven to some significant degree. PBL projects incorporate more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects.
- Projects are realistic, not school-like. PBL incorporates real-life challenges where the focus is on authentic problems or questions and where solutions have the potential to be implemented.

5. Science teachers

The one key factor to the success or failure of putting any curricular innovation into practice is the teacher (Mitchener & Anderson, 1989; Tobin *et al.*, 1994). Teachers, instead of being technician who apply instructions, are constructivists who process information, make decisions, generate routines and practical knowledge, and have beliefs that influence their professional activity (Shavelson & Stern, 1981). Usually on the real classroom, teachers construct simplified models with which they are comfortable and that they find no conflictive and permit them to act (Wallace & Louden, 1992). It is now generally accepted that to improve learning in our schools we need more and better teacher professional learning (Goodrum, 2006). Therefore, one effective way to induce a better knowledge and acceptability of society towards new science and technology is by promoting biotechnological literacy among teachers.

Teachers with differentiated and integrated knowledge will have greater ability than those whose knowledge is limited and fragmented, to plan and enact lessons that help students develop deep and integrated understandings (Magnusson *et al.*, 1999). Some authors found that science teacher's knowledge and beliefs have a profound effect on all aspects of their teaching (Carlsen, 1993; Cantrell *et al.*, 2003) as well as on how and what their students learn (Magnusson, 1991).

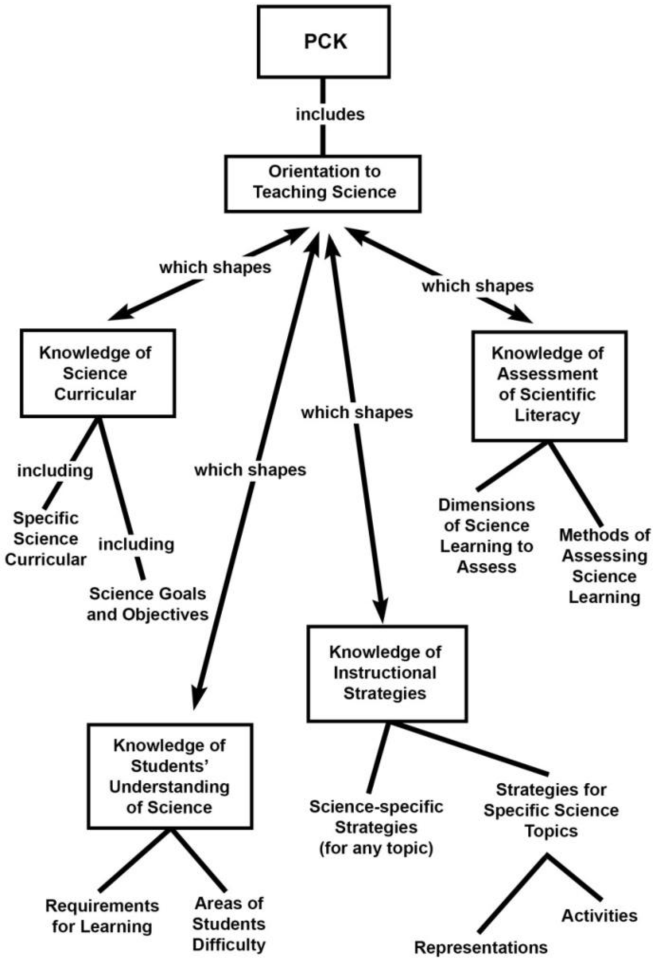
In the 80s it was suggested one of the most important component of teaching expertise named "Pedagogical Content Knowledge" (PCK) by Shulman (1986) and his colleagues and students (e.g. Carlsen, 1987; Grossman *et al.*, 1989; Gudmundsdottir, 1987a, 1987b; Gudmundsdottir & Shulman, 1987; Marks, 1990). Pedagogical content knowledge is a type of knowledge that is unique to teachers, and is based on the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach). It is the integration or the synthesis of teachers' pedagogical knowledge and their subject matter knowledge that comprises pedagogical content knowledge (Cochran, 1997). PCK is incorporated as a vital component of science teachers' professional development (National Research Council, 1996). For this reason, the role of PCK in science teaching field and the investigation of contexts for PCK development have attracted much attention from science educators (Nilsson & Loughran, 2012).

Magnusson *et al.*, (1999) conceptualize pedagogical content knowledge for science teaching as consisting of five components (Figure 8):

- Orientations towards science teaching.
- Knowledge and beliefs about science curriculum.
- Knowledge and beliefs about students' understanding of specific science topics.
- Knowledge and beliefs about assessment in science.
- Knowledge and beliefs about instructional strategies for teaching science.

It is important to know that what is unique about the teaching process is that it requires teachers to "transform" their subject matter knowledge for the purpose of teaching (Shulman, 1986). The transformation only can occur as the teacher critically reflects on and interprets the subject matter; finds multiple ways to represent the information as analogies, metaphors, examples, problems, demonstrations, and/or classroom activities; adapts the material to students' developmental levels and abilities, gender, prior knowledge, and misconceptions (Cochran, 1997).

Figure 8: Components of pedagogical content knowledge for science teaching (adapted from Magnusson *et al*., 1999).



Outline of the thesis

This thesis aims to contribute to the biotechnological literacy of future teachers, by doing research on knowledge and attitudes towards biotechnology of preservice teachers. What are the knowledge level and attitudes towards biotechnology of Spanish and Swedish pre-service teachers? Are these two concepts correlated? How can science education help to develop these aspects? The hypothesis considered in this Thesis is that the knowledge level of pre-service teachers on biology influences their attitudes towards biotechnology. Additionally, learning activities based on STS approach and Problem-Based Learning methodology could be suitable strategies to implement biotechnological literacy at pre-service teachers' training.

To achieve this, we have first analysed the knowledge and attitudes towards biotechnology of preservice teachers in two European countries (Spain and Sweden). Our first study triggered the creation of a new survey and the identificacion of some misunderstandings and hot spots concerning basic concepts of genetics. Afterwards, to address the identified lack of knowledge, new educational material, based on STSE and Problem-Based Learning strategies, were created and validated.

As previously mentioned, the first part of the thesis is based on the creation of a new survey to assess the knowledge and attitudes towards biotechnology of pre-service teachers. This new instrument consists in a 3-part questionnaire:

1. Socio-demographic data.
2. Knowledge questionnaire to assess the level basic biological knowledge that supports biotechnology development and its applications.
3. Attitude questionnaire to analyse the attitudes of the pre-service teachers towards different biotechnology aspects.

This questionnaire was previously validated and then conducted at Universitat Rovira i Virgili (URV) and Universitat Autònoma de Barcelona (UAB). The same questionnaire was translated into Swedish and was conducted at Karlstad University (KAU), in Sweden. The results of this first part are enclosed in the first and second chapters of this thesis:

Chapter 1. Knowledge and Attitudes towards Biotechnology of Elementary Education pre-service Teachers: The First Spanish Experience. *International Journal of Science Education* (Submitted on September 2014, first revision sent on February 2015, second revision sent August 2015).
Chapter 2. A comparison across Europe: Swedish and Spanish pre- service teacher students' knowledge and attitudes towards Biotechnology.

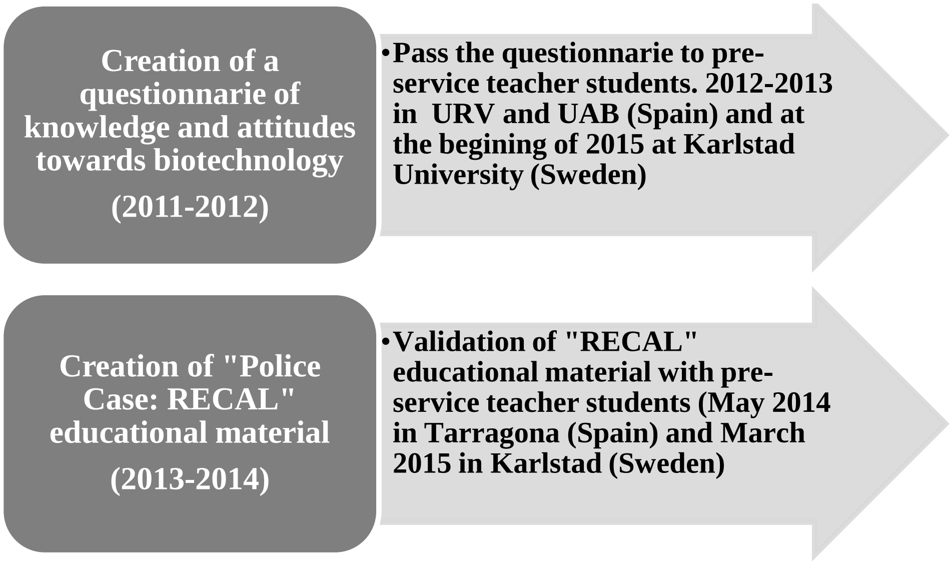
Mainly, the results of this first study point out that, although preservice teachers are aware of biotechnology applications, topics concerning the structure of DNA, management of genetic information inside the cell, GMO technology and the use of microorganisms as biotechnological tools were not correctly understood. Additionally, our results show a positive correlation between better knowledge and more positive attitudes towards biotechnology. From these results, the second part of the present Thesis was set out.

The second part of the thesis was focused on the development of new educational material to teach some of the basic concepts of genetics identified as unknown in the previous questionnaire, by applying the problem-based learning methodology and STSE approach. The new teaching material (RECAL activity) was validated and proved to be useful to both increase students' knowledge and develop their thinking and problem-solving skills. The results related to this second phase of the present thesis are enclosed in the following chapters:

Chapter 3. Learning genetics through a scientific inquiry game. *Journal of biological education* (Accepted for publication on October 2015).
Chapter 4. Assessment of a scientific inquiry game about genetics for pre-service teacher students from Sweden and Spain.

The outline of both studies dates from 2011 to 2015. During these four years both studies have been carried out at the same time (see Figure 9). First part of the thesis was started earlier and when it was found the first results of the knowledge and attitudes questionnaires it was started the second part focused on the creation of new educational materials.

Figure 9: Outline of the thesis.



References

American Association for the Advancement of Science (AAAS), (1989) http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. Teachers College Press.

Alberts, B. M., & Labov, J. B. (2003). The future of biotechnology depends on quality science education. *Electronic Journal of Biotechnology*, 6(3), 167-167.

Barrows, H.S. & Tamblyn, R. M. (1987). *Problem-based learning: An approach to medical education*. New York: Springer.

Barrows, H.S. (1992). The tutorial process. Springfield, MA: Southern Illinois University school of Medicine.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New directions for teaching and learning*, 1996(68), 3-12.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education*. 3(1), 349-377.

Bencze, J. L., Bowen, G. M., & Alsop, S. (2006). Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education*, 90(3), 400-419.

Bereiter, C., & Scardamalia, M. (1999). Process and product in PBL research. *Toronto: Ontario Institutes for Studies in Education/University of Toronto*.

Biggs, J. (2003). *Teaching for quality learning at university*. Buckingham: Open University Press.

Bingle, W. H., & Gaskell, P. J. (1994). Scientific literacy for decision making and the social construction of scientific knowledge. *Science Education*, 78(2), 185-201.

Bloom, B. S. (1956). *Taxonomy of educational objectives*. Vol. 1: Cognitive domain. New York: McKay.

Bodmer, W. (1985). *The public understanding of science*. London: Royal Society.

Boud, D., & Feletti, G. (1996). *The challenge of problem-based learning*. London: Kogan Page. 10

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*. National Academy Press.

Brickhouse, N. W., Ebert-May, D., & Wier, B. (1989). *Scientific literacy: Perspectives of school administrators, teachers, students, and scientists from an urban mid-Atlantic community*. In A. B. Champagne, B. E. Lovitts, & B. J. Calinger (Eds.), Scientific Literacy. Washington, DC: American Association for the Advancement of Science, pp. 157-176.

Bromme, R., & Goldman, S. R. (2014). The Public's Bounded Understanding of Science. *Educational Psychologist*, 49:2, 59-69.

Bruner, J. (1960). *The process of education*. Cambridge, MA: Harvard University Press.

Bruner, J. S. (1961). *The art of discovery*. Hardvard Educational Review, 31, 21-32.

Bud, R. (1994). *The uses of life: a history of biotechnology*. Cambridge University Press.

Campbell, B., Lazonby, J., Millar, R., Nicolson, P., Ramsden, J., & Waddington, D. (1994). Science: The Salters' approach - A case study of the process of large scale curriculum development. *Science Education*, 78, 415-447.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching efficacy of pre-service elementary teachers. *Journal of Science Teacher Education,* 14(3), 177-192. doi: 10.1023/A:1025974417256

Carlsen, W. S. (1987). Why do you ask? The effects of science teacher subject-matter knowledge on teacher questioning and classroom discourse. Paper presented at the Annual Meeting of the American Educational Research Association. (ERIC Document Reproduction Service NO. ED 293 181).

Carlsen, W. S. (1993). Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching*, 30(5), 471-481.

Carretero, M. (2000). *Constructivismo y educación*. Editorial Progreso.

Chabalengula, V. M., Mumba, F., & Chitiyo, J. (2011). American Elementary Education Pre-Service Teachers' Attitudes towards Biotechnology Processes. *International Journal of Environmental and Science Education*, 6(4), 341-357.

Champagne, A. B., & Lovitts, B. E. (1989). *Scientific literacy: A concept in search of definition*. In A. B. Champagne, B. E. Lovitts, & B. J. Calinger (Eds.), Scientific Literacy. Washington, DC: American Association for the Advancement of Science, pp. 1-14.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and instruction*, 8(4), 293-332.

Cheek, D. W. (1992). *Thinking Constructively About Science, Technology, and Society Education: General Introduction and From the Creation to the Flood.* SUNY Press.

Chua, B. L., Tan, O. S., & Liu, W. C. (2014). Journey into the problem-solving process: cognitive functions in a PBL environment. *Innovations in Education and Teaching International.*

Cochran, K. F. (1997). Pedagodical content Knowledge: Teachers' Intergration of Subject Matter, Pedagogy, Students, and Learning Environments. Research Matters to the Science Teacher, No. 9702. https://www.narst.org/publications/research/pck.cfm

Coles, M. (1998). Science for employment and higher education. *International Journal of Science Education*, 20, 609-621.

Communication From the Commission. (2010). Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels: European Commission.*

Costa, V. B. (1995). When science is "another world": Relationships between worlds of family, friends, school and science. *Science Education*, 79, 313-333.

Cutcliffe, S. (1987), "Three Stages in the Evolution of STS Studies", Mimeo. Lehigh University, Bethleham PA.-, (1989), "The Emergence of STS as an Academic Field", *Reserach in Philosophy & Technology*, Vol. 9, pp.287-01.

Darçin, E. S., & Güven, T. (2008). Development of an Attitude Measure Oriented to Biotechnology for the Pre-Service Science Teachers. *Journal of Turkish Science Education*, 5(3), 72-81.

DeBenedictis, D. J. (1990). Learning by Doing. *ABAJ*, 76, 54.

Dimopoulos, K., & Koulaidis, V. (2003). Science and technology education for citizenship: The potential role of the press. *Science Education, 87(2),* 241-256.

Dori, Y. J., & Tal, R. T. (2000). Formal and informal collaborative projects: Engaging in industry with environmental awareness. *Science Education*, 84(1), 95-113.

Driver, R. H. & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education*, 13, 105-122.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. McGraw-Hill International.

Duggan, S., & Gott, R. (2002). What sort of science education do we really need? *International Journal of Science Education*, 24, 661-679.

Durant, J. & Bauer (1997). Public understanding of science: the 1996 survey. Paper presented at a seminar at the Royal Society, 8 December 1997.

Durant, J. R., Evans, G. A. & Thomas, G. P. (1992). The public understanding of science in Britain: the role of medicine in popular representations of science. *Public Understanding Science*; 1: 161-82

Durant, J. R., Evans, G. A. & Thomas, G. P. (1989). The public understanding of science. *Nature*, 340, 11–14.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Harcourt Brace Jovanovich College Publishers.

Eijkelhof, H. M. C., & Verhagen, P.A.J. (1985). A thematic approach to curriculum development in senior high schools. In The Many Faces of Teaching and Learning Mechanics. Ed. P.L. Lijnse. Utrecht: WCC Publishers.

Eijkelhof, H. M. C. & Lijnse, P. (1988). The role of research and development to imporve STS education: Experiences from the PLON Project. *International Journal of Science Education*, 10(4), 464-474.

Enger, S. & Yager, R. (2001). Assessing Student Understanding in Science. Thousand Oaks, CA: Corwin Press.

Etherington, M. B. (2011). Investigative primary science: A problem-based learning approach. *Australian Journal of Teacher Education*, 36, 36–57.

European Commission (2010a). *Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels (Belgium): Directorate General Research, EU.

European Commission (2010b). *Special Eurobarometer 341. Biotechnology*. Brussels (Belgium): Directorate General Research, EU.

European Commission (2012). *Innovating for sustainable growth: A bioeconomy for Europe*. Brussels (Belgium): Directorate General Research, EU.

Fensham, P. J. (2000). Providing suitable content in the "science for all" curriculum. In R. Millar, J. Leach, & J. Osborne (Eds.), Improving science education: The contribution of research (pp. 147-164). Birmingham, UK: Open University Press.

Fensham, P. J. (2002). Time to change drivers for science literacy. *Canadian Journal of Science, Mathematics and Technology Education*, 2, 9-24.

Finkle, S.L., & Torp, L.L. (1995). Introduction to PBL. Aurora, IL: Illinois Math and Science Academy, The Center for Problem-Based Learning.

Forster, M. (2004). Higher order thinking skills. Research Developments, 11(11), 1.

Gaskell, G., Stares, S., Allansdottir, A., Allum, N., Castro, P., Esmer, Y. & Wagner, W. (2010). *Europeans and Biotechnology in 2010 Winds of change?.*

Goodrum, D. (2006). Inquiry in Science Classrooms: Rhetoric or Reality? *Australian Council for Education Research*. Retrieved from: http://research.acer.edu.au/research_conference_2006/11

Grossman, P. L., Wilson, S. M., & Shulman, L. (1989). Teachers of substance: Subject matter knowledge for teaching. In M. C. Reynolds (Ed.). *Knowledge base for the beginning teacher* (pp. 23-36). Oxford: Pergamon Press.

Gudmundsdottir, S. (1987a). Learning to teach social studies: Case studies of Chris and Cathy. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, D.C. (ERIC Document Reproduction Service NO. ED 290 700)

Gudmundsdottir, S. (1987b). Pedagogical content knowledge: teachers' ways of knowing. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, D.C. (ERIC Document Reproduction Service NO. ED 290 701)

Gudmundsdottir, S. & Shulman, L. (1987). Pedagogical content knowledge in social studies. *Scandinavian Journal of Educational Research*, 31, 59-70.

Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of research in science teaching*, 37(7), 655-675.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99-107.

Hodgson, V. (1997). Lectures and the experience of relevance. In *The experience of learning*, ed. F. Marton, D. Hounsell, and N. Entwistle, 159-71. Edinburgh. Scottish Academic Press.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education*, 25(6), 645–670.

Hurd, P.D. (1960). Biological education in American secondary schools, 1890-1960. Washington, DC: AIBS.

Jenkins, E. (1997). *Towards a functional public understanding of science*. In Science Today (pp.137-150). London: Routledge.

Jonassen, D. (1991). Objectivism vs. constructivism. *Educational Technology Reserach and Development*, 39(3), 5-14.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). *Real-life problem solving: A collaborative approach to interdisciplinary learning.* American Psychological Association.

Kember, D., A. Ho, & C. Hong. (2008). The importance of establishing relevance in motivating student learning. *Active Learning in Higher Education* 9: 249–63.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist*, 41(2), 75-86.

Klop, T. (2008). *Attitudes of secondary school students towards modern biotechnology*. Psychology.

Kolb, D. A., & Fry, R. (1975). Toward an applied theory of experiential learning. In C. Cooper (Ed.), *Studies of group process* (pp. 33-57). New York: Wiley.

Koray, O., Presley, A., Koksal, M. S., & Ozdemir, M. (2008). Enhancing problem solving skills of preservice elementary school teachers through problem-based learning. *Asia-Pacific Forum on Science Learning and Teaching*, 9, 1–18.

Kyle, W. C. (1996). Editorial: The importance of investing in human resources. *Journal of Research in Science Teaching*, 33, 1-4.

Lave, J. (1992). Word problems: A microcosm of theories of learning. In P. Light & G. Butterworth (Eds.), Context and cognition: Ways of learning and knowing (pp. 74–92). Hertfordshire: Harvester Wheatsheaf.

Lederman, N.G., & Zeidler, D. L. (1987). Science teachers' conceptioncs of the nature of science: DO they really influence teacher behaviour? *Science Education*, 71(5), 721-734.

Lederman, N. G., Schwartz, R., Abd-El-Khalick, F., & Bell, R. F. (2001). Preservice teachers' understanding and teaching of the nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education*, 1 (2), 135-160.

Levy-Nahum, T., Ben-Chaim, D., Azaiza, I., Herskovitz, O., & Zoller, U. (2010). Does STES-Oriented Science Education Promote 10th-Grade Students' Decision-Making Capability? *International Journal of Science Education*, 32(10), 1315-1336.

Lord, T., & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *The American Biology Teacher*, 68(6), 342-345.

Lyle, K.S. & Robinson W.R. (2001). Teaching science problem solving: An overview of experimental work. *Journal of Chemical Education*, vol. 78, no 9, p. 1162.

MacCleave-Frazier, Anne, & Murray, Eloise C. (1984). A framework for reconceptualizinf home economics. *Canadian Home Economics Journal, 34 (2)*, 69-73.

Magnusson, S. (1991). *The relationship between teacher's content and pedagogical content knowledge and students' content knowledge of heart energy and temperature*, unpublished doctoral dissertation, The University of Maryland, College Park, MD.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. *InExamining pedagogical content knowledge* (pp. 95-132). Springer Netherlands.

Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of teacher education*, 41, 3-11.

Martínez-Gracia, M. V., Gil-Quýlez, M. J., & Osada, J. (2003). Genetic engineering: a matter that requires further refinement in Spanish secondary school textbooks. *International Journal of Science Education*, 25(9), 1148-1168.

Marton, F., Beatty E., & Dall'Alba G. (1993). Conceptions of learning. *International Journal of Educational Research* 19, no. 3: 277–300.

Mayoh, K., & Knutton, S. (1997). Using out-of-school experience in science lessons: reality or rhetoric? *International Journal of Science Education*, 19(7), 849-867.

McKinley, E. (2005). Locating the global: Culture, language and science education for indigenous students. *International Journal of Science Education*, 27, 227-241.

McPhee, A. (2002). Problem-based learning in initial teacher education: Taking the agenda forward. *Journal of Educational Enquiry*, 3, 60–78.

Michael, M. (1992). Lay discourses in science: science in general, science in particular, and self. *Science Technology and Human Values*, 17, 313-333.

Miller, J. D., Pardo, R. & Niwa, F. (1997). Public perceptions of science and technology: a comparative study of the European Union, the United States, Japan, and Canada (Bilbao: BBV Foundation).

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science*, 7(3), 203-223. doi: 10.1088/0963-6625/7/3/001

Mitchener, C. P., & Anderson, R. D. (1989). Teachers' perspective: Developing and implementing an STS curriculum. *Journal of Research in Science Teaching*, 26(4), 351-369.

National Research Council (1996). National Science Education Standards. Washington, DC; National Academy Press.

Nilsson, P., & Loughran, J. (2012). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education*, 23(7), 699-721.

Ohtsubo, Y. (2005). Should information be redundantly distributed among group members? Effective use of group memory in collaborative problem solving. *Applied Cognitive Psychology*, 19(9), 1219-1233.

Pattison Muir, M.M., *The Story of Alchemy and the Beginnings of Chemistry*, D. Appleton and company, pp. 191-194, 1903.

Pedretti, E., & Hodson, D. (1995). From rhetoric to action: Implementing STS education through action research. *Journal of Research in Science Teaching*, 32(5), 463-485.

Pele, M; Campeanu, C; University of Agronomic Sciences and Veterinary Medicine, Romania. Biotechnology. An Introduction. Southampton: WIT, 2012. 332. ISBN: 9781283575348.

Piaget, J. (1973). *To understand is to invent: The future of education*. New York: The Viking Press.

Prokop, P., Lešková, A., Kubiatko, M., & Diran, C. (2007). Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education*, 29(7), 895-907.

Race, P. (2007). *The lecturer's toolkit*. London: Routledge.

Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., & Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. Cognition and instruction: Twenty-five years of progress, 263-305.

Reiss, M. J. (2000). *Understanding science lessons: Five years of science teaching*. Open Univ Pr.

Resnick, L. B., & Klopfer, L. E. (1989). Toward the Thinking Curriculum: Current Cognitive Research. 1989 ASCD Yearbook. Association for Supervision and Curriculum Development, 1250 N. Pitt St., Alexandria, VA 22314-1403.

Rettig, M. D., & Canady, R. L. (1996). All Around the Block: The Benefits and Challenges of a Non-traditional School Schedule. School Administrator, 53(8), 8-14.

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum.

Rutherford, F. J. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching*, 2, 80-84.

Sadler, T. D., & Zeidler, D. L. (2004). The morality of socioscientific issues: Construal and resolution of genetic engineering dilemmas. *Science education*, 88(1), 4-27.

Sáez MJ, Niño AG, Carretero A (2007). Matching Society Values: Students' views of biotechnology. *Int. J. Sci. Educ*., 30(2): 1-17.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, 24(5), 1289-1299.

Savin-Baden, M. (2003). Facilitating problem based learning: Illuminating perspectives. Buckingham: Society for Research in Higher Education and Open University Press.

Schank, R. C., Berman, T. R., & Macpherson, K. A. (1999). Learning by doing. *Instructional-design theories and models: A new paradigm of instructional theory*, 2, 161-181.

Schmidt, H. G., Loyens, S. M., Van Gog, T., & Paas, F. (2007). Problem-based learning is compatible with human cognitive architecture: Commentary on Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 91-97.

Shamos M. The myth of scientific literacy. Brunswick: Rutgers University Press, 1995.

Shavelson, R. J., & Stern, P. (1981). Research on teachers' pedagogical thoughts, judgments, decisions, and behavior. *Review of educational research*, 51(4), 455-498.

Shen, B. S. P. (1975). Scientific literacy and the public understanding of science. In S. B. Day (Ed.), The communication of scientific information (pp. 44-52). Basel, Switzerland: Karger.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15, 4-14.

Smithers, A. & Robinson, P. (1988). The growth of mixed A-levels (Manchester: Department of Education, University of Manchester).

Solomon, J. (1998). The Science curricula of Europe and notion of scientific culture. In D. A. Roberts & L. Östman (Eds.), Problems of meaning in science curriculum (pp. 166-177). New York: Teachers College Press.

Solomon, J., & Thomas, J. (1999). Science education for the public understanding of science. *Studies in Science Education*, 33:1, 61-89.

Sorgo, A., & Ambrozis-Dolinsek, J. (2009). The relationship among knowledge of, attitudes toward and acceptance of genetically modified organisms (GMOs) among Slovenian teachers. *Electronic Journal of Biotechnology*, 12(4), 1-2.

Stephenson, Neil (undated). *Introduction to Inquiry Based Learning.* [on line]. [Date of search: 10th April 2015]. http://www.teachinquiry.com/index/Introduction.html

Stepien, W., & Gallagher, S. (1993). Problem-based learning: As authentic as it gets. *Educational leadership*, 50, 25-25.

Sutherland, L., Howard, S., & Markauskaite, L. (2010). Professional identity creation: Examining the development of beginning preservice teachers' understanding of their work as teachers. *Teaching and teacher education,* 26(3), 455-465.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive science*, 12(2), 257-285.

Thomas, J. W. (1999). *Project based learning: A handbook for middle and high school teachers.* Buck Institute for Education.

Thomas, J. W. (2000). A review of research on project-based learning.

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 45-93). New York: Macmillan.

Turner, S. (2008). School science and its controversies; or, whatever happened to scientific literacy? *Public Understanding of Science*, 17(1), 55-72.

Turney, J. (1996a). Public understanding of science. *The Lancet*, 347(9008), 1087-1090.

Turney, J. (1996b). Research in practice: a public understanding of science research digest for practitioners. London: Committee on the Public Understanding of science, 1996.

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education*, 37(2), 123-130.

Vazquez-Alonso, A., Garcia-Carmona, A., Manassero-Mas, M. A., & Bennassar-Roig, A. (2013). Spanish Secondary-School Science Teachers' Beliefs about Science-Technology-Society (STS) Issues. *Science & Education*, 22(5), 1191-1218.

Von Glasersfeld, E. (1989). Constructivism in education. In the International Encyclopedia of Education -Research and Studies- Supplementary Volume One. Eds. Torsten Husen and T. Neville Postlewaite. New York: Pergamon Press.

Walberg, H. J. (1991). Improving school science in advanced and developing countries. *Review of Educational research*, 61, 25-69.

Wallace, J., & Louden, W. (1992). Science teaching and teachers' knowledge: Prospects for reform of elementary classrooms. *Science Education*, 76(5), 507-521.

Watts, M., Alsop, S., Zylbersztajn, A., and de Silva, S. M. (1997). "Event-centered-learning": An approach to teaching science technology and societal issues in two countries. *International Journal of Science Education*, 26, 341-351.

Welch, W.W. (1979). Twenty years of science curriculum developments: A look back. In D.C. Berliner (Ed.), *Review of research in education* (vol.7, pp. 282-306). Washington DC: AERA.

Wilson, B. G. (Ed.) (1996). Constructivist learning environments: Case studies in instructional design. *Educational Technology*.

Wood, D. F. (2003). Problem based learning. *Bmj*, 326(7384), 328-330.

Woodward, R. (2009). *The organisation for economic co-operation and development* (OECD). Routledge.

Zeidler, D. L., & Keefer, M. (2003). *The role of moral reasoning and the status of socioscientific issues in science education* (pp. 7-38). Springer Netherlands.

Ziman, J. (1984). An introduction to science studies: the philosophical and social aspects of science and technology. Cambridge: Cambridge University Press.

Zohar, A., & Dori, Y. J. (2003). Higher order thinking skills and low-achieving students: Are they mutually exclusive? *The Journal of the Learning Sciences*, 12(2), 145-181.

Zoller, U. (1993). Lecture and learning: Are they compatible? Maybe for LOCS; unlikely for HOCS. *Journal of Chemical Education*, 70(3), 195–197.

Zoller, U., & Tsaparlis, G. (1997). Higher and lower-order cognitive skills: The case of chemistry. *Research in Science Education*, 27(1), 117-130.

Zoller, U. (2000). Teaching tomorrow's college science courses: Are we getting it right? *Journal of College Science Teaching*, 29(6), 409–414.

Zoller, U., & Pushkin, D. (2007). Matching higher-order cognitive skills (HOCS)-promoting goal with problem-based laboratory practice in a freshman organic chemistry course. *Chemical Education Research and Practice*, 8(2), 153-171.

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *Journal of Chemical Education*, 89, 297-300. doi: 10.1021/ed300047v

CHAPTER I

Knowledge and Attitudes towards Biotechnology of Elementary Education pre-service Teachers: The First Spanish Experience

Under revision

Casanoves, M., González, A., Salvadó, Z., Haro, J. and Novo, M. Knowledge and Attitudes towards Biotechnology of Elementary Education pre-service Teachers: The First Spanish Experience. *International Journal of Science Education* (Submitted on setember 2014, first revision sent on February 2015, second revision sent on August 2015)

Abstract

Due to the important impact that biotechnology has on current Western societies, well informed critical citizens are needed. People prepared to make conscious decisions about aspects of biotechnology that relate to their own lives. Teachers play a central role in all education systems. Thus, the biotechnological literacy of pre-service teachers is an important consideration as they will become an influential collective as future teachers of the next generation of children. The attitudes towards science (and biotechnology) that teachers have, affect their behavior and influence the way they implement their daily practice of science teaching in school.

This study analyzes the attitudes and knowledge of Spanish pre-service teachers towards biotechnology. We designed a new survey instrument that was completed by 407 university students who were taking official degree programs in pre-school and primary education. Our results point out that, although they are aware of biotechnology applications, topics concerning the structure of DNA, management of genetic information inside the cell, GMO technology and the use of microorganisms as biotechnological tools were not correctly answered.

According to our attitude analysis, Spanish pre-service teachers could be defined as opponents of GM product acquisition, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and other scientific advances. Our results show a positive correlation between better knowledge and more positive attitudes towards biotechnology. A Spanish pre-service teacher with positive attitudes towards biotechnology tends to be a student with a strong biology background who scored good marks in our knowledge test.

Keywords: *Biotechnology education, Attitudes, Pre-service teachers, Survey*

Introduction

Over the last few decades, there has been a revolution in the field of biological research. Genomics and its related technologies (or modern biotechnology) has the potential to become one of the most important scientific and technological revolutions of the 21st century (Kirkpatrick, Orvis, & Pittendrigh, 2002). In 2010, the European Commission launched the Europe 2020 Strategy that is designed to help the nations of the European Union (EU) to come out stronger economically from the current crisis and to prepare their economies for the next decade's challenges (European Commission, 2010a). Biotechnology has been seen as a major driving force in the creation of better health and welfare for European citizens. Toward this goal, the EU has undertaken many initiatives in recent years to stimulate and coordinate biotechnology developments (European Commission, 2012). Although there is a strong chemical and agricultural base in the EU, issues such as environmental protection, consumer safety, politically strong environmental movements and a general lack of social acceptance of genetic modification (GM) technology have been seen as factors affecting the overall development of biotechnology in Europe (European Commission, 2010b).

New scientific methodologies allow cheaper and faster ways to sequence genomes and perform global analyses of these genomes at different biological levels (e.g., gene, mRNA, proteins, etc). In addition, newly developed techniques allow a vast landscape of applications that span the gamut from biomedical research to agriculture. This rapid development of modern biotechnology and genetic engineering has led to a huge gap between what the scientific community understands to be the risk and benefits and what is understood by the society (European Commission, 2010b). While some progress, in terms of basic knowledge, has been made since the Eurobarometer of 1996, the knowledge and information gap between science and society still exists (European Commission, 2010b). However, the perspective of a socially-viable science should be shared with citizens and, in this way, socially accepted technological innovations can be created. Thus, it would be advantageous if both citizens (society) and scientist (scientific community) were to share similar perspectives on scientific advances. In this way, citizens and their scientific community would share common perspectives about scientific advances and innovations created from these advances would be much more easily accepted into that society. Otherwise, in a society in which citizens hold different perspectives on science than their scientific community, socially accepted technological innovations will be more difficult to be promoted and supported (Gaskell *et al.*, 2006). However, in order to involve society in the scientific policy, well-informed citizens are needed who are able to make thoughtful decisions based on both scientific conclusions as well as ethical and moral consideration of the issues.

Following from this position, much research in science education worldwide promotes, as an important goal of science teaching, the scientific and technological literacy of entire populations (Dimopoulos & Koulaidis, 2003; González, Casanoves, Barnett, & Novo, 2013; Jenkins, 1997; Miller, 1998; Salvadó, Casanoves, & Novo, 2013; Zoller, 2012). The underlying notion is that the personal development of knowledge and appropriate mental habits will allows people to become more responsible citizens, better able to create informed opinions, even while living in societies that are becoming increasingly complex and ever more dependent on science and technology. Over the last few decades, interest in the biotechnological literacy of society has increased among science education researchers (Kidman, 2009; Klop & Severiens, 2007; Sorgo & Ambrozic-Dolinsek, 2009; Steele & Aubusson, 2004). These studies have aimed to analyze and develop the content that should be found in any school science curriculum that is intended to promote scientific literacy. To help achieve this purpose, such studies assessed teachers' and students' attitudes towards different aspects of biotechnology, including prior knowledge, fears, beliefs, and ethical views related to the use of these new technologies. It is important to point out that the levels of biotechnological literacy differ significantly amongst the various European nations. The highest proportion of informed citizens are found in The Netherlands and Scandinavian countries, which reflects their traditionally strong education systems along with their higher degree of awareness of scientific and technical issues. On the other hand states such as Greece, Ireland, Portugal and Spain appear to have minimally informed citizens regarding biotechnology (Pardo, Midden, & Miller, 2002).

It has been shown that the attitudes of science that teachers have affect their behaviors and influence the ways in which they approach good science teaching in schools (Cantrell, Young, & Moore, 2003). In particular, pre-existing attitudes and beliefs influence the way that teachers understand what they learn during their training and how they implement it in their daily practices at school (Fetters, Czerniak, Fish, & Shawberry, 2002; Lee & Ginsburg, 2007; Roehrig, Kruse, & Kern, 2007). A great many studies demonstrate that teachers with more positive attitudes towards science include science topics more often in the classroom and use active learning methodologies such as inquiry based learning activities, hands-on materials, etc. (Earl & Winkeljohn, 1977; Haney, Lumpe, Czerniak, & Egan, 2002; Shrigley, 1974; Stefanich & Kelsey, 1989). Similarly, those teachers who show more positive self-efficacy tend to invest more time in science teaching and developing scientific concepts as well as including more active learning practices in the classroom (Carleton, Fitch, & Krockover, 2008; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Riggs & Enochs, 1990). In addition, together with attitudes, knowledge level in scientific topics directly influences the self-confidence and self-efficacy of teachers in their approach to science activities in the classroom (Maier *et al.*, 2013).

Biotechnology is no exception. Elementary teachers may not have to teach complex biotechnology topics in their classroom. However, the more knowledge in biotechnology fundamentals the more self-confidence teachers will have in this subject and, therefore, it can be assumed to increase the chances that more biotechnology topics will seep into their teaching. Chabalengula *et al.* (2011) argued that, as a trusted source of information among elementary students, it is critical for pre-service elementary teachers to be well informed about the benefits and challenges of biotechnology. If these pre-service teachers are well informed, then they would possess attitudes that would reflect less biased and more accurate information about biotechnology. Interestingly, Klop and Severiens (2007) claim it is important to include an affective component of biotechnology in science education curricula. They argue that this change in emphasis might help students to develop a more balance attitude towards biotechnology.

Teachers play a critical, central role in the education system. Pre-service teachers are therefore an influential collective in that they become teachers of the next generation of citizens. They will obviously have an important role in informing younger students about modern biotechnology and its new related technologies (Chabalengula, Mumba, & Chitiyo, 2011). The analysis of pre-service teachers' attitudes towards biotechnology will help to point out the problematic aspects of biotechnology among this socially influential collective.

With the results of such analysis, changes in science courses in teacher education programs could be recommended.

In spite of the central role that teachers' attitudes play in teaching, most studies to date about biotechnology literacy have only investigated high school and university students. Indeed, only four studies have been focused on elementary education pre-service teachers, in four different countries: Slovakia (Prokop, Leskova, Kubiatko, & Diran, 2007), Lithuania (Lamanauskas & Makarskaite-Petkeviciene, 2008), Turkey (Darçin, 2011) and USA (Chabalengula, Mumba, & Chitiyo, 2011). In counterpoint, data related to Spaniards' attitudes towards biotechnology come from socio-economic studies (European Commission, 2010b; Lujan & Todt, 2000; Pardo *et al.*, 2002), economic surveys on genetically modified (GM) food products (Angulo & Gil, 2007) while only one study focused on high school students (Sáez, Niño, & Carretero, 2008). There are no published studies devoted to the assessment of biotechnology knowledge and attitudes of Spanish university students who are hoping to become elementary schoolteachers. This, then, is the purpose of our study, to better understand the knowledge and attitudes of one segment of the Spanish population, university students in the Catalonia region.

In the present study, we followed the tripartite model of attitudes towards modern biotechnology proposed by Klop (2008). In this model, attitudes are the product of knowing and thinking about biotechnology (the cognitive component), feelings and emotions about biotech issues (the affective component), and behavioral intentions towards biotechnology and its applications (the behavioral component). These three components have been included in the survey performed for the present study.

Purpose

This study analyzes Spanish elementary education pre-service teachers' views of two aspects of biotechnology, (i) the level of their knowledge of genetic and biotechnological facts (cognitive component) and (ii) their attitudes towards biotechnology, including both the affective and the behavioral components. Additionally, we collected socio-demographic data to identify the potential correlations between specific attitudes and socio-demographic variables (gender, age, previous training in biology and educational background of their parents). Authors declare no conflict of interest.

Methods

Participants

In this study we requested the collaboration of 407 students who were taking a program called "Preschool and Primary Education", 270 students in the Faculty of Education at the Universitat Rovira i Virgili, URV (Tarragona) and 137 students in the Faculty of Education at the Universitat Autònoma de Barcelona, UAB (Barcelona). Students were, on average, 22 years old.

Instrument and Instrument Design

Elementary education pre-service teachers took a new survey, expressly designed for this study. This new survey was divided into three parts. The first part was designed to obtain the following socio-demographic information about surveyed students: gender, age, previous training in biology and educational background of their parents. The second part consisted of 21 *True/False/Don't Know* items that assessed respondents' knowledge of genetics and some general aspects of biotechnology. Each item had an assertion (either correct or incorrect) that the participant had to evaluate as true or false. This second part aimed to identify participants' knowledge of those basic scientific concepts necessary to follow public debates about biotechnology issues. The last part consisted of a 4-point Likert-scale questionnaire composed of 45 items, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree) of statements regarding: 1) the implications of genetic modification in food production and consumption; 2) the implications of genetic modification in medical advances; 3) the social consequences of technological changes, and 4) the student's interest in science and biotechnology. To correctly analyze the attitudes towards biotechnology from these items, the answers of negatively formulated items were reversed. In Figure 1, items with reversed answers are identified with an asterisk.

The survey instrument was designed using, as a base, published instruments that assess attitudes towards biotechnology (Chabalengula, Mumba, & Chitiyo, 2011; European Commission, 2010b; Klop, 2008; Prokop *et al.*, 2007). Some items were taken from these surveys and new ones were formulated. Items from published instruments are identified in Figure 1. Once we had completed the initial draft, we asked a committee of 11 experts in biotechnology, molecular biology, pedagogy and methodology to validate the items. Experts were asked to analyze each item and mark it (from 0 to 10) regarding to its relevance to the issue and assessing if each item was valid, appropriate and unequivocal. We recorded their comments and observations. As a result of this validation process, some items were rewritten or eliminated (Annexe 1).

Exploratory Factor Analysis

We analyzed the data using SPSS Statistics 19 software and conducted an exploratory factor analysis in order to find the factorial structure of the participants' attitudes towards biotechnology. We employed principal components analysis with varimax rotation, without specifying the number of factors. In order to ensure the suitability of the respondent's data for factor analysis, we calculated the Kaiser-Meyer-Olkin measure of sampling adequacy (Kaiser, 1970) and Bartlett's test of sphericity (Bartlett, 1950). The Kaiser-Meyer-Olkin measure ranges between 0 and 1. A value of 0 indicates a diffusion in the pattern of correlations between items (i.e., the data are not suitable for factor analysis), whereas a value close to 1 indicates that the patterns of correlations are compact and so factor analysis should output distinct and reliable factors. The Bartlett's measure tests the null hypothesis that the items included in the factor analysis are not inter-correlated. Thus, if the result of the Bartlett's test is significant ($p < 0.05$) then the data are suitable for a factorial analysis. Finally, we used the Horn's parallel analysis methodology and the Screen test for selecting the optimal number of factors.

Cluster Analysis (K-means Clustering)

Once we had performed the exploratory factor analysis, we then carried out a K-means cluster analysis based on the factor scores of the set of attitudes. Cluster analysis is a statistical multivariate technique used to group a set of cases trying to get maximum intra-group similarity and between-group differences, according to the scores on one (or more than one) selected variables. In the clustering process, there are no predefined classes and no examples that would show what kind of desirable relations should be valid among the data and that is why it is perceived as an unsupervised process (Berry & Linoff, 1996; Halkidi, Batistakis, & Vazirgiannis, 2001). Cluster analysis depends on correlation and multiple linear regressions, and it groups the cases with greater similarity by calculating the distance between them, so the closest cases will be part of the same cluster. We used this cluster analysis in order to test some hypotheses concerning the attitudes towards biotechnology of our students. The interpretation of positive or negative attitudes was based on the mean value of each factor. Since we used a 4-point Likert-scale, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree) mean values above 2.5 are considered positive attitudes and values below this cut-off are considered negative ones.

Correlation analysis

We carried out some correlation analysis for measuring the degree of relationship between socio-demographic, knowledge and attitude variables. Data from the attitude questionnaire was analyzed as a unique variable and split into factors. Pearson's correlation coefficient (r) was used for measuring the correlation between quantitative variables (age, knowledge and attitude variables). Additionally, point-biserial coefficient (rpb) was calculated between nominal (biology background) and quantitative variables; the biserial coefficient (rb) was calculated between ordinal (parent's background) and quantitative variables, and rank-biserial coefficient (rrb) was calculated between nominal (biology background) and ordinal (parent's background) variables. See Glass and Hopkins (1996) for a description of these correlation coefficients.

Results

We conducted the surveys during the 2012-2013 academic year with University students who were taking degree programs in primary and pre-school education. Students in all 4 years of these university degrees were given the opportunity to participate this study. The following results are based on fully completed surveys that resulted in a sample of 407 individuals. Table 1 shows the socio-demographic features of the sample. Respondents were studying to become pre-school and primary education teachers, taking two different independent university degree programs. Spanish curriculum for these degrees does not include specific university courses in biology. However, biology content is integrated into a discipline named experimental sciences, which also includes physics, chemistry and geology. Additionally, in Spain, students are permitted to take these programs without any scientific background. In fact, only 27% of respondents declared that they had previously taken some academic scientific courses, in their high-school programs. As usual in these types of university programs, females were over-represented relative to males; in our case 86% of the sample was composed of females.

Table 1. Socio-demographic sample characteristics (sample size: 407).

Variable	Definition	Values
Age	Age in years	22.02 ± 5.25 (SD)
Gender	Female	86%
	Male	14%
Education	Science background	27%
	Non science background	73%
Parents education	Primary school degree	32%
	High school degree	45%
	University degree	23%

Knowledge of Basic Concepts Related to Biotechnology

We have designed a new survey to assess elementary education pre-service teachers in two aspects, level of knowledge and attitudes towards modern biotechnology and its applications. Regarding the assessment of knowledge level of biotechnology and genetics, there was a 21-item survey for which the answers could be *True/False/Don't Know.* The reliability (Cronbach's α) of the knowledge questionnaire was 0.721. The 21 knowledge items were split in two data groups. The first data group consists of 12 items that were correctly answered by 50% or more of participants and the second group correspond to the remaining 9 items that were answered incorrectly, or marked as "don't know", by more than 50% of the students (Table 2). In general, the majority of students know that genetic material can be exchanged between different species and that genetic modifications can occur naturally or be driven by humans. Additionally, they know that DNA changes can result in interesting characteristics such as an increase in the resistance to a plague, higher nutritional values or higher productivity (Table 2).

Table 2. Knowledge items sorted from most to least frequent correct responses. In the column "Correct answer", T (True) and F (False).

	Correct answer	Responded correctly (%)	Responded incorrectly (%)	Don't know (%)
It is possible to change the genetic characteristics of a plant to make it more resistant to a given plague.	T	85	3	12
A good hygiene helps to prevent genetic diseases.	F	75	18	7
Bacteria are used in the elaboration of daily products (cheese, vinegar, vitamin C).	T	75	10	15
Children resemble their parents because they share the red blood cells.	F	74	5	21
AIDS is a genetic disease.	F	72	22	6
Only when we eat GM food we eat genes.	F	69	4	27
Mutations are only possible by genetic manipulation in the laboratory.	F	66	24	10
Through genetic modification, foods with higher nutritional values can be achieved.	T	61	13	26
A high production of vitamins by a fruit is only possible by genetic manipulation of that fruit.	F	57	17	26
In our body there are more bacteria than people in the world.	T	56	8	36
Microorganisms are used to purify sewage.	T	55	2	43
Genetic material exchange between different species is only possible by manipulation in the laboratory.	F	50	23	27
Genetically Modified Organisms (GMO) are larger than normal.	F	36	19	45
A yogurt is a biotechnological product.	T	34	30	36
The most powerful toxic substances are naturally occurring.	T	34	22	44
GMO have a high number of toxic substances.	F	24	17	59
A GMO is always a transgenic.	F	22	31	47
In the kidney cells genome you can also find the information about the colour of your hair.	T	21	26	53
Insulin is obtained by genetically modified (GM) bacteria.	T	19	25	56
Chemically, the genetic material (DNA) is identical in all the organisms.	T	12	66	22
Crocodiles have the same genetic material as ostriches.	T	9	23	68

Regarding the least frequent scores in Table 2, we identified an important lack of knowledge about basic concepts of genetics. Topics concerning DNA structure and cell management of genetic information were not well understood. For instance, 88% of respondents did not know that, chemically, the genetic material (DNA) is identical in all the living beings. Additionally, 76% of students answered incorrectly, or did not know, that in the genome of kidney cells one can also find the information about hair color. One hot topic focused on genetically modified organisms (GMO's). Surprisingly, two-thirds of the students thought that, or did not know whether, GMO's have a higher amount of toxic substances or GMO's are larger than normal. Obviously, the more subtle items about GMO's were mostly answered incorrectly. An interesting result is that, although Spanish pre-service teachers are aware about biotechnology applications, items that include the use of microorganisms as a biotechnological tool, showed a high "Do Not Know" response rate (> 40%). The use of bacteria to produce insulin, yogurt or purify sewage were not known by our respondents.

Exploratory Factor Analysis

Using the results of this analysis we described respondents' attitudes towards biotechnology. The reliability (Cronbach's α) of the global survey was 0.839. An exploratory factor analysis on the responses to 45 attitude items resulted in an identification of four factors that explained 33.2% of the total variance. The Kaiser-Meyer-Olkin measure was 0.787 and the Barlett's test was statistically significant ($p < 0.001$), ensuring the suitability of the respondent's data for factorial analysis. Five items were deleted because their factor loadings were lower than 0.3. The four factors that were identified describe respondents' attitudes towards different aspects of biotechnology (Table 3).

Table 3. Attitude factors with description, number of items and reliability, based on principal component analyses.

Attitude factors	Description	Reliability (α) (number of items)
1. GMO (Genetically Modified Organisms)	Feelings and consuming intentions towards GMO products.	0.816 (n=13)
2. Biotech and Health	Medical applications of biotechnology focused on the improvement of live standards.	0.746 (n=13)
3. STS (Science, Technology and Society)	Relationship between scientific and technological advances and society (roles, implications, consequences)	0.589 (n=9)
4. Interest	Interest in increasing respondents' knowledge about science and biotechnology advances	0.771 (n=5)

The first factor, GMO, (13 items, factor score average 2.34±0.42) reflects respondents' opinions about and intentions towards consuming products based on GMO's. More precisely, items referred to consumption intentions of GMO-based food, opinions about the use of genetic modification technology for the development of new food products and items that related to GMO legislation policy and labeling. Results pointed out that our respondents would avoid the consumption of GM food, even when there was a clear benefit for the consumer in terms of taste, price and longer product shelf life. Additionally, respondents perceived the need for clearer labeling and stricter regulation of GMO-based products but, at the same time, they expressed disagreement to banning them (Figure 1).

The second factor, Biotech and Health (factor score average 2.91±0.37), demonstrated the respondents' opinions about biotechnology applications to medical purposes. The 13 items of this factor focused on the use of genetic modification technology for research and medical therapy purposes and their opinions about biotechnology implications for a healthy life. Results showed that the vast majority of students agreed that biotechnology is useful and contributes to improve our lifestyle. Additionally, they supported genetic investigation and manipulation, including the use of GMOs, for medical purposes (Figure 1).

The third factor, Science-Technology-Society (STS), included 9 items (factor score average of 2.70±0.42) focused on the respondents' opinions about how scientific and technological advances could affect society and vice versa. This factor also included aspects like the relationship between science and religion, their fears and feelings about biotechnology and environmental and social consequences of biotechnology advances.

From our results, students do not feel threatened by scientific research and biotechnological advances. Indeed, they consider that new biotechnological applications could be beneficial for society. Respondents do not agree or strongly disagree with the following affirmations: "The application of biotechnology will make the future more dangerous" (64%, this item showed a score average of 2.67±0.70); "The fast evolution of science threatens humanity" (62%, item score average 2.68±0.88) and "Biotechnology is evil for nowadays society" (90%, item score average 3.12±0.58).

More than a half of our respondents (54%) disagree with the affirmation "Genetically altering living beings is to play God" (score average 2.79±0.97). Respondents were also asked to express their attitude about the legitimacy of science to argue religious issues. In that case, 67% agree with, "Scientific investigations should not interfere with religion" (score average 2.81±1.04). Interestingly, half of respondents (54%) agreed with the following item "There should be limits to what can and cannot be investigated" (score average 2.40±0.98). In this case our students feel that science need limits to its development but we haven't been able to determine what they should be and who must establish them.

The fourth factor, Interest (sum score average of the factor 3.18±0.56), reflected respondents' interest in increasing their knowledge about scientific advances and biotechnological applications mainly focused on genetic modification technology. Results showed that the great majority of students (around 90%) were interested in having more information about GMO and scientific advances. Only one third held the view that biotechnology is boring (Figure 1).

Figure 1. Factor structure and loading of the 40 items related to attitudes towards biotechnology. The figure shows respondents attitudes (positive or negative) towards biotechnology issues. Responses to items presented as negative sentences were reversed in order to obtain a visually meaningful graphic representation of a positive or negative attitude to the different aspects of biotechnology included in the survey. Items with reversed answers are identified with an asterisk. Items from published instruments are identified by superscript letters; (A) Chabalengua (2011), (B) Eurobarometer (2010), (C) Klop, T. (2008) and (D) Lamanaskuas (2008).

			Reliability	Attitude			
				Strongly Negative	Negative	Positive	Strongly Positive
F.1 : GMO	1	I would buy GM food.	0.775	21	45	30	4
	2	I would feed my children with food produced with GM bacteria.	0.679	25	46	26	2
	3	The alteration of the genes of a fruit to make it more tasty.[C]	0.675	29	50	18	3
	4	If genetically modified food was cheaper, I would buy it.	0.644	20	50	26	4
	5	The genetical modification of fruits and plants to be fresh for a longer time.[C]	0.621	20	42	32	6
	6	The genetic modification of a bacteria to produce food.	0.478	12	40	42	6
	7	I would forbid the sale of trangenics in my country.*	0.460	7	22	60	11
	8	Consumption of GM foods is dangerous.*[D]	0.450	8	46	40	6
	9	The labeling of the transgenic products is clear enough.	0.434	27	54	16	3
	10	The law about GMO are strict enough.	0.429	9	50	37	4
	11	If I get a dish in a restaurant made out of transgenic food, I wold not eat it.*[C]	0.365	5	27	60	8
	12	I am opposed to the transfer of genes between plants and animals.*[D]	0.360	10	38	46	6
	13	The addition of genes to a plant to make it plague-resistant is unacceptable.*	0.343	7	27	50	16
F. 2 : Biotechnology and Health	1	Biotechnology can improve our life style.	0.575	1	13	69	16
	2	I agree with the genetic investigation in medicine.	0.561	2	7	51	41
	3	I agree with the genetic transformation in embryos to cure hereditary diseases.[A]	0.560	3	15	48	34
	4	The use of GMO for medical therapy and the study of diseases.[C]	0.543	2	14	55	29
	5	The genetic modification of a sheep to produce medicines.[A]	0.491	22	41	27	9
	6	The use of GMO to fight against diseases.	0.486	3	23	57	16
	7	If genetically modified food was healthier, I would eat them more often.[C]	0.476	6	23	55	15
	8	Genetic manipulation is not ethical.*	0.445	7	30	51	12
	9	Cloning as a tool to save endangered species.[D]	0.426	10	22	44	24
	10	Biotechnology makes our lives easier.[C]	0.420	3	17	67	13
	11	Science makes our lives easier.[B]	0.394	3	24	52	22
	12	A scientific discovery is not "good" or "bad", is how we use what matters.[B]	0.355	1	6	32	60
	13	GM foods can help alleviate world hunger.[C]	0.332	10	30	51	9
F.3 : STS	1	The fast evolution of science threatens humanity.*	0.608	11	27	45	17
	2	There should be limits to what can and can not be investigated.*[B]	0.488	21	33	31	15
	3	The application of biotechnology will make the future more dangerous.*	0.474	5	31	56	8
	4	Biotechnology is evil for nowadays society.*	0.463	1	9	67	23
	5	Genetic manipulation will drive to the extintion of a large number of species.*	0.454	11	38	43	8
	6	Genetically altering living beings is to play God.*	0.446	12	24	37	27
	7	Biotechnology does not play any role in environmetal protection.*	0.367	2	17	58	23
	8	Some numbers are specially lucky for some people.*[B]	0.363	6	27	28	39
	9	Scientific investigations should not interfere with religion.	0.305	16	17	37	30
F.4 : Interest	1	I would like to increase my knowledge about GMO.	0.846	3	6	46	45
	2	I would like to have more information about GM food.	0.822	4	9	40	47
	3	I would like to know more about GM food.[D]	0.785	4	11	43	41
	4	I would like to be aware of scientific advances.	0.676	1	6	47	46
	5	Biotechnology is boring.*	0.353	13	19	55	13

Segmentation by Attitudes towards Biotechnology

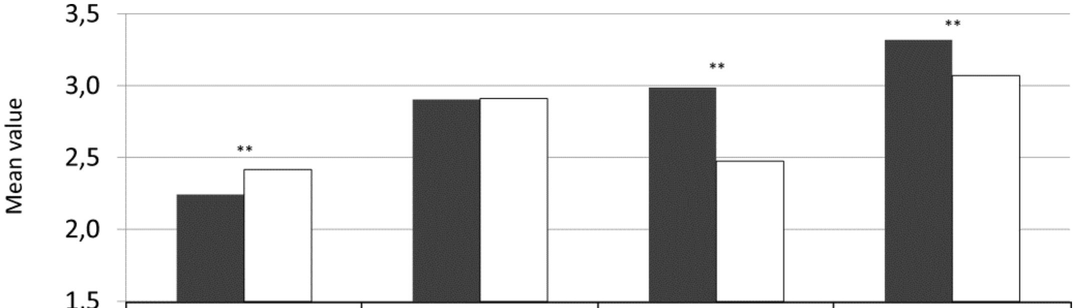
The purpose of this section was to identify whether subgroups could be identified within the larger group of all respondents. The scores of two respondents were eliminated from the analysis because they could not be assigned in any cluster. After performing K-means cluster analysis, we considered that two clusters led to interpretable and interesting groups as we can see in Figure 2. Our results show that Factor 1, GMO ($t\ (403) = 6.92$, $p<0.00$), Factor 3, STS ($t\ (403) = 19.426$, $p<0.01$), and Factor 4, Interest ($t\ (403) = 3.107$; $p<0.01$), displayed significant differences between both groups.

Cluster 1 (175 respondents). This cluster shows positive attitudes towards the aspects analyzed in the factors Biotech and Health, STS and Interest. They do not feel threatened by science evolution (Item 1, 3.18±0.71), do not perceive that biotechnology is dangerous (Item 4, 3.36±0.55) or its applications (Item 3, 2.90±0.65) (Factor 3, STS). On the other hand this group has a negative perception towards genetic modification technology for food applications (Item 5, 2.03±0.82 and Item 6, 2.25±0.82) and consumption purposes (Item 1, 1.94±0.78) (Factor 1, GMO). This group expressed negative intentions towards buying GMO products even if such foods are the cheapest (Item 4, 1.85 ±0.72) or the tastiest (Item 3, 1.72±0.69). They believe that the consumption of GMO food is dangerous (Item 8, 2.53±0.73) and they expressed their agreement with proposal to ban transgenic products (Item 7, 2.73±0.80).

Cluster 2 (230 respondents). Respondents included in this cluster mistrust the contribution of science and biotechnology in the social development and future of the humanity (Factor 3, STS). Moreover their perceptions of genetic modification technology on food applications and consumption purposes (Factor 1, GMO) showed by respondents in cluster 2 (2.42±0.42) was observed to be less negative than in cluster 1 (2.24±0.42), but still slightly negative (Figure 2).

Interestingly, within our cluster results, we found that both groups held no significant differences regarding Factor 2 ($t\ (403) = 0.853$; $p=0,39$) that described biotechnological applications for health purposes. Thus, both groups shared the same attitudes towards medical applications of biotechnology focused on the improvement of life standards. All students displayed positive attitudes towards biotechnology applications in medicine; they mainly agree that biotechnology is useful and contributes to improve our lifestyle (Figure 1). On the other hand, as previously mentioned, Factor 4 displayed significant differences between the groups. Nonetheless both groups showed strong interest on biotechnology topics. As we can see in Figure 2 the mean value of both clusters are above a value of 3, meaning that they expressed a positive attitude towards this factor.

Figure 2. Graphical representation of K-means cluster analysis results of attitudes towards biotechnology. GMO corresponds to Factor 1 (Genetically Modified Organisms); Biotech Health corresponds to Factor 2; STS corresponds to Factor 3 (Science-Technology-Society) and Interest corresponds to Factor 4 of the exploratory factor analysis. ** Significance of p< 0.01 using t-test statistical analysis between factors of each cluster.



	GMO		Biotech Health		STS		Interest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
■ Cluster 1	2,24	0,42	2,90	0,40	2,99	0,32	3,32	0,54
□ Cluster 2	2,42	0,42	2,91	0,35	2,48	0,34	3,07	0,55

Correlations between Socio-demographic Data, Knowledge and Attitudes towards Biotechnology

Correlation coefficients were calculated to determine the relationships between socio-demographic data, knowledge and attitude factors of elementary education pre-service teachers in the field of biotechnology (Table 4).

Some of the remarkable correlations showed that older respondents expressed less favorable attitudes to issues included in factor 1 (GMO) (correlation of -0.166**) (Table 3 and 4) as well as more interest in increasing knowledge about science and biotechnology advances (correlation of 0.144**) (Figure 1). Other correlations linked knowledge level and the GMO factor. Respondents with better marks in the knowledge test showed higher acceptance of GMO factor issues (correlation of 0.104*). Our results reveal that a pre-service teacher with positive attitudes towards biotechnology corresponds to a student with a biology background and a good mark in the knowledge test (Table 4). Hence, this fact indicates that improving population knowledge in biotechnological issues could lead to more positive attitudes towards biotechnology.

Table 4. Correlations between socio-demographic, knowledge and attitude's variables. Report statistical significance **p<.01 *p<.05.

	Age	Parent's Background	Knowledge	GMO	Biotech-Health	STS	Interest	Attitudes
Bio Background	,114*	,011	,184**	,065	,084	,095	,101*	,117*
Age		-,221**	,052	-,166**	,026	,063	,144**	-,007
Parent's Background			,085	,034	-,034	-,065	-,056	-,030
Knowledge				,104*	,095	,090	,076	,131**
GMO					,486**	,291**	,049	,775**
Biotech-Health						,288**	,222**	,794**
STS							,143**	,607**
Interest								,399**

Discussion

According to our results, Spanish elementary education pre-service teachers' knowledge about biotechnology varies depending on the topic. First of all, the majority of education pre-service teachers correctly answered items related to the applications and uses of biotechnology. The majority of students know that genetic material can be exchanged between different species and that genetic modifications can occur naturally or driven by humans. Comparing to similar studies in other countries when asking about uses of biotechnology, Spanish students have a higher percentage of correct answers on the same items than Slovakian (Prokop *et al.*, 2007), Turkish (Usak, Erdogan, Prokop, & Ozel, 2009) and Lithuanian (Lamanauskas & Makarskaite-Petkeviciene, 2008) students. This is the case, for example, when asking whether DNA changes can result in interesting characteristics such as an increase in the resistance to a plague, higher nutritional values or higher productivity. However, we identified an important lack of knowledge related to the basic concepts of genetics. Topics concerning DNA structure and cell management of genetic information are not well understood by our students. For instance, the concept that DNA is chemically identical in all living beings was only correctly answered by the 12% of our respondents, compared to a 22% in Turkey (Usak *et al.*, 2009) or a 33% in Slovakia (Prokop *et al.*, 2007). Interestingly, this item was answered incorrectly by a 66% of our students, pointing out that our students are not aware of their own ignorance in this topic. Another hot topic is focused on genetically modified organisms (GMO's). Items related to GMO's show the highest proportion of "Do Not Know" answers (around 50% in all items related to GMOs), indicating that our students are conscious of their ignorance about GMO's.

Summarizing, our results point out that Spanish pre-service teachers are aware of the applications of biotechnology but do not have a basic and fundamental knowledge on the biological implications of modern biotechnology on living beings. These two dimensions of knowledge about modern biotechnology (biotechnology applications and basic concepts of biology) were already identified by Klop and Severiens (2007), when analyzing the *cognitive component* of modern biotechnology of Dutch secondary school students. Our results point out that pre-service teachers show a low percentage of correct answers in biological topics related to biotechnology such as DNA structure and cell management of genetic information or basic concepts of genetics. This finding is not unique of Spain and it is shared in other countries such as Turkey, Slovakia, Slovenia, Lithuania and Lebanon (Darçin & Guven, 2008; Erdogan, Ozel, Bouiaoude, Usak, & Prokop, 2012; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop *et al.*, 2007; Sorgo & Ambrozic-Dolinsek, 2009; Usak *et al.*, 2009).

One of the main goals of this study was to analyze the attitudes towards biotechnology of Spanish pre-service teachers. Four attitude factors were identified by our survey, (i) feelings and consuming intentions towards GMO products, (ii) opinions about Biotechnology applications to medical purposes, (iii) opinions about how scientific and technological advances could affect society and vice versa and (iv) interest in increasing respondents' knowledge about scientific advances and biotechnological applications. Taking into account the results of the whole sample, Spanish pre-service teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances. It is interesting to point out that our respondents (around 90% of them) expressed their desire to have more information and to increase their knowledge in topics concerning GM technology, including GM food. Scientific and biotechnological advances are also interesting topics for our respondents. They mainly agreed with the idea that science and biotechnology are beneficial for their lifestyle and for the future of humanity. However, they feel that science needs limits to its development although they were not able to determine how they should be and who must establish them.

This study was also focused on the analysis of possible correlations between knowledge level and attitudes towards biotechnology. Our results show a positive correlation between better knowledge and more positive attitudes towards biotechnology (Table 4). This correlation is also valid for the GMO factor, since respondents with better knowledge of biotechnology show higher acceptance of GMO issues. This positive correlation between knowledge level and more positive attitudes towards biotechnology has been previously reported by other authors (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Klops & Severiens, 2007; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop *et al.*, 2007; Usak *et al.*, 2009).

Biotechnology is a relevant topic from the economical and scientific points of view but, at the same time, it has social, ethical and cultural implications which directly concern the whole society. The role of teachers in communicating the risks, benefits and challenges of biotechnology is crucial. In this sense, the improvement of the knowledge level of pre-service teachers on biotechnology would help them to develop attitudes that promote a deeper reflection on the benefits and complexity of biotechnology (Klop & Severiens, 2007; Chabalengula, Mumba, & Chitiyo, 2011). Well informed teachers will be able to handle ethical, social and cultural debates with their students on the implications of biotechnology. In this sense, Chabalengula *et al.* (2011) argued that if pre-service teachers are well informed, then they would possess attitudes that would reflect more unbiased and more correct information about biotechnology.

New teaching and learning methodologies should be developed to promote biotechnological literacy among citizens. Science education, as a broad field, and biological education in particular has to contribute to increasing the knowledge of society in general about the central concepts of modern biotechnology. By improving the biotechnological education of the whole society, citizens will then be better prepared to make conscious decisions about the biotechnology-related aspects of their own lives. The frame of the current paradigm of science education, mainly characterized to be teacher-centered, disciplinary, decontextualized and oriented towards low-order cognitive skills (LOCS) oriented should move to more adaptive paradigms. Science education should employ an interdisciplinary teaching approach, leading to the development of our students' higher-order cognitive skills (HOCS), promoting critical system thinking, problem-solving and decision-making (Zoller, 2012).

One of the most noticeable trends of the last two decades in science curriculum development has been to use contexts and applications of science as a means of developing scientific understanding. Teaching in this way is described as adopting a context-based or STSE (Science–Technology–Society-Environment) approach. In this kind of approach, contexts and applications of science are used as the starting point for the development of scientific ideas (Bennet *et al.*, 2006). Educational tools following the STSE approach could include different teaching methodologies oriented to increase student motivation and to help them to structure their knowledge, to develop reasoning processes and to implement self-directed learning skills. Interesting teaching methodologies to use in STSE approach are Problem-based learning (PBL) and Inquiry-based learning (IBL).

The key to educational innovation, reform and improvement is the teacher. It is now generally accepted that to improve learning in our schools we need more and better teacher professional learning (Goodrum, 2006). Therefore, one effective way to induce a better knowledge and therefore more informed decisions of society towards new biological sciences and technologies is by promoting biotechnological literacy among teachers. For this reason, our research group is now devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret biotechnological issues.

References

Angulo, A. M., & Gil, J. M. (2007). Spanish consumers' attitudes and acceptability towards GM food products. *Agricultural Economics Review, 8,* 50–63. doi:10.1016/j.foodpol.2007.07.002

Bartlett, M. S. (1950). Tests of significance in factor analysis. *British Journal of statistical psychology*, *3*(2), 77-85.

Bennet, J., Lubben, F., & Hogarth, S. (2006). Bringing Science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, 91, 347-370. doi:10.1002/sce.20186

Berry, M. J. A., & Linoff, G. (1997). *Data Mining Techniques For Marketing, Sales and Customer Support.* New York: John Wiley & Sons, Inc.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching efficacy of pre-service elementary teachers. *Journal of Science Teacher Education 14(3),* 177-192. doi:10.1023/A:1025974417256

Carleton, L. E., Fitch, J. C., & Krockover, G. H. (2008). An in-service teacher education program's effect on teacher efficacy and attitudes. The Educational Forum, 72, 46–62. doi:10.1080/00131720701603628

Chabalengula, V. M., Mumba, F., & Chitiyo, J. (2011). American elementary education pre-service teachers' attitudes towards biotechnology processes. *International Journal of Environmental & Science Education 6(4),* 341-357.

Chen, S.Y., & Raffan, J. (1999). Biotechnology: Student's knowledge and attitudes in the LJK and Taiwan. *Journal of Biological Education 34(1),* 17-23. doi:10.1080/00219266.1999.9655678

Darçin, E. S. (2011). Turkish pre-service science teachers' knowledge and attitude towards application areas of biotechnology. *Scientific Research and Essays 6(5),* 1013-1019. doi:10.5897/SRE10.552

Darçin, E. S., & Güven, T. (2008). Development of an Attitude Measure Oriented to Biotechnology for the Pre-Service Science Teachers. *Journal of Turkish Science Education, 5(3)*, 72-81. Retrieved from: http://pegem.net/dosyalar/dokuman/48105-2009042910432-06development-of-an-attitude-measure-oriented-to-biotechnology-for-the-pre-service-science-teachers.pdf

Dawson, V., & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology processes. *Journal of Biological Education, 38(1)*, 7-12. Retrieved from: http://researchrepository.murdoch.edu.au/id/eprint/6421

Dimopoulos, K., & Koulaidis, V. (2003). Science and technology education for citizenship: The potential role of the press. *Science Education, 87(2),* 241-256. Retrieved from: http://www.upf.edu/pcstacademy/_docs/Press_and_Citizenship.pdf

Erdogan, M., Ozel, M., Bouiaoude, S., Usak, M., & Prokop, P. (2012). Assessment of preservice teachers' knowledge and attitudes regarding biotechnology: A cross-cultural comparison. *Journal of Baltic Science Education, 11(1),* 78-93. Retrieved from: http://journals.indexcopernicus.com/abstract.php?icid=988264

Earl, R. D., & Winkeljohn, D. R. (1977). Attitudes of elementary teachers toward science and science teaching. *Science Education*, 61, 41–45. doi:10.1002/sce.3730610105

European Commission (2010a). *Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels (Belgium): Directorate General Research, EU.

European Commission (2010b). *Special Eurobarometer 341. Biotechnology*. Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/public_opinion/archives/ebs/ebs_341_en.pdf

European Commission (2012). *Innovating for sustainable growth: A bioeconomy for Europe.* Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/research/bioeconomy/pdf/201202_innovating_sustainable_growth.pdf

Fetters, M. K., Czerniak, C. M., Fish, L., & Shawberry, J. (2002). Confronting, challenging, and changing teachers' beliefs: Implications from a local systemic change professional development program. *Journal of Science Teacher Education*, 13, 101–130. doi:10.1023/A:1015113613731

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Revuelta, G., Schreiner, C., Stares, S., Torgersen, H., & Wagner, W. (2006). *Europeans and Biotechnology in 2005: Patterns and Trends*. Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report may 2006_en.pdf

Glass, G. V., & Hopkins, K. D. (1996). *Statistical methods in education and psychology* (3rd ed.). Needham Heights: Allyn & Bacon.

González, A., Casanoves, M., Barnett, J., & Novo, M. (2013). Biotechnology literacy: Much more than a gene story. *The International Journal of Science in Society, 4(2),* 27-35. Retrieved from: http://ijy.cgpublisher.com/product/pub.187/prod.243

Goodrum, D. (2006). Inquiry in Science Classrooms: Rhetoric or Reality? *Australian Council for Education Research.* Retrieved from: http://research.acer.edu.au/research_conference_2006/11

Halkidi, M., Batistakis, Y., & Vazirgiannis, M. (2001). On Clustering Validation Techniques. *Journal of Intelligent Information Systems 17,* 107–145. doi:10.1023/a:1012801612483

Haney, J. J., Lumpe, A. T., Czerniak, C. M., & Egan, V. (2002). From beliefs to actions: The beliefs and actions of teachers implementing change. J*ournal of Science Teacher Education*, 13, 171–187. doi:10.1023/A:1016565016116

Jenkins, E. (1997). *Towards a functional public understanding of science*. In Science Today (pp.137-150). London: Routledge.

Kaiser, H. F. (1970). A second generation little jiffy. *Psychometrika*, *35*(4), 401-415.

Kidman, G. (2009). Attitudes and interests towards biotechnology: the mismatch between students and teachers*. Eurasian Journal of Mathematics, Science and Technology Education, 5(2),* 135-143.

Kirkpatrick, G., Orvis, K., & Pittendrigh, B. (2002). GAME: A teaching model for biotechnology. *Journal of Biological Education, 37(1)*, 31-35. doi:10.1080/00219266.2002.9655843

Klop, T. (2008). Attitudes of Secondary School Students towards Modern Biotechnology. (Unpublished doctoral dissertation). Erasmus University, Rotterdam (The Netherlands).

Klop, T., & Severiens, S. (2007). An exploration of attitudes towards modern biotechnology: a study among Dutch secondary school students. *International Journal of Science Education, 29(5),* 663-679. doi:10.1080/09500690600951556

Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The impact of science content and professional learning communities on science teaching efficacy and standards-based instruction. *Journal of Research in Science Teaching*, 48, 534–551. doi:10.1002/tea.20404

Lamanauskas, V., & Makarskaite-Petkeviciene, R. (2008). Lithuanian university student's knowledge of biotechnology and their attitudes of the taught subject. *Eurasian Journal of Mathematics, Science and Technology Education, 4(3)*, 269-277.

Lee, J. S., & Ginsburg, H. P. (2007). Preschool teachers' beliefs about appropriate early literacy and mathematics education for low and middle socioeconomic status children. *Early Education & Development*, 18, 111–143. doi:10.1080/10409280701274758

Lujan, J.L., & Todt, O. (2000). Perceptions, attitudes and ethical valuations: the ambivalence of the public image of biotechnology in Spain. *Public Understanding of Science, 9(4),* 383-392. doi:10.1088/0963-6625/9/4/303

Maier, M., Greenfield, D., & Bulotsky-Shearer, R. (2013). Development and validation of a preschool teachers' attitudes and beliefs toward science teaching questionnaire. *Early Childhood Research Quarterly*, *28*(2), 366–378. doi:10.1016/j.ecresq.2012.09.00

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science, 7(3),* 203-223. doi:10.1088/0963-6625/7/3/001

Pardo, R., Midden, C., & Miller, J. (2002). Attitudes towards biotechnology in the European Union. *Journal of Biotechnology, 98(1),* 9-34. doi:10.1016/S0168-1656(02)00082-2

Prokop, P., Leskova, A., Kubiatko, M., & Diran, C. (2007). Slovakian Students' Knowledge of and Attitudes toward Biotechnology. *International Journal of Science Education, 29(7)*, 895-907. doi:10.1080/09500690600969830

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74, 625–637. doi:10.1002/sce.3730740605

Roehrig, G. H., Kruse, R. A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science* Teaching, 44, 883–907. doi:10.1002/tea.20180

Saez, M.J., Niño, A.G., & Carretero, A. (2008). Matching society values: Students' view of biotechnology. *International Journal of Science Education 30(2),* 167-183. doi:10.1080/09500690601152386

Salvadó, Z., Casanoves, M., & Novo, M. (2013). Building Bridges between Biotech and Society through STSE Education*. International Journal of Deliberative Mechanisms in Science, 2(1),* 62-74. doi:10.4471/demesci.2013.09

Shrigley, R. L., Koballa, T. R., & Simpson, R. D. (1988). Defining attitude for science educators. *Journal of Research in Science Teaching*, 25, 659–678. doi:10.1002/tea.3660250805

Sorgo, A., & Ambrozic-Dolinsek, J. (2009). The relationship among knowledge of, attitudes toward and acceptance of genetically modified organisms (GMOs) among Slovenian teachers. *Electronic Journal of Biotechnology, 12(3),* 1-13. doi:10.2225/vol12-issue4-fulltext-1

Steele, F., & Aubusson, P. (2004). The Challenge in Teaching Biotechnology. *Research in Science Education, 34(4)*, 365-387. doi:10.1007/s11165-004-0842-1

Stefanich, G. P., & Kelsey, K. W. (1989). Improving science attitudes of preservice elementary teachers. *Science Teacher Education*, 73, 187–194. doi:10.1002/sce.3730730205

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education, 37(2),* 123-130. doi:10.1002/bmb.20267

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *Journal of Chemical Education, 89*, 297-300. doi:10.1021/ed300047v

CHAPTER II

A comparison across Europe: Swedish and Spanish pre-service teachers students' knowledge and attitudes towards Biotechnology

Abstract

In the 21st century, the fast increase of biotechnology in areas of sanitation, agriculture, food industry and in medicine has changed the living conditions of people society overall. This impact, for good and worse, of biotechnology suggest the need for citizens at large to be scientifically literate about these issues, and in the forefront to educate new generations are the teachers. This study focuses to a Swedish sample of 155 future pre-service school teachers. The main goal is to see the level of their knowledge of genetic and biotechnological facts and their attitudes towards biotechnology. Our findings point out that Swedish pre-service teachers do not have a satisfactory level on basic concepts of genetics although they are aware of biotechnology applications. Pre-service Swedish teachers differs their attitudes towards GMO in two different views. One is the applications of GMO in aspects that affect whole society and the other GMO products for personal consumption. Based on Pearson correlation results indicate that improved population knowledge in biotechnological issues could lead to more insightful attitudes towards it. This positive correlation between knowledge and attitudes towards biotechnology is an evidence to reconsider science curricula in former education.

Keywords: Biotechnology education, knowledge, Attitudes, Pre-service teachers, Survey.

Introduction

In the 21st century biotechnology become one of the science disciplines that have undergone the most rapid growth (Usak *et al.,* 2009). The international Organization for Economic Cooperation and Development [OECD] (2005) defines biotechnology as: "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods, and services". The biotechnology processes in areas of sanitation, agriculture, food industry and in medicine have impacted our personal lives and society (Dawson, 2007).

In 2010, the European Commission launched the Europe 2020 Strategy to put forward some strategies in order to help the nations of the European Union (EU) to come out stronger economically from the economic crisis and to prepare their economies for the challenges of the next decade (European Commission, 2010a). In this context European Commission prepared a bioeconomy strategy for Europe in which biotechnology has been identified as one of the major driving force in the creation of better health and welfare for European citizens (European Commission, 2012).

The fast increase of biotechnology applications and the reinforcing loop of media coverage have kept this technology alive in public opinion. Therefore it is important to study the underlying agreement between understanding and attitudes of different populations in society in relation to scientists. These applications also raise ethical, social, environmental as well as philosophical questions (Salvadó, Casanoves, Novo, 2013). In most biotechnology applications it is the public that judges its desirability and determines the technology's success (Costa-Font & Mossialos, 2006). In response to this rapid development of biotechnology and its importance to society, around the world several national curriculum frameworks strongly support, recognize, and include biotechnology education for teachers and students (Klop & Severiens, 2007).

In most of the cases deeper understanding is often necessary simply to understand the scientific phenomenon and in addition, public controversies often invoke knowledge claims that involve deeper and broader knowledge to validate. So this fact poses theoretical and educational challenges for researchers and teachers in their attempts to explain and improve the general public's understanding and use of science information (Bromme & Goldman, 2014). For this reason, there is need for citizens at large to be scientifically literate about these issues, and in the forefront to educate new generations are the teachers.

International studies on knowledge and attitudes towards biotechnology

Europe does not present a level playing field when it comes to matters of science and society. Some countries have a longish history of bringing moral and ethical issues into science; others have not (Gaskell *et al*., 2006). In terms of Biotechnology is interesting to compare among European countries because it is an increasing scientific field and it is present in our everyday lives. For this purpose is important to analyse the knowledge and the attitudes of respondents, as Durant *et al.* (1998) says, that level of knowledge is definitely a factor influencing public opinions.

As the Eurobarometer surveys showed (across the period 1991-2005), European respondents faced to a group of knowledge questions designed to tap the extent of their knowledge about biology and genetics. The results of knowledge items indicated a general lack of knowledge regarding biotechnology and genetics (Gaskell *et al*., 2006). In Europe, about one in five adults qualified as well-informed about biotechnology, and we will generally refer to the group as the informed public for biotechnology. In the Eurobarometer study 30% of Swedish citizens belongs to the group of well-informed public while only 11% of Spanish citizens were considered as a well-informed. Sweden is ranked third among the European countries participating in the Eurobarometer with quite a large population of well-informed public regarding biotechnology only surpassed by Netherlands and Denmark. Spain on the other hand is placed as 4th last together with Greece Ireland and Portugal in a total of 15 European countries analysed (Pardo *et al.,* 2002). This indicates that there might exist interesting differences between Swedish and Spanish teachers as well.

We can also find cross-national comparisons regarding attitudes towards biotechnology in the Eurobarometer studies. In 2010 the trends in optimism towards biotechnology and genetic engineering was compared between different countries. Results show that 74% of Spanish citizens are optimists in using these technologies in comparison to a 63% of Swedish citizens. From 1991 to 2010 Spain and Sweden have been the two most optimistic countries in comparison between 15 different European countries. However in terms of attitudes towards GM food there are great differences between European countries. In Czech Republic, Slovakia, Portugal and Spain the populations are most optimist to consume and produce GM food, while countries like Sweden, Italy, Austria and Germany are the most negative (Gaskell *et al*., 2010). The positive attitudes are found in the countries in which GM crops are currently cultivated and some of the countries in which negative attitudes prevail, such as Austria and Germany, are the countries which have bans on the cultivation of GMOs. In Sweden, foods that contain GMOs need to be labelled. However, animal products intended for human consumption originating from animals raised on GM fodder do not need to be labelled (such as eggs from hens, beef, etc.). In terms of cultivation, in Sweden is only approved for cultivation the GM Amflora potato it is important to note that this potato is not suitable nor intended for human consumption (Restrictions on Genetically Modified Organisms: Sweden).

Teachers' attitudes and knowledge towards biotechnology

In order to involve society in the decision-making process about scientific policies, we need well-informed citizens who are able to make thoughtful decisions based on scientific conclusions in combination with ethical and moral consideration of the issues. Following from this position, much research in science education worldwide promotes, as an important goal of science teaching, the scientific and technological literacy of entire populations (Dimopoulos & Koulaidis, 2003; González, Casanoves, Barnett, & Novo, 2013; Jenkins, 1997; Miller, 1998; Salvadó, Casanoves, & Novo, 2013; Zoller, 2012). The underlying notion is that the development of knowledge and the mental habits will allow people to become more responsible citizens, better able to create informed opinions, even while living in societies that are becoming increasingly complex and ever more dependent on science and technology. Over the last decades, interest in the biotechnological literacy of society has increased among science education researchers (Kidman, 2009; Klop & Severiens, 2007; Sorgo & Ambrozic-Dolinsek, 2009; Steele & Aubusson, 2004).

These studies have aimed to understand the content that should be in any school science curriculum to promote scientific literacy. To achieve this purpose, these studies assessed teachers' and students' attitudes towards different aspects of biotechnology, including previous knowledge, fears, beliefs, and ethics related to the use of these new technologies. It is important to point out that European's information literacy levels about biotechnology differ significantly amongst the various nations as discussed earlier.

It has been shown that attitudes of science teachers affect their behaviours and influence the ways in which they approach good science teaching in schools (Cantrell *et al.*, 2003). In particular, pre-existing attitudes and beliefs influence the way that teachers understand what they learn during their training and how they implement it in their daily practices at school (Fetters *et al*., 2002; Lee & Ginsburg, 2007; Roehrig *et al*., 2007). A great many studies demonstrate that teachers with more positive attitudes towards science include science topics more often in the classroom and use active learning methodologies such as inquiry based learning activities, hands-on materials, etc. (Earl & Winkeljohn, 1977; Haney *et al*., 2002; Stefanich & Kelsey, 1989).

In spite of the central role that teachers' attitudes play, most studies to date have only investigated high school and university students. Indeed, only five studies have been focused on elementary education pre-service teachers, in five different countries: Slovakia (Prokop *et al*., 2007), Lithuania (Lamanauskas & Makarskaite-Petkeviciene, 2008), Turkey (Darçin, 2011), USA (Chabalengula *et al*., 2011) and Spain (Chapter I). There are no published studies devoted to the assessment of biotechnology knowledge and attitudes of Swedish pre-service teachers. However, a small number of studies have examined citizens' attitudes or values towards biotechnology. These studies have investigated citizens' attitudes and values in topics related to genetic modification (Magnuson & Hursti, 2002; Koivisto- Hursti *et al*., 2002). Magnusson's study is related to some specific applications in different kinds of food such as rice, tomato, pork among others. The main findings are that respondents were rather negative towards the use of genetic engineering, and 58% of the respondents think that it would be morally wrong for them to eat genetic modified food (GM food) and only 12% of the respondents would be interested in buying GM food even if they had lower price and tasted better. Related to their personal knowledge the authors claim that most of subjects had good knowledge about biology and genetics. While in the EU some progress, in terms of basic knowledge, has been made since the Eurobarometer of 1996, the knowledge and information gap between science and society still exists (European Commission, 2010b). Koivisto-Hursti *et al*., (2002) studied Swedish consumers' opinions regarding genetic modifications for food productions, animal production and for medical purposes. Koivisto-Hursti's findings in terms of attitudes were that 68% of respondents did not agree to eat GM food. In general terms males and younger (18-24) respondents are more positive to eat, buy and accept marketing of GM foods. Across many of the EU Member States have an average of three to one opponents that outnumber supporters towards the GM food (Gaskell *et al*., 2010).

Spaniards' data related to attitudes towards biotechnology come from socio-economic studies (European Commission, 2010b; Lujan & Todt, 2000; Pardo *et al*., 2002), economic surveys on genetically modified (GM) food products (Angulo & Gil, 2007) while only one study focused on high school students (Sáez *et al.*, 2008). In previous studies, it was studied attitudes towards biotechnology of pre-service teachers (Chapter I).

As we have seen, there are no published studies devoted to the assessment of biotechnology knowledge and attitudes of Swedish university students. The purpose is to better understand the knowledge and attitudes of the Swedish pre-service teacher students who are most influential in shaping future generations towards biotechnology. Comparisons will be made with a similar population of Spanish pre-service teachers in order to elucidate trends and cultural differences regarding these issues. In the present study, we use the questionnaire created by (Chapter I) which was validate with a sample of 407 Spanish pre-service teachers from two universities of Spain. The study followed the tripartite model of attitudes towards modern biotechnology proposed by Klop (2008). In this model, attitudes are the product of knowing and thinking about biotechnology (the cognitive component), feelings and emotions about biotechnology issues (the affective component), and behavioral intentions towards biotechnology and its applications (the behavioral component). Related to students attitudes towards biotechnology, Spanish pre-service teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances. The findings also showed a positive correlation between knowledge and attitudes towards biotechnology.

Purpose and research questions

This study analyzes Swedish elementary education pre-service teachers' views of two aspects of biotechnology addressing the following research questions: (i) the level of their knowledge of genetic and biotechnological facts (cognitive component) and (ii) their attitudes towards biotechnology, including both the affective and the behavioral components. Finally, (iii) a comparison was made between answers from Spanish pre-service teachers obtained in a previous study using the same instrument (Chapter I) and the answers from the present Swedish sample in order to see if there are some knowledge and attitudes similarities or differences between a southern Europe country and a Nordic country.

Methods

Participants and data collection

The surveys were administered during January and February of 2015 to a sample of 155 teacher students from Karlstad University (Sweden). These students were taking three different programs to be teachers, which were called "Preschool education", "Primary education (grades 1 to 3)" and "Primary education (grades 4 to 6)". It should be noted that, in Sweden, Primary education degree is divided into two different degrees: Students could choose between primary education from 1st to 3rd grade or primary education from 4th to 6th grade.

The Spanish sample used for comparison consisted of 407 teacher students. Of these, 270 were from the Faculty of Education at the Universitat Rovira i Virgili, URV (Tarragona), and 137 were from the Faculty of Education at the Universitat Autònoma de Barcelona, UAB (Barcelona). Spanish students were taking a program to be teachers called "Preschool and Primary Education". This sample of students was assessed during the 2012-2013 academic year, and the results were published elsewhere (Chapter I).

The questionnaire was distributed to participants in paper format in both countries (Sweden and Spain) during the teacher students' university studies. Participation was voluntary and the questionnaire was completed anonymously. The first author was present during the questionnaire session, which took around 10 and 15 minutes to complete, in order to secure that all participants got the same information.

Instrument Design

The questionnaire used in this study was create in a previous study and was validated with a sample of Spanish pre-service teachers (Chapter I). This instrument is based on a biotechnology framework, and it includes some items taken from previous published and validated surveys (Chabalengula *et al.*, 2011; European Commission, 2010b; Klop & Severiens, 2007; Prokop *et al.*, 2007) as well as new ones in order to facilitate our purpose. It is important to know which is the knowledge of pre-service teachers on the basic genetic concepts because it is needed a basis to learn or understand about biotechnology applications. Currently these topics are present in our daily life, and teachers have to understand the content that should be in any school science curriculum to promote scientific literacy. In addition, some attitude questions were added to the questionnaire in order to know if pre-service teachers are positives or opponents to the use in different fields of the applications of biotechnology and these attitudes could probably affect on their way of teaching. The construct validity of the instrument was first assessed by 11 experts in biotechnology, molecular biology, pedagogy and methodology, who were presented with a draft version of the questionnaire. Then, as a result of this assessment, some items were rewritten or eliminated. Finally, the questionnaire was validated for face validity with a sample of students from two universities of Spain, for a more detailed description of instrument development (Chapter I). Finally we have for both data sets (Sweden and Spain) conducted an explanatory factor analysis that provides construct validity evidence of self-reporting scales (Nunnally, 1978).

In order to administer the questionnaire to Swedish students, the questionnaire was translated to Swedish based on a developed English standard version of the original. A second independent back translation was then made back into English to secure the validity of the translation. Based on the back translation some changes were made on the original Swedish translation.

The questionnaire consists of three distinct parts (Annexe 1). The first part was designed to obtain some socio-demographic information from the preservice teacher students regarding: sex, age, previous training in biology [1] and educational background of their parents (see Table 1 in the result section). The second part of the instrument consists of 21 *True/False/Don't Know* items that assessed respondents' knowledge of background genetics and some general aspects of biotechnology (see Table 2 in result section). Each item had an assertion (either correct or incorrect) that the participant had to evaluate as true or false. This part aimed to measure participants' knowledge of some basic scientific concepts about biotechnology issues. Finally, the third part consists of a 4-point Likert-scale questionnaire with 45 items, in which students rated their opinions in 4 points scale which are 1 (*strongly disagree*), 2 (disagree), 3 (agree) and 4 (*strongly agree*) of statements (see Figure 1 in the result section). The objective of this part was to analyze the attitudes of the student towards biotechnology, from strongly negative to strongly positive. In order to secure validity some items were reversed so that the respondents could not detect any peculiar response patterns. When thereafter analyzing the answers to negatively formulated statements they had to be reversed. For example, if a participant rated the question "Consumption of GM food is dangerous" as 4 (strongly agree), then his/her attitude towards this aspect of biotechnology was assessed as strongly negative.

The reliability of the second (knowledge items) and third (attitudes) sections of the questionnaire was assessed by calculating Cronbach's α (CA), see result

[1] One of the questions included in this part (i.e., "personal biology background") was originally aimed to known if Spanish students had studied the non-compulsory Biology subject on upper secondary school. However, Swedish students, unlike Spanish students, have a compulsory science subject on upper secondary education that includes some hours of Biology. Therefore, it was necessary to add a new question exclusively for assessing the Swedish sample. This question was included in order to identify whether Swedish students had studied biology courses on upper secondary education, apart from the compulsory science subject.

section. The Cronbach's α (CA) values indicate the ability of the instrument to generate the same results under the same conditions, and thus the consistency of the underlying constructs over time (Field 2013, 706). High to perfect reliability is indicated by CA-values between 0.7 and 1.0 (Fischer *et al.*, 2014). However, if the diversity of the construct is large, values are likely to be lower than 0.7 (Field 2013, 709). The CA also depends on the number of items reflecting the construct: increasing the number of items for a construct generally increases its CA value.

Statistical analysis

The data from the questionnaires was collected and inserted into an excel document. The statistical analysis was then done using the SPSS Statistics 20 software. Three different statistical analysis were conducted: exploratory factor analysis, cluster analysis and correlation analysis which are described as follows:

Exploratory Factor Analysis

We conducted an exploratory factor analysis to find the factorial structure of the participants' attitudes towards biotechnology. We employed principal components analysis with varimax rotation and without specifying the number of factors. The suitability of the respondent's data for factor analysis was assessed by the Kaiser-Meyer-Olkin measure of sampling adequacy (Kaiser, 1970) and by the Bartlett's test of sphericity (Bartlett, 1950). The Kaiser-Meyer-Olkin is a measure that ranges between 0 and 1: a value of 0 indicates a diffusion in the pattern of correlations between items (i.e., the data are not suitable for factor analysis), whereas a value close to 1 indicates that the patterns of correlations are compact and so factor analysis should output distinct and reliable factors. The Bartlett's measure tests the null hypothesis that the items included in the factor analysis are not intercorrelated. Thus, if the result of the Bartlett's test is significant (i.e., $p < 0.05$), then the data are suitable for factor analysis. Finally, in order to select the optimal number of factors, we used the Horn's parallel analysis methodology and the Screen test.

The factorial scores of each participant were interpreted as his or her attitudes towards biotechnology. This interpretation was based on the mean value of each factor. Since we used a 4-point Likert-scale, in which students rated their opinions from 1 (*strongly disagree*) to 4 (*strongly agree*), mean values above 2.5 were considered positive attitudes and values below this cut-off were considered negative attitudes.

Cluster Analysis (K-means Clustering)

We carried out a K-means cluster analysis based on the factorial scores of each participant. The aim of this analysis was to group the participants according to their attitudes towards biotechnology. Cluster analysis is a statistical multivariate technique employed to group sets of observations according to the scores on one (or more than one) selected variables. It depends on correlation and multiple linear regressions, and it groups the cases with similar scores by calculating the distance between them in an N-dimensional space, where N is the number of variables included in the analysis. The closest cases in the N-dimensional space will be part of the same cluster, whereas the furthest cases will be included in different clusters. Importantly, the main advantage of this technique is that groups without providing predefined classes or examples (Berry & Linoff, 1997; Halkidi *et al*., 2001). For this reason, it is of great utility to find underlying connections among the data.

Correlation analysis

We performed correlation analyses for examining the relationship between socio-demographic, knowledge and attitude variables. Pearson's correlation coefficient (r) was calculated between quantitative variables (age, knowledge and attitude variables). Moreover, point-biserial coefficient (rpb) was calculated between nominal (biology background) and quantitative variables; biserial coefficient (rb) was calculated between ordinal (parent's background) and quantitative variables, and rank-biserial coefficient (rrb) was calculated between nominal (biology background) and ordinal (parent's background) variables. See Glass and Hopkins (1996) for a description of these correlation coefficients.

Before comparing factors' scores between samples, it was necessary to calculate a factorial similarity index. To do so, we computed the Pearson's correlation coefficient (r) between the factor loadings (45 items) of each factor of each sample. The factorial similarity index indicates how similar the factorial structures of different samples are; that is, a high factorial similarity means that the items load on the same factors across samples, whereas a low factorial similarity means that the items load on different factors across samples.

Comparisons of knowledge scores between samples

We conducted some statistical tests to compare the knowledge scores between Swedish and Spanish samples. Independent samples t-test was used for comparing the total knowledge scores and also factors of each country, and Pearson's chi-squared tests were employed for comparing the percentage of correct responses of each knowledge question. Importantly, "Don't know" responses were considered incorrect responses.

Results

Socio-demographic sample characteristics of Swedish teachers

Only fully answered questionnaires were analyzed. A sample of 155 Swedish teacher students completed the questionnaires. Table 1 shows the socio-demographic information of the sample, obtained from the responses of the first part of the questionnaire.

Table 1. Socio-demographic characteristics of the Swedish sample (N = 155).

Variable	Definition	Values
Age	Age in years	26.61 ± 7.21
Gender	Female	86%
	Male	14%
High school general science	Science background	94%
	Non science background	6%
High school Biology courses	Biology background	32%
	Non biology background	68%
Parents education	Elementary school degree	14%
	High school degree	43%
	University degree	43%

It has to be noted that Swedish curriculum for upper high-school education include a compulsory subject of science of approximately 40 hours. The content of this science subject comprises environmental sciences, biology, chemistry and physics. This is the reason why the 94% of the teacher students reported a science background. Moreover, 32% of students declared that they had previously followed specific courses in biology in their upper high-school programs.

Knowledge of Basic Concepts Related to Biotechnology among Swedish teacher students

The second part of the questionnaire consisted of 21 questions related to knowledge of genetics and some general aspects of biotechnology. The reliability (Cronbach's α) of this part was 0.66, which is an acceptable value for the reliability. Table 2 shows the 21 items ordered from higher percentage to less percentage of correct answers. The 10 first items were correctly answered by more than 50% of the Swedish teacher students and the last 11 items correspond to the questions that were answered incorrectly, or marked as "don't know", by more than a half of students.

As is it shown in Table 2, we found that the Swedish teacher students have a lack of knowledge about many basic concepts of genetics and about some aspects related to GMO. For instance, 68% of students answered incorrectly, or did not know, that DNA is chemically identical in all the organisms. Only 21% knew that GMO organisms are not necessarily larger than other organisms, and many were insecure about whether GMO withheld toxic substances. However, the respondents had fairly good understanding of some of the GMO applications. Just to name some examples: 80% of students are aware that bacteria are used in the elaboration of cheese, vinegar, among other daily products, and 65% of students know that it is possible to change genetic characteristics in order to increase in the resistance to a plague, higher nutritional values or higher productivity.

Table 2. Knowledge items with the most frequently correct responses among Swedish teachers. In the column "Correct answer", T (True) and F (False).

	Correct answer	Responded correctly (%)	Responded incorrectly (%)	Don't know (%)
AIDS is a genetic disease.	F	83	14	4
Bacteria are used in the elaboration of daily products (cheese, vinegar, vitamin C).	T	80	6	14
Only when we eat GM food we eat genes.	F	78	7	15
In our body there are more bacteria than people in the world.	T	77	8	14
A good hygiene helps to prevent genetic diseases.	F	75	15	9
Children resemble their parents because they share the red blood cells.	F	72	8	21
It is possible to change the genetic characteristics of a plant to make it more resistant to a given plague.	T	65	9	26
Mutations are only possible by genetic manipulation in the laboratory.	F	65	16	19
A high production of vitamins by a fruit is only possible by genetic manipulation of that fruit.	F	63	11	26
Through genetic modification, foods with higher nutritional values can be achieved.	T	50	13	37
Microorganisms are used to purify sewage.	T	48	11	41
A yogurt is a biotechnological product.	T	41	17	42
Insulin is obtained by the use of genetically modified (GM) bacteria.	T	38	16	46
Genetic material exchange between different species is only possible by manipulation in the laboratory.	F	35	32	32
The most powerful toxic substances are naturally occurring.	T	34	30	36
GMO have a high number of toxic substances.	F	33	19	48
Chemically, the genetic material (DNA) is identical in all the organisms.	T	32	41	28
In the kidney cells genome you can also find the information about the colour of your hair.	T	27	26	47
Genetically Modified Organisms (GMO) are larger than normal.	F	21	26	53
Crocodiles have the same genetic material as ostriches.	T	17	34	50
A GMO is always a transgenic.	F	8	22	70

Attitudes towards biotechnology among Swedish teacher students

Attitudes part consists of a 4-point Likert-scale questionnaire with 45 items, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree) of statements. In general terms Swedish teacher students show an average score in total of the attitudes towards biotechnology is 2.61 (±0.89). We could conclude that they have neutral attitudes towards biotechnology.

We conducted a factor analysis for exploring the Swedish teacher students' attitudes towards biotechnology in order to examine the structure or relationship between the selected items. By means a factorial scores of each participant were interpreted as his or her attitudes towards biotechnology. This interpretation was based on the mean value of each factor. The suitability of the respondents' data for performing the analysis was supported by two measures: the Kaiser-Meyer-Olkin measure was 0.74, and the Barlett's test was statistically significant ($p < 0.001$). The reliability (Cronbach's α) of this part of the questionnaire was 0.81 which indicates a good reliability of this instrument. We included the responses to the 45 attitude items (the question of the third part of the questionnaire) in an exploratory factor analysis, resulting in four factors that explained 37.7% of the total variance (see Figure 1 for details of the factorial structure). Three items were deleted because their factor loadings were lower than 0.3. The resulting factors were named as follows: *General opinions of GMO applications, Personal feelings towards GMO, Biotechnology and health*, and *Interest of biotechnology*, and are described below.

Figure 1. Factor structure and loading of the 42 items related to attitudes towards biotechnology. The Figure shows respondents attitudes (positive or negative) towards biotechnology issues. Responses to items presented as negative sentences were reversed in order to obtain a visually meaningful graphic representation of a positive or negative attitude to the different aspects of biotechnology included in the survey. Items with reversed answers are identified with an asterisk. Items from published instruments are identified by superscript letters; (A) Chabalengula *et al*. (2011), (B) Eurobarometer (2010), (C) Klop (2008) and (D) Lamanaskuas & Makarskaite- Petkeviciene (2008).

			Average	SD	Loading	Attitude			
						Strongly Negative	Negative	Positive	Strongly Positive
F.1 : General opinion of GMO applications	1	Consumption of GM foods is dangerous.*[D]	2,58	0,81	0,678	10	34	46	11
	2	Genetically altering living beings is to play God.*	2,68	1,00	0,608	14	28	32	25
	3	Genetic manipulation will drive to the extintion of a large number of species.*	2,50	0,77	0,585	10	37	46	7
	4	I would forbid the sell of trangenics in my country.*	2,47	0,78	0,570	10	41	41	8
	5	The genetical modification of fruits and plants to be fresh for a longer time.[C]	2,87	0,84	0,538	3	32	39	26
	6	Genetic manipulation is no ethical.*	2,63	0,74	0,532	6	35	50	10
	7	The addition of genes to a plant to make it plague-resistant is unacceptable.*	2,65	0,79	0,529	8	31	50	12
	8	The fast evolution of science threatens humanity.*	2,79	0,89	0,485	9	25	44	22
	9	There should be limits to what can and can not be investigated.*[B]	2,50	0,94	0,471	15	36	33	16
	10	I am opposed to the transfer of genes between plants and animals.*[D]	2,30	0,82	0,457	17	41	35	6
	11	Genetic manipulation should be more strictly regulated.	2,76	0,77	0,428	6	27	52	15
	12	The application of biotechnology will make the future more dangerous.*	2,43	0,76	0,399	12	39	45	5
	13	If I get a dish in a restaurant made out of transgenic food, I wold not eat it.*[C]	2,47	0,82	0,388	12	39	41	9
	14	The genetic modification of a sheep to produce medicines.[A]	2,43	0,84	0,334	12	43	34	10

			Average	SD	Loading	Attitude: Strongly Negative	Negative	Positive	Strongly Positive
F.2 : Personal feelings towards GMO	1	If genetically modified food was cheaper, I would buy it.	1,92	0,79	0,719	30	52	14	5
	2	The alteration of the genes of a fruit to make it more tasty.[C]	1,84	0,74	0,644	35	48	15	2
	3	The labeling of the transgenic products is clear enough.	1,85	0,62	0,603	28	60	12	0
	4	I would buy GM food.	2,14	0,81	0,599	23	45	29	4
	5	If genetically modified food was healthier, I would eat them more often.[C]	2,50	0,93	0,591	18	26	43	12
	6	I would feed my children with food produced with GM bacteria.	1,95	0,74	0,569	27	53	17	3
	7	The genetic modification of a bacteria to produce food.	2,37	0,78	0,466	13	43	38	6
	8	Society should decide what is right or wrong in science	2,32	0,79	0,417	14	46	34	6
	9	GM foods can help alleviate world hunger.[C]	2,77	0,82	0,341	7	26	49	17
	10	Biotechnology does not play any role in environmetal protection.*	2,94	0,70	0,315	2	21	57	19
	11	Biotechnology is used to produce chemicals in a less polluted way	2,48	0,69	0,311	5	47	42	6
F. 3 : Biotechnology and Health	1	Biotechnology makes our lifes easier.[C]	2,98	0,62	0,629	2	14	68	16
	2	I agree with the genetic investigation in medicine.	2,95	0,77	0,613	4	21	52	23
	3	I would support the use of GMO for non-food purposes	2,39	0,79	0,608	14	37	45	5
	4	Biotechnology can improve our life style.	2,98	0,74	0,593	4	17	57	23
	5	The use of GMO for medical therapy and the study of diseases.[C]	2,79	0,65	0,588	3	26	61	10
	6	Biotehnology is evil for nowadays society.*	3,06	0,64	0,556	2	12	65	21
	7	The use of GMO to fight against diseases.	2,61	0,72	0,487	6	35	52	8
	8	The law about GMO are strict enough.	2,37	0,68	0,466	8	50	39	3
	9	I agree with the genetic transformation in embryos to cure hereditary diseases.[A]	2,65	0,90	0,443	13	25	46	16
	10	A scientific discovery is not "good" or "bad", is how we use what matters.[B]	3,43	0,70	0,417	1	8	37	54
	11	Science makes our lifes easier.[B]	3,19	0,79	0,402	3	14	44	39
	12	The clonation as a tool to save endangered species.[D]	2,59	0,84	0,311	10	33	45	12
F.4 : Interest	1	I would like to know more about GM food.[D]	3,10	0,85	0,836	6	14	45	35
	2	I would like to have more information about GM food.	3,15	0,91	0,804	7	13	37	43
	3	I would like to increase my knowledge about GMO.	3,08	0,86	0,738	5	17	41	36
	4	I would like to be aware of scientific advances.	3,21	0,77	0,725	4	10	48	39
	5	Biotechnology is boring.*	2,57	0,89	0,453	12	35	38	15

The first factor was called "General opinion of GMO applications" which had an average 2.58 (±0.16). This factor included 14 items (Cronbach's α = 0.586), which to large degree express perceptions and opinions of the students towards the use of genetic modified organisms in a global or societal context. In addition, some of these items required students to make decisions that affect society. It is worth noting that the students had not a clear position in most of the items of this factor. For example, 57% of the students did not think that consumption of GM foods is dangerous, while on the other hand 67% of them said that genetic manipulation should be more strictly regulated. Hence, the Swedish teacher students' opinions were diverse and not consistent within this factor which could explain the somewhat low Cronbach's α value.

The second factor was named "Personal feelings towards GMO" which had an average 2.28 (±0.38). This factor consisted of 11 items representing to large degree personal feelings and consuming intentions towards GMO products (Cronbach's α = 0.768). The results pointed out that the teacher students had negative attitudes towards GMO produced food and would avoid the consumption of GM food, even when the benefit for the consumer is in term to produce tastier or cheaper food. (Items 1, 2, 5 and 7 of factor 2) Otherwise if the genetic modification of food production is focused on healthier products there was a tendency towards more positive intentions to buy it.

The third factor, named "Biotechnology and Health" which had an average 2.83 (±0.32), included 12 items (Cronbach's α = 0.775). The main topic of this factor was the biotechnology innovations in health care applications. Students had positive attitudes to use new biotechnology advances for health purposes. For example, 71% percent of students agreed with the use of GMO for medical therapy and the study of diseases, and three in four respondents approved the use of genetic investigation in medicine.

The forth factor were named "Interest" comprised 5 items and relates to the interest students have towards increasing their biotechnology knowledge (Cronbach's α = 0.792). This factor had an average 3.02 (±0.26) In general, the students are very interested in knowing more about biotechnology topics. For example, 77% of the students declared that they would like to increase their knowledge about GMO, and an 80% declared that they would like to have more information about GM food.

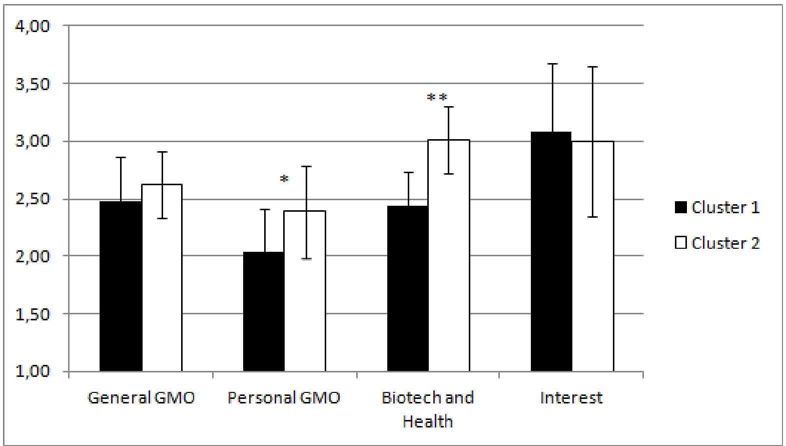
Segmentation by Attitudes towards Biotechnology

We analyzed whether subgroups (hereafter, referred to as clusters) could be identified among the sample of students. To do so, we performed a K-means cluster analysis, resulting in two interpretable and interesting clusters (see Figure 2). These clusters differed significantly in Factor 2, personal feelings towards GMO ($t(155) = 2.58$, $p < 0.01$), and in Factor 3, Biotechnology and health ($t(155) = 13.59$, $p < 0.001$). In contrast, they did not differ significantly in Factor 1 (General opinion of GMO applications) or Factor 4 (Interest) (all $ps > 0.05$).

Cluster 1 (N = 48 students). We defined this cluster as "The scepticals". These students are reluctant to using biotechnology in medical applications for improving living standards and to consuming GMO products than other students. They showed a lower mean score in biotechnology applications in healthcare field (Factor 3), a result that suggests that they are less inclined to support genetic investigation in medicine development, and to the use of GMO in medical therapy and in the study of diseases (Item 2 (2.95 ±0.77) and item 5 (2.79 ±0.65) from factor 3). Moreover, they refuse the consumption GM food by their own or by the members of their family even if it would be cheaper or tastier (Item 1 (1.92 ±0.79), item 2 (1.84 ±0.74), item 4 (2.14 ±0.81) and item 6 (1.95 ±0.74) from Factor 2). Furthermore, they do not accept the use of genetic modified bacteria to produce food, and they feel that labelling of transgenic products is not clear enough (Item 3 (1.84 ±0.62) and item 7 (2.37 ±0.78) from Factor 2).

Cluster 2 (N = 107 students). We defined this cluster as "The Confidents". These students are more confident to personal feelings and to consuming intentions towards GMO products. They are more positive to eat GM food and to feed their family with GMO products (Item 1 (1.92 ±0.79), item 4 (2.14 ±0.81), item 5 (2.50 ±0.90) and item 6 (1.95 ±0.74) from Factor 2). Furthermore they agree that medical applications of biotechnology could improve our live standards; they trust in biotechnology applications for medical therapy, the study of diseases and for the genetic transformation in embryos to cure hereditary diseases (Item 9 (2.65 ±0.90) from factor 3).

Figure 2. Graphical representation of K-means cluster analysis results of attitudes towards biotechnology. GMO corresponds to Factor 1 (General GMO); Personal GMO corresponds to Factor 2; STS corresponds to Factor 3 (Biotechnology and Health) and Interest corresponds to Factor 4 of the exploratory factor analysis. ** Significance of $p < 0.01$ and * significance of $p < 0.05$ using t-test statistical analysis between factors of each cluster. The attitudes' scale ranged from 1 (strongly negative) to 4 (strongly positive).



	General GMO	Personal GMO	Biotech and Health	Interest
■ Cluster 1	2,48	2,04	2,43	3,08
□ Cluster 2	2,62	2,39	3,01	3,00

Correlations between Socio-demographic Data, Knowledge scores and Attitudes towards Biotechnology scores

Correlation coefficients were calculated to examine to which extent socio-demographic data, knowledge scores and attitudes scores of the teacher students were related (Table 3). Significant correlations were observed between knowledge and attitudes scores. Swedish pre-service teachers who obtain better marks on the knowledge they have also more positive attitudes towards biotechnology applications in healthcare field and they have also more interest in increasing their knowledge in biotechnology related topics. This correlation is between knowledge and factor 3 (Biotechnology and health) and factor 4 (Interest).

Table 3. *Correlations between socio-demographic data, knowledge scores and attitudes scores. Reported statistical significance: **p < 0.01; *p < 0.05*

	Parents	Knowledge	General GMO	Personal GMO	Biotech Health	Interest
Age	-,073	,339**	-,022	-,154	,057	,090
Parents		-,048	,002	,130	,096	,015
Knowledge			,067	,017	,262**	,169*
General GMO				,329**	,336**	,017
Personal GMO					,427**	,134
Biotech Health						,244**

Comparison between Swedish and Spanish samples

In this subsection we present the results of the statistical comparisons between the sample assessed in the present study and a similar sample of Spanish students. The Spanish sample data was obtained from a previous study (Chapter I), in which 407 Spanish pre-service teachers completed the same questionnaire that was used in the present study.

Knowledge scores

Knowledge part of the questionnaire consisted of 21 *True/False/Don't Know* items that assessed respondents' knowledge of genetics and some general aspects of biotechnology. We carried independent samples t-test in order to compare the knowledge between Swedish and Spanish samples. Results showed no differences between samples in total knowledge scores, t (560) = 1.05, $p > 0.05$, suggesting that Swedish and Spanish students have the same level of knowledge related to genetics and biotechnology applications.

Attitudes towards biotechnology

Attitudes part consisted of a 4-point Likert-scale questionnaire composed of 45 items, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree). The Spanish sample average of the attitudes answers is 2.69 (±0.89). Four factors were identified after analyzing Spanish respondents' attitudes towards different aspects of biotechnology (Chapter I). First factor, GMO, reflects respondents' opinions about and intentions towards consuming products based on GMO's. The second factor, Biotech and Health, demonstrated the respondents' opinions about biotechnology applications to medical purposes. The third factor, Science-Technology-Society (STS), focused on the respondents' opinions about how scientific and technological advances could affect society and vice versa, including issues concerning GMO applications in a global or societal context. The fourth factor, Interest, reflected respondents' interest in increasing their knowledge about scientific advances and biotechnological applications.

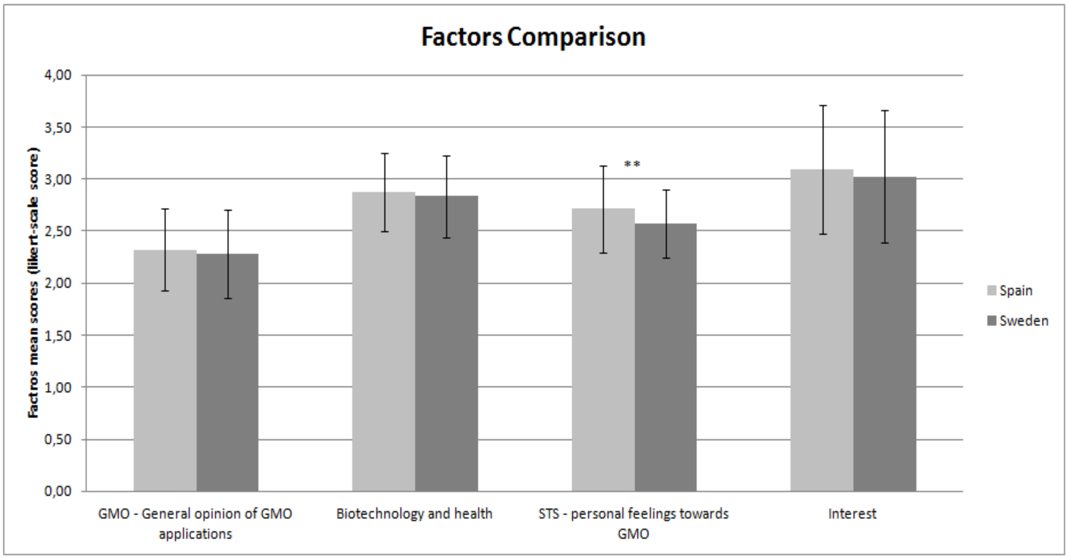
Factor distribution for Swedish sample is also in four factors. The first factor was called "General opinion of GMO applications", which to large degree express perceptions and opinions of the students towards the use of genetic modified organisms in a global or societal context. The second factor was named "Personal feelings towards GMO" which represents to large degree personal feelings and consuming intentions towards GMO products. The third factor, named "Biotechnology and Health" which main topic was the biotechnology innovations in health care applications. The forth factor were named "Interest" relates to the interest students have towards increasing their biotechnology knowledge.

Before comparing the factorial scores of the Spanish and Swedish students, it was necessary to assess the factorial similarity between samples' factorial structures. This was done by calculating the Pearson's correlation coefficients between the factor loadings of the 45 items of each sample. The results showed a correlation between the factor called "GMO" (factor 1) of the Spanish sample and the factor called "Personal feelings towards GMO" (factor 2) of the Swedish sample (r = .56, p < .01). These factors have a similar basis due to students' personal opinion about implications and consequences of using new technologies related to GM products and their personal behaviours about consuming these products. In addition, it was reported a positive and significant correlation between the factor called "STS" (factor 3) of the Spanish sample and the factor called "General opinion of GMO applications" (factor 1) of the Swedish students (r = .49, p < .01). These factors share in common a concern about the applications of GMO in a global and social context.

Furthermore, factor called "Biotechnology and health" (factor 2 for Spanish and factor 3 for Swedish) reported a positive and significant correlation between both countries (r = .54, p < .01). Spanish students and Swedish students grouped together questions related to new biotechnology applications in healthcare field. Finally, factor called "Interest" (Factor 4 in both countries) included the same five questions in both countries and showed a high correlation between samples (r = .81, p < .01). These questions were related to the interest of the students to increase their knowledge and learn more about biotechnology. These high correlations indicate a high factorial similarity between samples' factorial structures and, thus, allow us for comparing the factorial scores of the Spanish and Swedish students.

Due to samples differ in number of participants, we selected a random set of 155 participants from the Spanish sample for conducting t-tests (Bruce, 2015) (Figure 3).

Figure 3. Graphical representation of independent T-test of factors comparison. Factor 1 Spain (GMO) with factor 1 Sweden (General GMO); Factor 3 Spain (STS) with Factor 2 Sweden (Personal GMO); Factor 2 of Spain with correspond to Factor 3 Sweden (Biotechnology and Health) and Interest corresponds to Factor 4 in both countries. **Significance of p < 0.01. The attitudes' scale ranged from 1 (strongly negative) to 4 (strongly positive).



The results showed that it was reported a significant difference between the factor called "STS" (factor 3) for the Spanish sample and the factor called "General opinion of GMO applications" (factor 1) for the Swedish one (t (308) = 3.204, p<.01). These results show us that Spanish respondents (mean 2.71, SD 0.41) are slightly more confident in their attitudes towards issues about the applications of GMO in a general and social context to than Swedish (mean 2.58, SD 0.33). No statistical significant differences have been found between the factor called "GMO" (factor 1) for Spanish study and the factor called "Personal feeling towards GMO" (factor 2) for the Swedish preservice teachers. Both populations show a lightly negative attitude towards buying or consuming GMO (Sweden, mean 2.28, SD 0.42) (Spain, mean 2.32, SD 0.40). Furthermore, factor called "Biotechnology and health" (factor 2 for Spanish and factor 3 for Swedish) was present in both countries. In this case both, Spanish and Swedish respondents, grouped together questions related to new biotechnology applications in healthcare field. Our statistical analysis did not found significant differences within these averages values of these factor both

(Spanish mean 2.88, SD 0.37 and Swedish mean 2.83, SD 0.40). Hence, attitudes towards biotechnology applications in healthcare are positive in both countries. Finally, factor called "Interest" (Factor 4 in both countries) included the same five questions in both studies. These questions are related to the interest of the students to increase their knowledge and learn more about biotechnology. In this case also no significant differences were found among the two countries. Both Spanish (mean 3.10, SD 0.62) and Swedish respondents (mean 3.02, SD 0.63) have expressed that they are interested to know and learn more about biotechnology issues.

Discussion

This study analyzes Swedish elementary education pre-service teachers' views of the level of their knowledge of genetic and biotechnological facts and their attitudes towards biotechnology. Then, a comparison was made between answers from Spanish pre-service teachers obtained in a previous study using the same instrument (Chapter I) and the answers from the present Swedish sample in order to see if there are some knowledge and attitudes similarities or differences between a Southern Europe country and a Nordic country.

Our results in knowledge test revealed that Swedish pre-service teachers score higher percentage of correct answers on questions related to understanding of a genetic disease concept and to applications of biotechnology (such as the uses of bacteria for biotechnological production food or the possibility to modify genetics of a living organism to improve it). Lower scores were obtained in questions related to basic concepts of genetics (for example DNA structure and difference between genetic information and genetic material) as well as in questions related to GMO characteristics. Eurobarometer 2005 revealed that Europeans do not achieve expected knowledge scores on basic concepts of genetics. In our studies, results were in accordance with this finding and neither Swedish nor Spanish pre-service teachers achieve a satisfactory knowledge level in basic concepts of genetics (Gaskell *et al.*, 2006).

Although 78% of our Swedish pre-service teachers sample know that both GM food and non GM food contain genes, this is a similar results of that found in Magnusson and Hursti (2002) study in which 67% of Swedish consumers answers correctly the same concept of genetics. Our results also show that Swedish pre-service teachers do not have clear concept of DNA as a chemical molecule and they do not understand differences between genetic information and genetic material. On one hand, comparing to other studies, Swedish pre-service teachers as well as Spanish ones had higher percentage of correct answers on questions related to uses of biotechnology than Slovakian (Prokop *et al*., 2007), Turkish (Usak *et al*., 2009) and Lithuanian (Lamanauskas & Makarskaite-Petkeviciene, 2008). But in the other hand, in relation to questions concerning biological topics related to biotechnology such as DNA structure and cell management of genetic information or basic concepts of genetics both Swedish and Spanish pre-service teachers show poor knowledge level. This finding is not unique of Sweden and Spain, it is also detected in other countries such as Turkey, Slovakia, Slovenia, Lithuania and Lebanon (Darçin & Güven, 2008; Erdogan *et al*., 2012; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop *et al*., 2007; Sorgo & Ambrozic-Dolinsek, 2009; Usak *et al*., 2009).

As a summary of our results, scores of the knowledge test in both Swedish and Spanish pre-service teachers had shown an important deficit in basic scientific concepts behind the field of biotechnology. Due to the lack of understanding in these basic concepts, mainly related to genetics, more complex knowledge such as chemical events behind transgenic or cisgenic organisms or what really are genetic engineering technics or theories that explain the origin of live, among others, may not be understood. In near future these knowledge and concepts might be highly important for our societies and us as a citizens and voters in order to take informed decisions about issues related with the advance of biotechnological applications and its acceptance by our society.

One of the main goals of this study was to analyze the attitudes towards biotechnology of Swedish pre-service teachers. Four attitude factors were identified in this analysis, (i) general opinions of GMO applications, (ii) personal feelings towards GMO, (iii) opinion about biotechnology in health applications and (iv) interest in increasing respondents' knowledge about biotechnology applications. Swedish pre-service teachers show an average score of the attitudes towards biotechnology of 2.61 (±0.89), so Swedish have a neutral attitude towards biotechnology in general. Swedish pre-service teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances. Swedish pre-service teachers are not judging the "biotechnology" as such, contrarily they are judging the purpose of its use. There might be an underlying value of a utility-value system that influence the shift in attitudes towards GMO applications. This utility-value system is based on what it is used for. So, GMO are acceptable when they are used to save human lives or prevent diseases, but it is not accepted for our pleasure or economic gain. In concordance with this idea, a study performed by Magnusson and Hursti (2002) in a population of Swedish consumers, showed that only 12-13% said that they would be interested in buying GM foods even if they had lower price and tasted better. However, if GMO are healthier and better for the environment the proportions of the respondents increases around 31-43%. Our study the collective of preservice teachers in Sweden express in their attitude assessment similar values in items included in factor 3 "Personal feelings towards GMO" in which they express their attitudes about buying, consuming or producing GM products.

This study was also focused on the analysis of possible correlations between knowledge level and attitudes towards biotechnology. Results of correlations show that students with a higher score in the knowledge part of the questionnaire also have more positive attitudes towards biotechnology related to health applications and to the interest towards learning and increasing their knowledge on biotechnology related topics. The same has been shown in a UK study where it was found that knowledge significantly influenced a positive attitude towards clinical biotechnology procedures (Costa-Font & Mossialos, 2006). Hence, this fact indicates that improving teacher students' knowledge in biotechnological issues could lead to more positive attitudes towards biotechnology.

The final part of the study consists of the comparison between Spanish and Swedish teacher students' knowledge and attitudes towards biotechnology and GMO. Related to knowledge questionnaire, it was found that Spanish and Swedish pre-service teachers have no significant differences between knowledge questions related to genetics and biotechnology applications. These results suggest that Swedish and Spanish students have the same level of knowledge related to these topics.

Comparison between Spain and Sweden it was made also on the attitudes part of the questionnaire. It was reported significant differences between factors called "STS" for Spanish students and factor "General opinion of GMO applications" for Swedish students. Means show that Spanish pre-service teachers are more confident to the applications of GMO than Swedish pre-service teachers. These findings are in line with other research that have consistently shown the European and especially Nordic consumers' rejection of genetically modified food is strong and persistent (Bredahl, 1999). It is noteworthy that no significant differences were found in the remaining factors, therefore we observed that both populations of preservice teachers have shown that they have more similarities than differences in their attitudes towards biotechnology. Hence, differences detected in other studies like Eurobaromenter 2005 (Gaskell *et al*., 2006) between northern and southern European countries seem to be overcame in collective of preservice teachers.

One of the most important key to educational innovation, reform and improvement is the teacher. It is now generally accepted that to improve learning in our schools we need more and better teacher professional learning (Goodrum, 2006). Therefore, one effective way to induce a better knowledge and as a consequence more informed decisions of society towards new biological sciences and technologies is by promoting biotechnological literacy among teachers. For this reason, is important know devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret biotechnological issues.

References

Angulo, A.M., & Gil, J.M. (2007). Spanish consumers' attitudes and acceptability towards GM food products. *Agricultural Economics Review*, 8, 50–63. doi:10.1016/j.foodpol.2007.07.002

Bartlett, M. S. (1950). Tests of significance in factor analysis. *British Journal of statistical psychology*, *3*(2), 77-85.

Berry, M. J. A., & Linoff, G. (1997). *Data Mining Techniques For Marketing, Sales and Customer Support.* New York: John Wiley & Sons, Inc.

Bredahl, L. (1999). Consumers» Cognitions With Regard to Genetically Modified Foods. Results of a Qualitative Study in Four Countries. *Appetite*, 33(3), 343-360.

Bromme, R., & Goldman, S. R. (2014). The Public's Bounded Understanding of Science. *Educational Psychologist*, 49:2, 59-69.

Bruce, P. (2015). *Introductory Statistics and Analytics: A Resampling Perspective*. John Wiley & Sons.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching efficacy of pre-service elementary teachers. *Journal of Science Teacher Education 14(3),* 177-192. doi:10.1023/A:1025974417256

Chabalengula, V. M., Mumba, F., & Chitiyo, J. (2011). American elementary education pre-service teachers' attitudes towards biotechnology processes. *International Journal of Environmental & Science Education 6(4),* 341-357.

Costa-Font, J., & Mossialos, E. (2006). The public as a limit to technology transfer: the influence of knowledge and beliefs in attitudes towards biotechnology in the UK. *The Journal of Technology Transfer*, 31(6), 629-645.

Darçin, E. S., & Güven, T. (2008). Development of an Attitude Measure Oriented to Biotechnology for the Pre-Service Science Teachers. *Journal of Turkish Science Education*, 5(3), 72-81.

Darçin, E. S. (2011). Turkish pre-service science teachers' knowledge and attitude towards application areas of biotechnology. *Scientific Research and Essays 6(5),* 1013-1019. doi: 10.5897/SRE10.552

Dawson, V. (2007). An exploration of high school (12–17 year old) students' understandings of, and attitudes towards biotechnology processes. *Research in science education*, 37(1), 59-73.

Dimopoulos, K., & Koulaidis, V. (2003). Science and technology education for citizenship: The potential role of the press. *Science Education, 87(2),* 241-256.

Durant, J., Bauer, M. W., & Gaskell, G. (1998). *Biotechnology in the public sphere: a European sourcebook*. Science Museum.

Earl, R. D., & Winkeljohn, D. R. (1977). Attitudes of elementary teachers toward science and science teaching. *Science Education*, 61, 41–45. doi:10.1002/sce.3730610105

Erdoğan, M., Özel, M., Bouiaoude, S., Usak, M., & Prokop, P. (2012). Assessment of preservice teachers' knowledge and attitudes regarding biotechnology: A cross-cultural comparison. *Journal of Baltic Science Education*, 11(1).

European Commission (2010a). *Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels (Belgium): Directorate General Research, EU.

European Commission (2010b). *Special Eurobarometer 341. Biotechnology*. Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/public_opinion/archives/ebs/ebs_341_en.pdf

European Commission (2012). *Innovating for sustainable growth: A bioeconomy for Europe.* Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/research/bioeconomy/pdf/201202_innovating_sustainable_growth.pdf

Fetters, M. K., Czerniak, C. M., Fish, L., & Shawberry, J. (2002). Confronting, challenging, and changing teachers' beliefs: Implications from a local systemic change professional development program. *Journal of Science Teacher Education*, 13, 101–130. doi:10.1023/A:1015113613731

Field, A. (2013). *Discovering statistics using IBM SPSS Statistics*. London: Sage.

Fischer, H. E., Boone W. J., & Neumann K. (2014). *In Handbook of Research in Science Education*, edited by N. G. Lederman, and S. K. Abell, Vol. II, 18-37. New York, Routledge.

Gaskell G., Allansdottir A., Allum N., Corchero C., Fischler C., Hampel J., Jackson J., Kronberger N., Mejlgaard N., Revuelta G., Schreiner C., Stares S., Torgersen H., & Wagner W. (2006). *Europeans and Biotechnology in 2005: Patterns and Trends*, Eurobarometer 64.3, http://ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_ final_report-may2006_en.pdf.

Gaskell, George and Stares, Sally and Allansdottir, Agnes and Allum, Nick and Castro, Paula and Esmer, Yilmaz and Fischler, Claudeand Jackson, Jonathan and Kronberger, Nicole and Hampel, Jürgen and Mejlgaard, Niels and Quintanilha, Alex and Rammer, Anduand Revuelta, Gemma and Stoneman, Paul and Torgersen, Helge and Wagner, Wolfgang (2010). Europeans *and Biotechnology in 2010 Winds of change? Technical Report*. European Commission , Brussels.

Glass, G. V., & Hopkins, K. D. (1996). *Statistical methods in education and psychology* (3rd ed.). Needham Heights: Allyn & Bacon.

González, A., Casanoves, M., Barnett, J., & Novo, M. (2013). Biotechnology literacy: Much more than a gene story. *The International Journal of Science in Society, 4(2),* 27-35.

Goodrum, D. (2006). Inquiry in Science Classrooms: Rhetoric or Reality? *Australian Council for Education Research.*

Halkidi, M., Batistakis, Y., & Vazirgiannis, M. (2001). On Clustering Validation Techniques. *Journal of Intelligent Information Systems 17,* 107–145. doi:10.1023/a:1012801612483

Haney, J. J., Lumpe, A. T., Czerniak, C. M., & Egan, V. (2002). From beliefs to actions: The beliefs and actions of teachers implementing change. J*ournal of Science Teacher Education*, 13, 171–187. doi:10.1023/A:1016565016116

Jenkins, E. (1997). *Towards a functional public understanding of science*. In Science Today (pp.137-150). London: Routledge.

Kaiser, H. F. (1970). A second generation little jiffy. *Psychometrika*, *35*(4), 401-415.

Kidman, G. (2009). Attitudes and interests towards biotechnology: the mismatch between students and teachers. *Eurasian Journal of Mathematics, Science and Technology Education, 5(2),* 135-143. Retrieved from: http://eprints.qut.edu.au/28904/1/28904.pdf

Klop, T., & Severiens, S. (2007). An exploration of attitudes towards modern biotechnology: a study among Dutch secondary school students. *International Journal of Science Education, 29(5),* 663-679. doi: 10.1080/09500690600951556

Klop, T. (2008). *Attitudes of Secondary School Students towards Modern Biotechnology*. (Unpublished doctoral dissertation). Erasmus University, Rotterdam (The Netherlands).

Koivisto- Hursti, U.K., Magnusson, M.K., & Algers, A. (2002). Swedish consumers' opinions about gene technology. *British Food Journal*, 104(11), 860-872.

Lamanauskas, V., & Makarskaite-Petkeviciene, R. (2008). Lithuanian university student's knowledge of biotechnology and their attitudes of the taught subject. *Eurasian Journal of Mathematics, Science and Technology Education, 4(3)*, 269-277. Retrieved from: http://www.ejmste.org/v4n3/EURASIA_v4n3_Lamanauskas.pdf

Lee, J.S., & Ginsburg, H.P. (2007). Preschool teachers' beliefs about appropriate early literacy and mathematics education for low and middle socioeconomic status children. *Early Education & Development*, 18, 111–143. doi:10.1080/10409280701274758

Lujan, J.L., & Todt, O. (2000). Perceptions, attitudes and ethical valuations: the ambivalence of the public image of biotechnology in Spain. *Public Understanding of Science, 9(4),* 383-392. doi:10.1088/0963-6625/9/4/303

Magnusson, M.K., & Hursti, U.K.K. (2002). Consumer attitudes towards genetically modified foods. *Appetite*, 39(1), 9-24.

Miller, J.D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science, 7(3),* 203-223. doi:10.1088/0963-6625/7/3/001

Nunnally, J.C. (1978). *Psychometric theory* (2^{nd}). New York: McGraw-Hill.

Pardo, R., Midden, C., & Miller, J. D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, 98(1), 9-24.

Prokop, P., Leskova, A., Kubiatko, M., & Diran, C. (2007). Slovakian Students' Knowledge of and Attitudes toward Biotechnology. *International Journal of Science Education, 29(7)*, 895-907. doi:10.1080/09500690600969830

Roehrig, G.H., Kruse, R.A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science* Teaching, 44, 883–907. doi:10.1002/tea.20180

Saez, M.J., Niño, A.G., & Carretero, A. (2008). Matching society values: Students' view of biotechnology. *International Journal of Science Education 30(2),* 167-183. doi:10.1080/09500690601152386

Salvadó, Z., Casanoves, M., & Novo, M. (2013). Building Bridges between Biotech and Society through STSE Education. *International Journal of Deliberative Mechanisms in Science, 2(1),* 62-74. doi:10.4471/demesci.2013.09

Sorgo, A., & Ambrozic-Dolinsek, J. (2009). The relationship among knowledge of, attitudes toward and acceptance of genetically modified organisms (GMOs) among Slovenian teachers. *Electronic Journal of Biotechnology*, 12(3), 1-13. doi:10.2225/vol12-issue4-fulltext-1

Steele, F., & Aubusson, P. (2004). The Challenge in Teaching Biotechnology. *Research in Science Education, 34(4)*, 365-387. doi:10.1007/s11165-004-0842-1

Stefanich, G.P., & Kelsey, K.W. (1989). Improving science attitudes of preservice elementary teachers. *Science Teacher Education*, 73, 187–194. doi:10.1002/sce.3730730205

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education*, 37(2), 123-130.

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *Journal of Chemical Education, 89*, 297-300. doi:10.1021/ed300047v

CHAPTER III

Learning genetics through a scientific inquiry game

Accepted October 2015

Casanoves, M., Salvadó, Z., González, A., Valls, C. and Novo, M. (2015). Learning genetics through a scientific inquiry game. *Journal of Biological Education.* (Accepted October 2015).

Abstract

In this paper we discuss an activity, through which students learn basic concepts of genetics by taking part in a police investigation game. This police case is entitled RECAL. The activity improves students' knowledge of genetics (phenotype, genotype, genetic inheritance, etc.) and shows them how genetic evidence can be applied in forensic science. Students play the role of a member of the police scientific support unit so they have the opportunity of learning in a motivational and challenging context.

RECAL uses a problem-based learning educational methodology. It is learner-centred and students play an active collaborative role. The methodology requires students to structure their knowledge, and develop their reasoning processes and self-directed learning skills. It also increases their motivation to continue learning.

RECAL has been developed for a range of audiences, including high school students, undergraduates engaged in pre-service teaching and adults of all ages as part of university outreach. A case study has also been carried out with a group of 120 pre-service student teachers from the Universitat Rovira i Virgili (URV) (Tarragona, Spain) to check whether the activity has been correctly designed, whether it is effective as a learning activity and whether its dynamics and motivational aspects are acceptable.

Keywords: Pre-service teacher training, secondary education, classroom activity, problem-based learning, STSE and genetics.

Introduction

Currently, the revolution in the field of biological research affects and sometimes determines important aspects in the daily life of all citizens. The rapid development of modern biotechnology and genetic engineering has led to a huge gap between what the scientific community understands to be the risk and benefits and what is understood by the society (European Commission, 2010). Modern biotechnology raises numerous ethical, social, environmental and philosophical questions. For this reason, there is a need to increase the scientific and technological literacy of the population and it is on this issue that much of the research in this area focuses. Genetics is one of the pure biological sciences included on the biotechnology field. The vast majority of a society is only informed about genetics development through mass media and this may lead to lack of information (Kılıç & Sağlam, 2014). Hott el al. (2002) emphasised that, given the increasing importance of genetics in daily life, it is important that the education system should increase public understanding of the subject.

Genetics can be difficult for students to understand because it involves integration of abstract and complex concepts, highly specific terminology, integration of mathematical content and micro-macro view of the different biological organization levels (Knippels, 2002). To cope with these difficulties students should be able to think abstractly and hypothetic-deductively and they should be able to conduct reasonable relationships among concepts (Lawson *et al.,* 2007; Knippels *et al.*, 2005; Kiliç, 2014).The abstract nature of genetics may lead to a loss of motivation if learners are not situated in contexts with connections to their everyday life or with problems that have personal or societal relevance (Knipples *et al.*, 2005).

Some studies have addressed this challenge by designing and testing new teaching and learning activities. Law and Lee (2004) used simulations to teach Mendelian genetics, Tsui and Treagust (2003) used computer-based activities to enable students to investigate meiosis, fertilisation and monohybrid crosses. Ben-nun and Yarden (2009) developed a lab activity to teach molecular genetics and Carrió *et al.* (2011) compared a problem-based learning approach with a lecture-based learning with students of the bachelor degree in biology, among others.

It is also important for students to be motivated to take part in decisions on scientific issues that affect their daily lives, so that society can be taught to be more responsible in their own decision-making process (Zoller, 2012; Dimopoulos & Koulaidis, 2003). The goals are to develop higher-order cognitive skills (HOCS), critical thinking, question asking, decision making and problem solving (Zoller, 2012).

During the last two decades, context-based or STSE (Science, Technology, Society and Environment) programs have been increasingly used in formal education. The STSE approach is based on the use of scientific contexts and applications as a means of developing scientific understanding. Its main goal is to ensure that knowledge gained is at the heart of any decision-making process regarding scientific issues. This approach involves all education levels, from primary to university education. The number of new educational tools being created has rapidly increased, particularly at the secondary school level (Bennett *et al.*, 2006).

In the late 1960s, McMaster University (Canada) pioneered the first problem-based learning (PBL) experience on the medicine curriculum. PBL contextualizes learning by presenting students with a problem for which they have not been prepared or given information (Klegeris, 2011). The goal is to study new teaching units while solving real-life cases or common problems for students. This way of working increases student motivation and helps them to structure their knowledge, develops reasoning processes, implements self-directed learning skills and increases the motivation to continue learning (Kilroy, 2014). Enthusiasts of the PBL methodology believe that during the problem-solving procedure students use their procedural skills to integrate knowledge. In addition, teachers should catalyze students' critical thinking and their ability to find information related to different problem situations (Sonmez, 2003).

In this article we present a new activity called RECAL that was designed by combining the STSE approach and PBL educational methodology. The principles of PBL were followed when designing RECAL activity. Those principles are: research, group discussion and the acquisition of new knowledge that will lead to answer the questions that will solve the suggested problem (Carrió *et al.*, 2011). As mentioned above, STSE approach is based on the use of scientific contexts and applications as a means of developing scientific understanding. The activity described in this paper merges both. In one side, RECAL activity immerses students in a scientific-based scenario in which they play a role as a scientific assessor. And in the other side, players have to develop and use scientific reasoning and evidence based decision making to solve the given enigmas along the workflow of the game. Students practice scientific procedures by adopting the role of a forensic police officer in a police investigation, so they learn by doing. The student is the main character in the learning process. To reflect on learning by doing from a psychological point of view, we must first consider how learning takes place in real life. Schank (1996) considers that natural learning means learning on an "as needed" basis. In these learning situations, motivation is never a problem: we learn because something has caused us to want to know. RECAL is based on a motivating police case and students need to learn if they are to solve the case.

The main goal of RECAL is for students to apply and understand evidence and clues from a police investigation which will require them to be able to handle genetic knowledge.

The learning outcomes of RECAL are the following:

Students will

1. Understand the concepts of phenotype and genotype.
2. Know what chromosomes are, how they are formed, their functions and the differences between species.
3. Understand genetic inheritance.
4. Be able to apply their knowledge of genetics.
5. Understand the concepts of dizygotic and monozygotic.
6. Be aware of hereditary genetic disorders.

RECAL was developed for a range of audiences, including high school students from 15 to 18 years of age (genetics is on the secondary education curriculum), pre-service student teachers and adults of all ages. Participants do not need to have any genetics or biology background to have a successful and profitable participation in the activity. All the information and materials provided during the game allow participants to advance successfully through the story and reach the desired learning objectives of the activity without the needing of any previous knowledge or external information.

Methodology

RECAL is an educational training activity that involves a case of robbery and its associated police investigation. The activity was designed to reflect the real world as closely as possible in order to engage students in the learning process. The activity requires students to analyse clues, as real investigators would, while learning the genetic concepts they need for such analyses.

Materials

- Dossier containing a description of the context and a notebook for recording the clues (Annexe 2).
- Worksheets: These guide the participants through the game. Each worksheet advances the story and includes a questionnaire and a puzzle.
    - Questionnaires (available on the Moodle learning platform): Students have to answer these multiple choice questionnaires before they try to solve each puzzle in order to acquire the knowledge they need (Annexe 3).
    - Puzzles: Students are presented with new questions that link previous information and clues. To be able to continue with the game, participants must be able to find suitable answers.
- Additional information cards: They contain information about the genetic concepts required to solve the case (Annexe 4).
- Clues: They provide information collected from the scene of the robbery and the results of laboratory tests (Annexe 5).

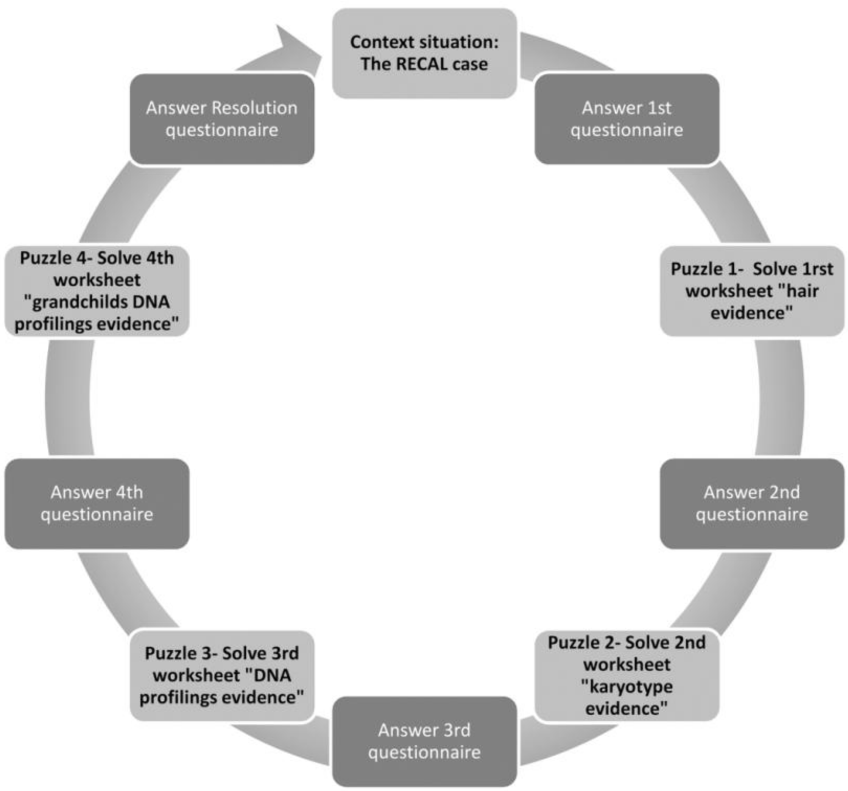
Outline of RECAL

The RECAL case activity is planned to last between 90 and 120 min, depending on the problem-solving skill of the group of students. It has been designed as a collaborative activity in which students work in groups of 3 or 4. Students play the role of a member of the police scientific support unit. The activity involves a case of robbery, so the clues that are provided and the puzzles that must be solved all focus on finding the thief and solving the case.

During the activity, participants have to solve a questionnaire before each puzzle and a final questionnaire that will ultimately lead them to the solution. All the questionnaires together with the paired additional information cards provide the participants with the knowledge they need to solve the puzzles. Additionally, and as a motivational target, the different groups compete to get the highest mark on the questionnaires carried out during the activity.

A workflow diagram of the game is shown in Figure 1.

Figure 1. Workflow of the RECAL activity.



When the game starts, the situation is presented and given to the students together with four worksheets and the extra information cards. The worksheets guide the participants in the tasks as described below:

- **Context situation sheet** describes the game and explains the story of the case. It also explains the role and tasks of the participants and the mechanics of how the groups of players compete by using the questionnaires (Annexe 2).
- **Worksheet 1** focuses on the concepts of phenotype and genotype, which correspond to learning outcomes 1 and 4. First of all, students are asked to use the additional information cards to solve the first questionnaire. It is subsequently corrected by the class group as a whole, and the concepts that have been misunderstood are pointed out and discussed. Then, puzzle 1 is presented together with the corresponding clues (pictures of hair samples found at the scene of the robbery) and students have to analyse the subject's phenotypic characteristics (see supplementary information 1).
- **Worksheet 2** focuses on concepts related to karyotype information, which correspond to learning outcomes 2, 4 and 6. As for worksheet 1, students answer and correct the second questionnaire within the class group. They are then given the second group of clues (three karyotypes). With this information students can identify the gender and some of the phenotypic traits of the thief (Annexe 2).
- **Worksheet 3** focuses on genetic inheritance (learning outcomes 3 and 4). As in previous worksheets, once students have answered and corrected the third questionnaire, they are provided with two DNA profiles (third group of clues). Students should determine if these profiles belong to a member of the family or not. They should conclude that the thief and the victim are relatives (Annexe 2).
- **Worksheet 4** focuses on the concepts monozygotic, dizygotic and genetic inheritance which correspond to learning outcomes 3, 4 and 5. After students have completed and corrected the fourth questionnaire, they are given seven DNA profiles (fourth group of clues). Students should solve the last puzzle and hence the case (see supplementary information 1). Finally, they have to answer the "Resolution questionnaire" in which they are asked about the resolution of the case and also about other issues that have been raised by the clues and the concepts they have learned. The

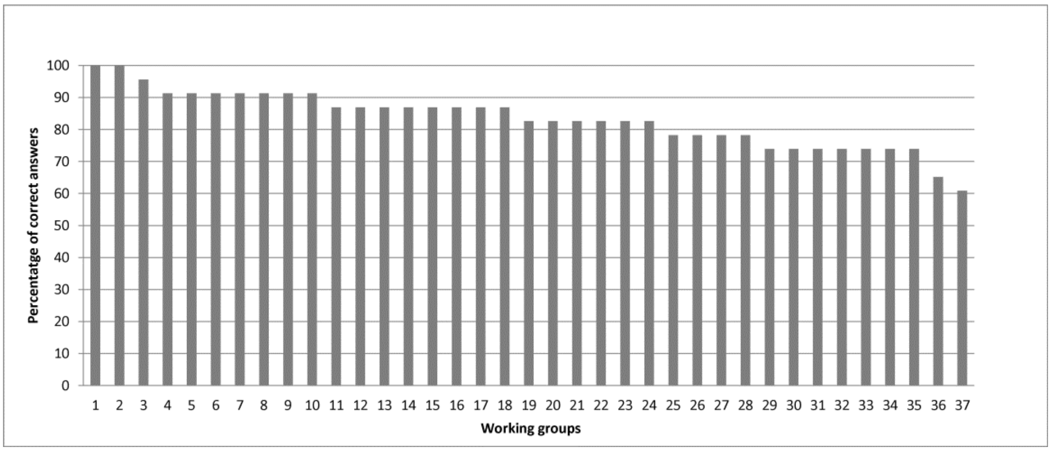
groups must respond to these last questions if they wish to obtain the maximum score.

Results

A case study was carried out with 120 pre-service teachers from the Universitat Rovira i Virgili (URV) in Tarragona (Spain). The activity was performed in six different class groups. The average number of participants in each class group was 20.2 (± 5.19). In order to perform the activity participants were organized in working groups of 3 or 4 students. The total number of working groups that took part in the activity was 37.

A total of 23 questions distributed among 5 different questionnaires were answered throughout the activity (see supplementary information 2). Of these 23 questions, an average of 19.1 (± 2.03) were answered correctly. Thus, the average of correctly answered questions during the activity was 83% (±8.8) All groups of students correctly answered more than 60% of the questions and more than 50% of the groups rank more than 80% of correct answers (Figure 2). The high percentage of correctly answered questions (83%) indicates that participants acquire most of the learning outcomes expected in the activity.

Figure 2. Percentage of correct answers to the 23 questions for each of the 37 working groups of students.



The questions were analysed individually (Annexe 3) by calculating how many groups had answered correctly. All the questions were answered correctly by more than 73% of the groups, except question 17, which was correctly answered by just 35%. The high degree of effectiveness shown by participants in solving the questionnaires indicates that the learning objectives of the activity were achieved.

Finally, the Resolution questionnaire shows that all students manage to solve the police case RECAL. This questionnaire leads the participants to reveal the resolution of the case. 100% of students correctly answered the "Who is guilty?" question. In addition, other enigmas that emerge from the story are also solved at this final questionnaire. 97% of students discovered which one of the suspects was actually adopted and 100% correctly identified the two monozygotic twins revealed by the DNA profiling evidence. These results allow us to conclude that this activity is appropriate for this educational level and the materials provided allow the game to be completed.

Discussion

The RECAL case is an educational, inquiry-based, motivational learning activity that aims to teach basic genetic knowledge. The activity gives students the opportunity to learn in a realistic context as protagonists of the learning process. The activity is designed according to experimental learning paradigms that suggest that students learn best when they are given the opportunity to acquire and apply knowledge and skills in realistic and relevant settings (Goodwin, 2012).

Participants needed more time and more assistance to carry out the first two worksheets, even though they were the easiest (in terms of the complexity of the concepts). Once they had understood how the game worked, they managed to do it autonomously. Therefore, at the beginning of the activity the teacher has to play the important role of initiating and guiding the inquiry, problem-solving and self-directed learning process.

It should be pointed out that participants in this "case study" are future teachers, therefore they will be able to apply this problem-based learning methodology in their professional careers. As Lawson (1993) stated, if students learn in a certain way, then they should be able to use the same pattern to solve new tasks. Therefore, exposing pre-service teachers to new teaching and learning methodologies, such as RECAL activity, is one of the main ways in which formal education can be improved.

Only 14.9% of URV pre-service student teachers have any background in genetics. Spanish curriculum for this university degree does not include specific university courses in biology. However, biology content is integrated into a discipline named experimental sciences. Additionally, in Spain, students are permitted to take this degree without any scientific background. For this reason, RECAL was designed using the questionnaires so that students would be gradually assessed throughout the activity. After each questionnaire, the teacher discusses the answers with all the groups, pointing out mistaken conceptions and misunderstandings. It would be interesting to find out whether the RECAL activity can be used with/by students with a solid background in biology and genetics. It would also be interesting to evaluate if the RECAL activity develops student's higher-order cognitive skills (HOCS).

To conclude, the game dynamics observed, the fact that the game unfolded quite normally and the high marks obtained on the questionnaires indicate that the game design and the materials provided make up an appropriate activity that enables students to achieve the required learning outcomes.

References

Ben-Nun, M.S. & Yarden, A. (2009). Learning molecular genetics in teacher-led outreach laboratories. *Journal of Biological Education*, 44(1), 19-25.

Bennett, J., Lubben, F. & Hogarth, S. (2006). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education* 91, 347–370.

Carrió, M., Larramona, P., Banos, J. E., & Pérez, J. (2011). The effectiveness of the hybrid problem-based learning approach in the teaching of biology: a comparison with lecture-based learning. *Journal of Biological Education*, 45(4), 229-235.

Dimopoulos, K.; & Koulaidis, V. (2003). Science and technology education for citizenship: The potential role of the press. *Science Education* 87 (2), 241-256.

European Commission (2010). *Special Eurobarometer 341. Biotechnology*. Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/public_opinion/archives/ebs/ebs_341_en.pdf

Goodwin, M., Kramera, C. & Cashmorea, A. (2012). The 'ethics committee': a practical approach to introducing bioethics and ethical thinking. *Journal of Biological Education* 46 (3), 188-192.

Hott, A. M., Huether, C. A., McInerney, J. D., Christianson, C., Fowler, R., Bender, H., Jenkins, J., Wysocki, A., Markle, G. & Karp, R. (2002). Genetics content in introductory biology courses for non-science majors: Theory and practice. *BioScience*, 52 (11), 1024-1035.

Kılıç, D., & Sağlam, N. (2014). Students' understanding of genetics concepts: the effect of reasoning ability and learning approaches. *Journal of Biological Education*, 48 (2), 63-70.

Kilroy, D. A. (2004). Problem based learning. *Emergency medicine journal* 21 (4), 411-413.

Klegeris, A., Hurren, H. (2011). Impact of problem-based learning in a large classroom setting: student perception and problem-solving skills. *Advances in Physiology Education* 35 (4), 408-415.

Knippels, M.C.P.J. (2002). Coping with the abstract and complex nature of genetics in biology education. The yo-yo learning and teaching strategy. Utrech: CD-β Press (http://dspace.library.uu.nl/bitstream/handle/1874/219/full.pdf?sequence=2)

Knippels, M.C.P.J., Waarlo, A.J. & Boersma, K.T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education* 39 (3), 108-112.

Law, N., & Lee, Y. (2004). Using an iconic modelling tool to support the learning of genetics concepts. *Journal of Biological Education* 38 (3), 118-124.

Lawson, A. E. (1993). Deductive Reasoning, Brain Maturation, and Science Concept Acquisition: Are they Linked? *Journal of Research in Science Teaching* 30 (9), 1029–1052.

Lawson, A. E., Banks, D. L. & Logvin, M. (2007). Self-Efficacy, Reasoning Ability, and Achievement in College Biology. *Journal of Research in Science Teaching* 44 (5), 706–724.

Schank, R. C. (1996). Goal-Based Scenarios: Case-Based Reasoning Meets Learning by Doing. In: David Leake (ed.). Case-Based Reasoning: Experiences, Lessons & Future Directions. AAAI Press/The MIT Press. 295-347.

Sonmez, D., & Lee, H. (2003). Problem-based learning in science. ERIC Clearinghouse for Science, Mathematics, and Environmental Education, *ERIC Digest* EDSE–03–04, 1-2.

Tsui, C.Y. & Treagust, D. (2003). Learning genetics with computer dragons. *Journal of Biological Education*, 37(2), 96-98.

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *Journal of Chemical Education* 89 (3), 297–300.

CHAPTER IV

Assessment of a scientific inquiry game about genetics for pre-service teachers: a comparison between students from Sweden and Spain.

Abstract

During last decades, scientific and teachers community work together in order to improve citizens scientific and technological literacy. Meanwhile, many researchers have observed a steady decline of satisfaction and usability toward science in middle and high school. One of the main core of non satisfaction are the textbooks, that under-represent the scientific process, which could be an impediment to students' understanding of science. Consequently many authors started to develop new educational material in order to change the teacher-centred educational trend and to keep students engaged. In this paper we analyze the efficacy of RECAL activity in two different countries Spain and Sweden. The main goal is to find out if students knowledge increases after taking part of the educational game. By means of this activity students learn the basic concepts of genetics by taking part in a police investigation. RECAL improves students' knowledge of genetics (phenotype, genotype, genetic inheritance, etc.) and shows them how genetic evidence can be applied in forensic science. RECAL uses a problem-based learning educational methodology. It is learner-centered and students play an active collaborative role. This activity uses strategies in order to shifting HOCS learning such as active participation of the students; critical and evaluative thinking, group work which are effective students' teacher feedback mechanisms.

Keywords: Pre-service teacher training, secondary education, classroom activity, problem-based learning, STSE and genetics.

Introduction

Over the past decades, there has been a revolution in the field of biology research and, more concretely, in biotechnology and genetic fields. The rapid development of modern biotechnology and genetic engineering has led to a huge gap between what the scientific community understands to be the risk and benefits and what is understood by the society (European Commission, 2010). The perspective of a socially-viable science should be share with citizens (Gaskell *et al.*, 2005). However, in order to involve society in the decision-making process about scientific policies, we need well-informed citizens who are able to make thoughtful decisions based on scientific conclusions combined with ethical and moral considerations. A primary goal for science education is to help students to develop their knowledge, skills and epistemologies necessary for dealing with 21st century, real world scientific issues (Barab & Dede, 2007).

Currently, research in science education is increasing worldwide. More concretely, the scientific and technological literacy is becoming more and more relevant in the teaching field (Zoller, 2012). All members of the education community work together in order to improve citizens' scientific and technological literacy. School provides the first steps of a long process through which a person would be educated into the culture of science (Fensham, 2002). Many researchers have observed a steady decline of satisfaction and usability toward science in middle and high school, resulting in a decreasing number of students who pursue science at the college level (Gibson & Chase, 2002; Tai *et al*., 2006; Martin *et al*., 2007). Also a recent study determined that introductory undergraduate biology textbooks under-represent the scientific process, which could be an impediment to students' understanding of science (Duncan *et al*., 2011).

Biological contents are important in order to establish a basis to literate citizens on biotechnology. Genetics is one of the pure biological sciences included on the biotechnology field. The vast majority of a society is only informed about genetics development through mass media and this may lead to lack of information (Kılıç & Sağlam, 2014). Some authors have found that genetic information presented informally through different types of media is not always correct (Grinell, 1993, Lanie *et al*., 2004). For these reason it can be difficult for people without a solid foundation in the basic concepts to distinguish valid genetic information from misinformation (Jennings, 2004). Hott *el al*., (2002) emphasized that, given the increasing importance of genetics in daily life, it is important that the education system should increase public understanding of the subject. In our priors studies (Chapter I) we identified that Spanish and Swedish pre-service teachers are aware of the applications of biotechnology but they have a lack of knowledge about basic concepts of genetics such as, the difference between genetic information and genetic material, the same genetic information in all cells of a living being, and students have some misconceptions related to Genetic Modified Organisms (GMO) characteristics (such as size, toxicity among others) and they do not know possible applications of GMO. However, finding of previous studies shows that pre-service teachers from Spain and Sweden have interest in increasing their knowledge on genetics and biotechnology (Chapter I). It is known elementary teachers may not have to teach complex biotechnology topics in their classroom. However, the more knowledge in biotechnology fundamentals the more self-confidence teachers will have in this subject (Maier *et al*., 2013) and, therefore, it can be assumed to increase the chances that more biotechnology topics will seep into their teaching.

Frame of new educational materials

In last two decades it has been appeared and extended a new educational approach called STSE (Science, Technology, Society and Environment) which involves all educational levels, from primary to university education. The main goal of the STSE concept is based on the use of scientific contexts and applications as a means developing scientific understanding (Bennett *et al*., 2006). To work within the context STSE there exist different learning approaches that could be used, such as inquiry-based learning, problem-based learning (PBL), game-based learning among others. In this paper we are keeping attention to PBL methodology, since is the basis of the RECAL activity (Casanovas *et al.,* 2015) which is the new educational resource that we assessed in this manuscript. PBL contextualizes learning by presenting students with a problem for which they have not been prepared or given information (Klegeris & Hurren 2011). PBL engages learners in thinking processes such as exploring perspectives, questioning assumptions, looking for connections and synthesizing information. Principles of this approach are: research, group discussion and the acquisition of new knowledge that will lead to answer the questions that will solve the suggested problem (Carrió *et al.*, 2011). However, on our study PBL methodology is complemented with and structure of a game. The use of the game in a scientific subject is based on a context that support interacting socially (not just individualized learning) and doing science (not simply memorizing information), as well as involving socio-scientific inquiry (not just learning science facts and recipe-like processes) (Barab & Dede, 2007). The main characteristics of a game that structure the activity are: non-spontaneous, rules, goals, structure, non-real world outcome and non-system activity (Herger, 2014).

The frame of the current paradigm of science education in Spain and Sweden, mainly characterized to be teacher-centered, disciplinary, decontextualized and low-order cognitive skills (LOCS) oriented should move to more adaptive paradigms. Currently, teaching of science used techniques like rules, formal definitions, equations and algorithms in terms of 'knowing', 'remembering' and 'defining' which require just LOCS of the students to respond correctly to examination questions. Science education should employ an interdisciplinary teaching approach, leading to the development of our students' higher-order cognitive skills (HOCS) (Zoller, 2012). This approach uses methodologies leading to improved students problem-solving capabilities. The main components involved in science education in the context of the development of students' HOCS are: problem solving, critical thinking and practical activities (Zoller & Pushkin, 2007).

Spanish and Swedish education system

Northern and Southern countries have differences such as cultural, economical among others. Sweden is ranked third among the European countries for 1996 Eurobarometer (Gaskell *et al*., 1998) with quite a large population of well-informed public regarding biotechnology, only surpassed by Netherlands and Denmark. Spain, on the other hand, is placed as 4th last together with Greece Ireland and Portugal in a total of 15 European countries analyzed (Pardo *el al*., 2002).

There exist some differences between Swedish and Spanish education systems. In Sweden there are some independent schools which permit citizens to choose which school they prefer for their children but at the same time the government guarantee the equality of opportunities and do not permit that socioeconomic factors will condition students to the school choice. Contrarily, Spanish educational system is made up of two educative sectors, public and private. Duality of the system causes educative and social inequality (Bonal, 2002). This inequality leads to a segregation of students' profiles, mainly based on immigration, economic resources, and also depending on the organizations of the cities. As Savage *el al*., (1993) say, the development and the population of the cities is not made a randomly because cities follows gentrification dynamics and ghettoization of neighborhoods. In addition, Sweden invests much more money in its education system, a 13.2% of the total public expenditure in 2009. Swedish budget is over the OECD average (13%) and also over EU21 average (11.5%). Instead Spain investment represents only a 10.8% of the total public expenditure on education (OECD, 2012). Another difference between both countries consists in the decentralization reform which took place in Sweden around 1991 when each municipality assumed its own competences. In contrast, in Spain nowadays this reform is being developing nowadays, thus there exist more than 20 years of difference between both countries. One point that is similar in both countries is the fact that teachers' status has decreased. In the case of Spain, the continuous change of teachers among different schools makes even more difficult the education programs' coherence and continuity and of course this affects schools' team work (García-Zarza, 2014).

Comparing education system is not enough to have an idea of the differences between northern and southern countries, actually it is also important to compare students' educational level. PISA (Program for International Student Assessment) test is a good indicator to assess the skills of secondary school students in reading, mathematics and science and is useful to compare the educational level between Swedish and Spanish students. The results of PISA 2009 indicate that Spain is clearly below the OECD average in the last four editions of PISA reports, while Sweden is above average. According to the study of Ferrera *et al*., (2012), low academic results of Spanish students cannot be attributed to the type of school, public or private or the educational level of parents. The study indicates that the main factors explaining these results are: the first-generation immigrant status, having no preschool, repeat the course, little interest in the study and the lack of study habits. On the other hand, a Swedish study made by Penick (2003) show that the Swedish curriculum focused in the knowledge of science processes the same as the philosophy programs PISA which may be responsible for the good results achieved in Sweden.

A new educational game

Keeping in mind the main findings of previous studies (Chapter I and II) of Swedish and Spanish pre-service teachers, we created new educational activity (RECAL case) aimed to allow students to acquire basic concepts of genetics (Chapter III). In one side, "RECAL case" activity immerses students in a scientific-based scenario in which they play a role of a scientific assessor. And in the other side, students have to develop and use scientific reasoning and evidence based decision making to solve the given enigmas along the workflow of the game. "RECAL case" activity is framed on a STSE context. The educational methodology used on this activity is Problem-Based Learning (PBL) and it has a structure of a game. This activity uses strategies in order to shifting HOCS learning such as system critical thinking, question-asking, decision-making and problem solving that can apply these skills and practices beyond the science disciplines to the complex problems and decisions that need to be addressed in society as a whole for global sustainability (Zoller & Pushkin, 2007; Zoller 2012).

Purpose

The present work analyzes the usefulness of RECAL activity. We evaluate the learning achievement of some aspects of genetics by means of this new educational activity, by comparing a sample of Spanish and Swedish pre-service teachers. We also test if the methodology fits new educational paradigm and finally if improves the biotechnology literacy of the pre-service teachers. For this analyze it was used a knowledge and an expectations pre-test and then a knowledge and a satisfaction and usability post-test.

Additionally, we collected socio-demographic data in order to identify the potential correlations between knowledge and socio-demographic variables (education level of parents, previously taken biology courses, age, and gender and so on). Regarding the differences between Spanish and Swedish education system and also the results of biotechnology knowledge in the Eurobarometer we found important to evaluate our PBL educational material called "RECAL Case" in these countries in order to see if the increase of students' knowledge differs in such different countries. Authors declare no conflict of interest.

Methods

Intervention

RECAL activity is not based on memorizing large number of genetic concepts like Karyotype, Chromosomes, DNA or inheritance. Instead, the key point is that students will practice scientific procedures as a forensic police inspector in an investigation police case so they learn by doing. The main goal of RECAL activity is for students to apply and understand evidence and clues from a police investigation which will require them to be able to handle genetic knowledge. The main target of the present study is to validate the efficacy of "RECAL game" and for that it was used a sample of undergraduate pre-service teachers from Universitat Rovira i Virgili (Spain) and Karlstad University (Sweden). The learning outcomes and contents worked at the RECAL activity can be used in primary pre-service teacher degree which does not include specific university courses in biology. The development of this PBL activity could be useful to increase students' knowledge in basics genetics related topics.

Table 1: Learning outcomes of RECAL activity.

Learning outcomes	Contents	Question in the survey
Understand DNA chemical structure.	Chemical components of DNA are A, T, G and C. All living being have same chemical molecules in their DNA.	3, 7
Understand the concepts of phenotype and genotype.	Phenotype and genotype concepts, DNA is found inside cell, DNA composition and gen concept.	1
Know what the chromosomes are and the number of chromosomes permit to identify species.	A chromosome is a structure which serves to package the DNA content. Identify the chromosomes as a transmitting of genetic information. Sex determination and specie by means of a Karyotype.	2, 4, 5, 6, 9, 10
Understand genetic inheritance.	Identification humans' variability: Heritable and non-heritable characteristics. Chromosome theory of inheritance and transmission of hereditary characteristics. Identification of some chromosome hereditary genetic disorders.	6, 8
Be able to apply their knowledge of genetics. Understand the concepts dizygotic and monozygotic.	DNA profiling is a technique employed by forensic scientists to assist in the identification of individuals.	8, 10

Participants

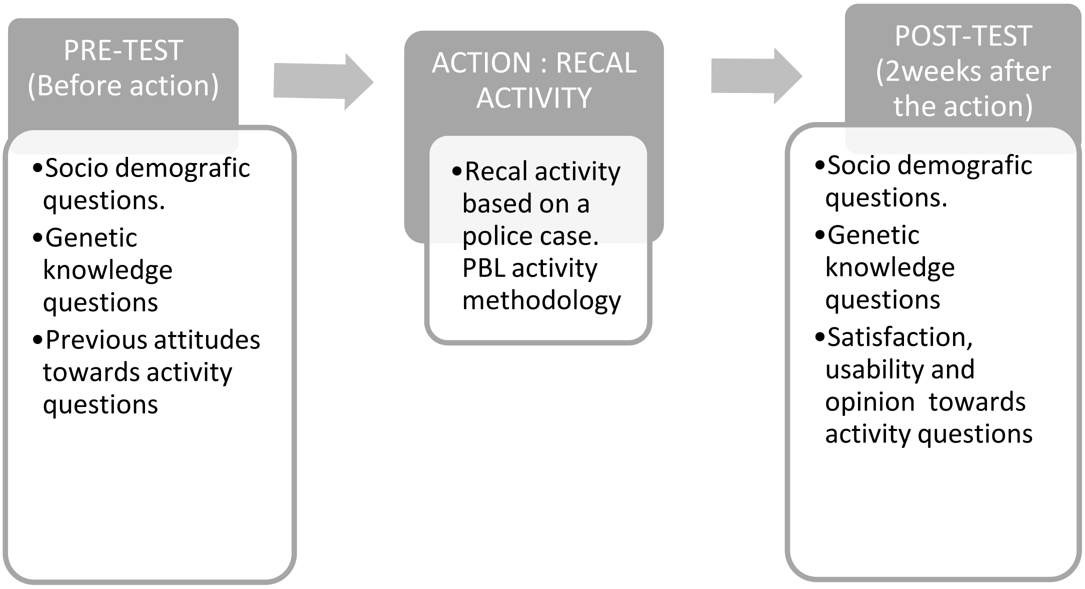
First part of the sample was composed by a group of pre-service teacher students from Universitat Rovira i Virgili (URV) in Tarragona (Spain). Students attended to experimental science subject that takes place at 2nd level of the primary school teacher education program. This group contains 120 pupils which were divided into 6 laboratory groups. We have to say that after all procedure of the activity we could only collect data from only 94 students because subjects with missing data and those who did not complete all class activity were eliminated from the data set. The second group of sample was from Karlstad University (KAU) of Karlstad (Sweden). Students attended to technologic and linguistics subjects in the two different degrees of primary school teacher education program. This group contains 51 students which were divided into 5 groups. After all procedure of the activity we could only collect data from only 33 students. As we did with Spanish sample, subjects with missing data were deleted from the data set.

Procedure

Evaluation of "RECAL" problem-based learning activity was independent of other instructional intervention. One in-person class, ranging from 90 to 120 minutes, was part of the intervention. A coding system blinded the researchers to identify of the students.

All measures were administered during their classes at university. First part consisted in a Pre-test which included some socio-demographic data, questions of knowledge and questions of expectations. After an intentional 2 weeks delay, in-person class occurred in which student solve the RECAL problem based learning activity. Final part was a post-test occurring 2 weeks after in-person class and included the same socio-demographic questions of pre-test, also the same knowledge question and a group of questions about activity satisfaction and usability. The minimum 2 weeks time delay between in-person class and post-testing was purposely planned to test the persistent effects of the problem based learning activity beyond the immediacy of the intervention.

Figure 1: Phases and schedule.



Instruments

Pre-test is composed by 3 parts (see Tables 3, 4 and 5) (Annexe 6). First part consists of one question for coding system and 5 socio-demographic questions of the students (gender, age, education, parent's education, and current studies). The second part consists of 10 basic genetics knowledge which their possible answers are True, False or Do not know. And finally there is a part with 3 questions to collect from learners to get information on their perceptions and expectations of the PBL activity. In order to assess the consistency of the questionnaire an exploratory factor analysis was used to identify the factor structure of the questionnaire. The reliability analyses were determined by measuring the internal consistency of each scale calculating the Cronbach's alpha. Alpha coefficients ranging from 0.89 to 0.96 were all well above the 0.70 standard of reliability.

Post-test is composed by 4 parts (see Table 3, 4 and 6) (Annexe 7). First and second parts are identical as pre-test. Third part consisted of a 4 points Likert-scale questionnaire where participant were asked to express agreement or disagreement (strongly agree, agree, disagree, and strongly disagree). This part was composed of 31 closed questions analyzed in six different sections depending on the topic (Table 2). The questionnaire was an adaptation of another student self-evaluation on the basis of theoretical models described in the relative literature (Garrido, 2005). Last part of post-test consist in analyze and categorize a three open questions trough a qualitative data questionnaire. The qualitative questionnaire was an inspiration of another open-questions evaluation questionnaire (Biasutti, 2011). In this qualitative questionnaire, students have to write down three aspects that they would like to keep, three aspects that they would like to eliminate and finally three aspects that they would like to change of the PBL activity.

Table 2: Satisfaction and usability group questions.

Satisfaction and usability group questions	No. of Items
Previous biology background	2
Fitting of the activity (timing, cards, teacher)	13
Group working environment	4
Motivation	3
Student assessment of the activity	5
Future applications of the activity	4

Closed questions of the evaluation questionnaire

The data from the questionnaires was collected and inserted into an excel document. The statistical quantitative analysis was then done using the SPSS Statistics 20 software. Two different statistical analysis were conducted: a paired-sample t test and a repeated measure ANOVA was conducted using a General Linear Model (GLM).

Open questions of the evaluation questionnaire

An inductive method based on the "constant comparative method" (Strauss & Corbin, 1998) was employed to analyze and to categorize the three open questions. The following five phases of the constant comparative method were applied for analyzing the three open questions: 1) immersion, in which all the discernibly different answers are recognized, 2) categorization, in which "categories" appear from the discernibly different answers, 3) phenomenological reduction, in which "themes" come out from the "categories" 4) triangulation, in which supplementary aspects were used for sustaining researcher interpretations, 5) interpretation, the final step in which a complete explanation of outcomes is carried out in connection to previous research and/or models. The coding of the open questions was later validated by an independent researcher who separately checked the data coding. The author and the independent researcher examined any disagreements relating to their coding and through a process of negotiation reached 100% agreement.

This study had a sample of 94 Spanish students and 33 Swedish students. Each student had the opportunity to respond at most three proposals from each group: aspects to would like to keep, aspects to would like to change and aspects to would like to eliminate. The answers from each group were analyzed separately and independently according to sample Spanish or Swedish.

Finally, taking account the weight of each category according to the number of responses was calculated for each category, the percentage of total responses independently in each group and each country.

Results

We conducted RECAL activity during May 2014 at Universitat Rovira i Virgili (URV), Spain, and March 2015 at Karlstad University (KU), Sweden. The analyzed population consisted in pre-service teacher students, who were taking official degree program in primary education. Table 3 shows the average values (or frequencies) of the different socio-demographic variables in each group of students according to their country. Interestingly, it is important to note that the average age of Spanish students is 21.15 (SD 3.53) and 28.27 (SD 7.99) of Swedish students. Spanish and Swedish curriculum for these university degrees does not include specific university courses in biology. However, biology content is integrated into a discipline named experimental sciences. In Spain this subject also includes physics, chemistry and geology and in Sweden includes physics, chemistry and technology. Additionally, in Spain, students are permitted to take these programs without any scientific background. In fact, only 15% of Spanish respondents declared that they had previously followed some academic scientific courses, in their high-school programs.

Table 3: Sample socio-demographic data.

Variable	Definition	Spain	Sweden
Age	Age in years	21,15±3,53	28,27±7,99
Gender	Female	79%	91%
	Male	21%	9%
Education	Science background	15%	58%
	Non science background	85%	42%
Parents education	Primary school degree	31%	12%
	High school degree	44%	46%
	University degree	25%	42%

In Sweden, students are permitted to take these programs with only a basic scientific background. They have a compulsory subject of science during upper secondary education of approximately 40 hours. This science subject content includes environmental sciences, biology, chemistry and physics. In fact, a 58% of students answered that they have science background taking only this compulsory subject and the rest of students (42%) thought that the knowledge content of this subject was not enough to be scientific literate. As usual in these types of university programs, females are over-represented relative to males; in Spanish case 79% of the sample was composed of females and in

Swedish sample 91% were women. As seen in Table 3, when comparing parent education in both countries we identified some differences. In Sweden, 42% of parents have followed university studies, while in Spain only 25%. The proportion of parents who have high school degree was similar in the two regions, 44% in Spain and 46% in Sweden. Finally, the proportion of parents who have a lower educational level (Primary school degree) is 12% in Sweden and 31% in Spain.

Content knowledge acquisition analysis

As shown in Table 4, we used a pre- and post-test designed to explore content knowledge gains following implementation of RECAL activity. Knowledge questionnaire consists in 10 basic questions, the same questions both at pre and post-test, which their possible answers are True, False or Do not know. This questionnaire was conducted in the same way in Spain and Sweden.

The reliability analyses of the knowledge questionnaire were determined by measuring the internal consistency of each scale, by calculating the Cronbach's alpha. The reliability (α) of the knowledge questionnaire in Spain in pre-test is 0.617 and in post-test is 0.541.In the case of Sweden the reliability (α) in pre-test is 0.542 and in post-test is 0.512.

Table 4: Results of the pre- and post- test in both countries.

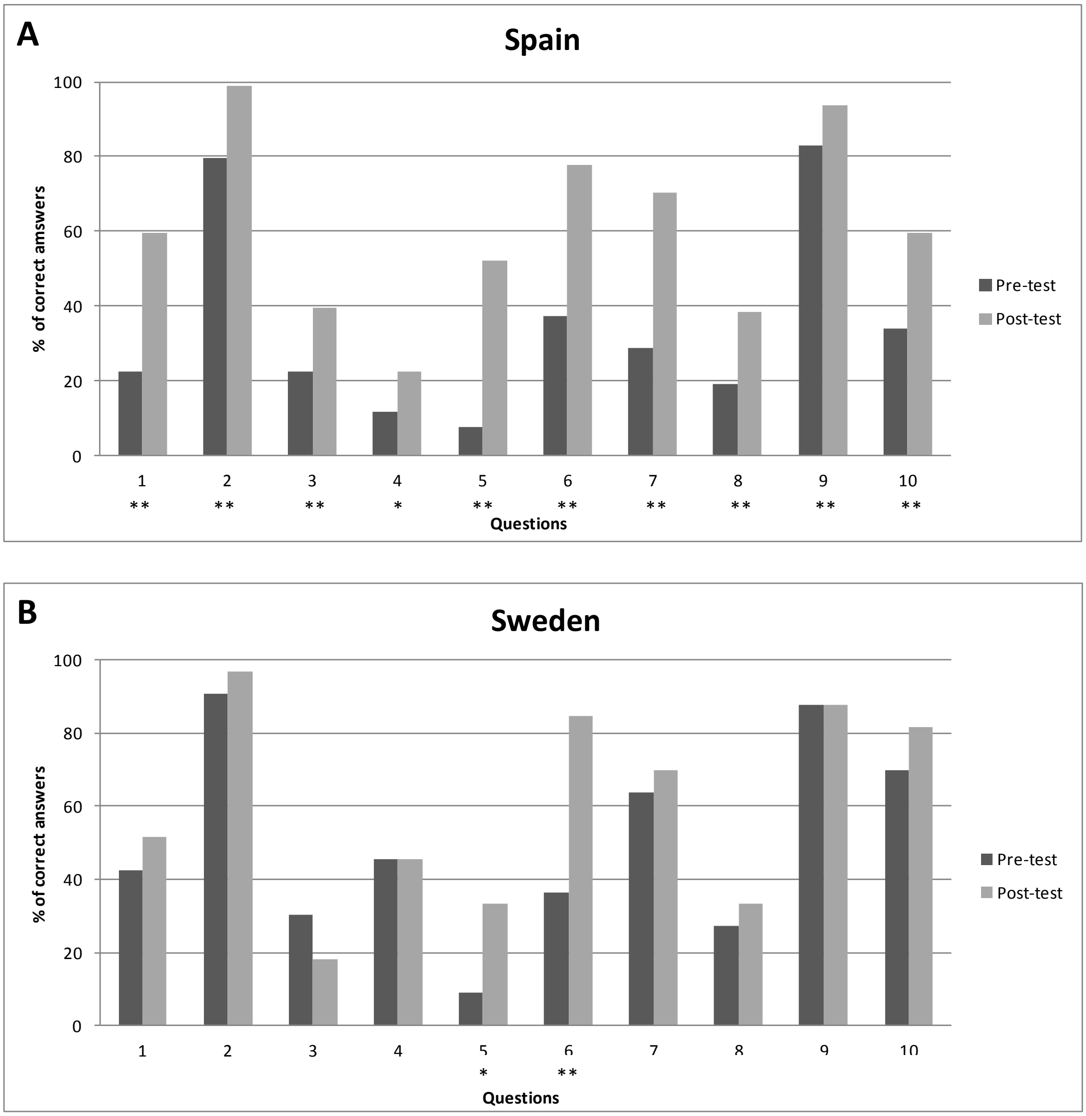
			Spain						Sweden					
			Pre-test			Post-test			Pre-test			Post-test		
		Correct answer	% Correct	% Wrong	% D.K.	% Correct	% Wrong	% D.K.	% Correct	% Wrong	% D.K.	% Correct	% Wrong	% D.K.
1	The phenotype is independent of genetic information.	F	22	11	67	60	17	23	42	15	42	52	21	27
2	All living beings have the same number of chromosomes.	F	79	4	16	99	0	1	91	6	3	97	0	3
3	DNA molecules are the same in all living beings.	T	22	53	24	39	50	11	30	64	6	18	73	9
4	Chromosomes are made up of cells.	F	12	41	47	22	52	26	45	45	9	45	45	9
5	We can distinguish two women by the information that we get from a karyotype.	F	7	22	70	52	34	14	9	24	67	33	52	15
6	We can obtain information about species, gender and some genetic diseases by means of a karyotype.	T	37	3	60	78	10	13	36	9	55	85	9	6
7	Human beings have more DNA because they are more evolved.	F	29	18	53	70	12	18	64	15	21	70	15	15
8	A son looks more like his father when he receives a higher percentage of genetic information from him.	F	19	71	10	38	57	4	27	55	18	33	55	12
9	Men have one chromosome that is the same as in women and another that is different.	T	82	3	14	94	3	3	88	9	3	88	6	6
10	A boy has 23 pairs of chromosomes. His father transmits to him one chromosome of each pair and his mother the other.	T	33	13	53	60	16	24	70	15	15	82	9	9

Table 4 shows that Swedish students show a slightly high knowledge level at the initial phase of the research, just before the educative intervention was carried out. In the case of Spain, only two questions were correctly answered by more than 50% of students (question 2 correctly answered by the 79% and question 9 by the 82%). On the other side, three questions were correctly answered by more than 50% of Swedish students (question 2 correctly answered by the 91%, question 9 by the 88% and question 10 by the 70%). Additionally, the percentage of "Do not Know" answers at the pre-test were higher at the Spanish sample, indicating that Spanish students are conscious of their ignorance about those genetic concepts.

As a relevant result, we found that the percentage of correct answers in both countries clearly increases after performing the educative intervention (RECAL activity). As shown in Table 4, the number of questions correctly answered by more than 50% of students at the post-test was 7 in the case of Spain and 6 in Swedish sample. In the case of Spanish students, most of the "Do not Know" answers at the pre-test become correct answers at the post-test analysis.

A paired-sample t test was performed to statistical analyze pre- to post-test knowledge acquisition, considering the answers to each question (Figure 2) and to the whole survey. By adding up the correct answers of the whole survey, we calculated the final mark, in which one correct answer corresponds to one point. In Spain, the final mark at pre-test (mean 3.46, SD 1.90) increases significantly at post-test (mean 6.12, SD 1.90). In the case of Sweden, the initial mark was higher (mean 5.03, SD 1.93) and it increase significantly at the post-test (mean 6.03, SD 1.81) as well. The comparison of delayed post-test performance with pre-test performance on content knowledge using a paired sample t-test revealed that this increase was statistical significant in both Spain (t (93) = 11.78, $p<.01$) and Sweden (t (31) = 3.35, $p<.01$).

Figure 2: Percentage of correct answers of all questions at the pre- and post-test in Spain (A) and Sweden (B). *Reported statistical significance **p<.01 and *p<.05.*



Although the increase in correct answers in the Spanish sample (Figure 2A) was significant in all questions, three of them (3, 4 and 8) were still wrongly answered at the post-test for more than a half of students. Contrary to the results of Spain, in Swedish sample (Figure 2B) most of the increase in correct responses is not significant, except question 5 and 6. Similarly, there are four questions (3, 4, 5 and 8), most of them coincident with Spain, that knowledge is achieved in less than a half of students. Looking closer to these no correctly answered items by both populations, we found that two of them, item 3 (*DNA molecules are the same in all living beings*) and item 4 (*Chromosomes are made up of cells*) referred to genetic concepts concerning DNA structure and cell management of genetic information which actually have not been deeply worked with RECAL activity. In the case of item 8 (*A son looks more like his father when he receives a higher percentage of genetic information from him*) concerning genetic inheritance, we found that the degree of comprehension of genetic inheritance through RECAL activity was not deep enough to correctly answer this question.

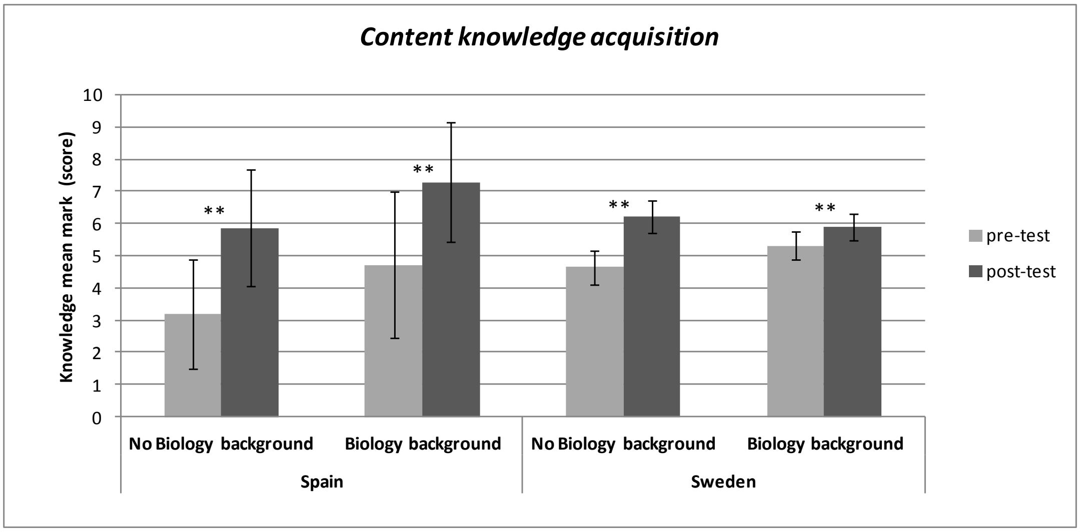
Differences in content knowledge acquisition between respondents according to their biology background

First part of the questionnaire it is composed by 5 socio-demographic questions. The socio-demographic question whether students have previous biology background was used to classify the participants in two groups, naming students who have previous biology background and students who have not previous biology background. To investigate possible differences in knowledge gains between students who have biology background and students who have not, a repeated measure ANOVA was conducted using a General Linear Model (GLM). Pre-test and post-test content knowledge were entered as two repeated measurement occasion and biology background was entered as a between subject variable. Descriptive statistics is analyzed in terms of mean and standard deviation. In order to test the learning effectiveness, the mean of the results obtained from the pre-test and post-test was first calculated.

As a result, we found that Spanish students with biology background have a significantly increase in knowledge, with mean scores of 4.71±2.27 from the pre-test to 7.29±1.86 at the post-test (Figure 3). Spanish pre-service teachers who did not have biology background also increase significantly their knowledge after taking part of the activity, with a mean that increases from 3.18±1.69 at pre-test to 5.87±1.82 at the post-test. The Spanish trend of two groups of students is parallel and students with previous biology background have a higher mean of correct answers both at the pre-test but also at the post-test. These results indicate that the knowledge level on genetics concepts increases in the two groups of Spanish students at the same rate. In Sweden, there was also a significant increase in content knowledge mean scores from the pre-test to the post-test for the two groups of students. Students with biology background evolved from 5.32±0.44 to 5.90±0.42 and students without biology background from 4.64±0.52 to 6.21±0.49. However, Swedish students without biology background have a higher increase in knowledge acquisition after taking part of the activity than the students with biology background.

Summarizing, RECAL activity is a suitable learning material to increase the knowledge in genetics, independently if the student have or have not any biological background.

Figure 3: Differences between respondents with or without biology background. *Reported statistical significance: **p < 0.01.*



Analysis of students' expectations and satisfaction level about RECAL activity

The attitudes of students towards RECAL activity were also analyzed both before and after the activity was carried out. Participants' expectations of RECAL activity were quantified by three selective chosen statements at the pre-test questionnaire, which possible answers consisted in a 4 point-Likert scale (strongly disagree, disagree, agree and strongly agree) (Table 5). The reliability (Cronbach α) of expectations questionnaire was 0.610 in Spain and0.667 in Sweden.

Results indicate that, in both countries, the 79% of students have great expectations about the activity and the 85% perceived the activity to be dynamic and motivating. Regarding the opinion if the activity will help to improve their knowledge, a 88% of Swedish students are agree or strongly agree with that and these levels achieve the 97% in the case of the Spanish sample.

Table 5: Students' pre-test expectation about RECAL activity.

	Spain				Sweden			
	% Strongly disagree	% Disagree	% Agree	% Strongly agree	% Strongly disagree	% Disagree	% Agree	% Strongly agree
I have great expectations about this new activity.	1	20	68	11	3	18	58	21
I think that this activity is going to improve my knowledge.	0	3	54	43	0	12	67	21
I think that this activity is going to be dynamic and motivating.	0	15	73	12	0	15	70	15

Additionally, students' satisfaction level and usability of RECAL activity was analyzed at the post-test questionnaire by both a quantitative and a qualitative assessment. The quantitative questionnaire was an adaptation of another student self-evaluation survey (Garrido, 2005) and it is composed by 31 items which were organized in six groups. These groups are: previous biology background, fitting of the activity (timing, cards, and teacher), group working environment, motivation, student assessment of the activity and future applications of the activity (Table 6). The qualitative assessment was performed by an open-questions questionnaire, adapted from Biasutti (2011). This questionnaire is composed by a table where students have to write down three aspects that they would like to keep, three aspects that they would like to change and finally three aspects that they would like to eliminate to the RECAL activity (Tables 7, 8 and 9).

1. Results from the quantitative questionnaire

In order to measure the consistency of the quantitative questionnaire, a reliability analysis was used to calculate the Cronbach's alpha in both countries, Spain and Sweden. The reliability (α) of the satisfaction and usability questionnaire was 0.874 in the case of Spain and 0.829 in the case of Sweden.

Results (Table 6) show that Swedish pre-service teachers are more used to participate in PBL activities than Spanish students. More than 80% of Spanish students agreed that the main goals of the activity were understandable and that the activity dynamics and police case topic used were appropriated and interesting. This percentage is still high although it decreases around the 70% in the case of Sweden. Around 90% of students in both countries believed that this activity is motivating and dynamic. Pre-service teachers from both countries also agreed that the professor was a good guide during the development of the activity and that the activity was clear and well organized. Most of the students of both countries also believe that the educational material was helpful. In addition, the group working atmosphere was satisfactory, students express their preference to team working and the fact that they have learned from other team members.

Per-service teachers have also assessed the activity from a learning point of view. Most of Spanish and Swedish students declared that problem-based learning activity is a good way to learn and acquire new knowledge and they would like to do this kind of activities more often. More than a 90% of the students from Spain and a 73% from Sweden declared that RECAL activity has accomplished their expectations. Likewise, around nine of every ten of Spanish and Swedish pre-service teachers declared that they are going to recommend this activity to other students.

Table 6: Post-test results. Satisfaction and usability group questions. Previous biology background and fitting of the activity (A) and group work environment, motivation student assessment of the activity and future applications of the activity (B).

A

	Spain				Sweden			
Previous biology background:	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
I had biology background before starting the activity.	41	54	4	1	21	36	39	3
I had already participated in a activity like this (Based in solving a case in a collaborative way).	61	24	13	2	36	27	24	12
Fitting of the activity (timing, cards, teacher..):	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
the activity main goals were understandable and simples.	0	5	76	19	0	21	73	6
Activity dynamics was appropriated and interesting.	1	10	53	36	0	3	73	24
Police case topic used was appropriated.	0	5	50	45	0	0	76	24
Wordings were clear and I could understand all it was demanded.	0	7	64	29	3	36	42	18
I have understood all questions which were found at the end of each activity.	1	6	60	33	3	27	39	30
The activity organization was clear and ordered.	0	13	42	45	3	27	48	21
The teacher / professor was a good guide during the development of the activity.	0	6	44	50	0	15	45	39
I had enough time to finish the activity.	2	9	32	57	3	3	58	36
The resources that we had during the activity were enough to solve the police case.	1	18	53	28	0	3	58	39
I think that all educational materials were useful.	0	15	58	27	3	21	48	27
I have used the educational material at the right moment.	0	8	61	31	0	30	42	27
I could obtain all the information that I didn't know by means of Extra information cards	0	5	53	42	0	15	61	24
Extra information cards gave me motivation to continue solving the police case.	1	15	62	22	3	15	58	24

B

	Spain				Sweden			
Group working environment:	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
Group working atmosphere was satisfactory.	0	1	24	75	0	6	45	48
I would have preferred to do the activity by my own.	80	13	4	3	42	36	15	6
I had some problems with other team members to solve the activity.	81	16	1	2	67	21	6	6
I have learned from other members of the team when I had doubts.	3	9	52	36	3	18	55	24
Motivation:	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
I have more interest about genetics and biotechnology by means of this activity.	9	54	35	2	15	39	45	0
This police case has motivated me to increase my knowledge about scientific topics.	15	47	37	1	18	55	27	0
I think that this activity is motivating and dynamic.	0	9	60	31	3	9	73	15
Student assessment of the activity:	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
I think that this Problem-based activity learning is a good way to learn.	0	5	61	34	0	3	70	27
The research that we did to solve the police case it was useful to gaining knowledge.	0	18	58	24	0	6	76	18
This activity make me learn new knowledge.	1	14	63	22	0	12	73	15
It was difficult to solve all activities of this case.	17	66	16	1	9	36	48	6
I would like to do this kind of activities most often.	1	6	48	45	3	12	61	24
Future applications of the activity:	%Strongly disagree	% Disagree	% Agree	% Strongly	%Strongly disagree	% Disagree	% Agree	% Strongly
I have accomplished my expectations of this new activity.	0	9	81	10	3	24	70	3
I think that I have improved my knowledge.	0	38	54	8	0	24	70	6
I am going to recommend this activity to other students.	0	6	62	32	0	12	58	30
I think that I could apply all acquired knowledge at the future.	1	41	52	6	0	33	55	12

2. Results from the qualitative questionnaire

Last part of post-test questionnaire consisted on three open questions in which students had the opportunity to respond at most three proposals from each group: aspects to would like to keep (Table 7), aspects to would like to change (Table 8) and aspects to would like to eliminate (Table 9).

The categories of the aspects to be kept, the aspects to be changed and the aspects to be eliminated were subjected to a quantitative evaluation. The quantitative evaluation was made by counting the number of times that participants responded in each category. The weight of each category of total responses calculated the percentage.

The aspects of the RECAL activity that students consider that should be kept are shown in Table 7. In both countries, the same top categories have been found. The highest percentage of responses are devoted to the category "team work" (25% in Sweden and 26% in Spain) followed by “police case” (17.31% in Sweden and 14.89% in Spanish) and by “the use of extra information cards” (11.54% in Sweden and 13.30% in Spain). As differences, we found that Swedish students feel motivating of taking part of this PBL activity (11.54%). An 11.17% of Spanish students agree that "RECAL case" activity has game structure as a key point.

The aspects of the activity that students consider that should be change are shown in Table 8. In the case of Swedish students (18.92%) declare that the instructions should be clearer at the beginning of the activity. In Spain a 16.25% of students agree that they need more extra information cards and also more information in each card in order to solve the activity. As differences, in Spain a 12% declare divergent opinions about the timing of the activity, since some students expressed that they needed more time to solve each worksheet and some others said that they should have to wait too much for the other groups. Regarding "Teacher" and "Information" categories answers from Spaniards, students declare that they would like to introduce genetic contents before taking part of the activity or by a previous teacher explanation or by more resources of information. In addition, Swedish students (10.81%) propose to simplify the activity or to make it shorter.

The aspects of the RECAL activity which students consider that should be eliminated are shown in Table 9. Swedish students (21.05%) expressed that the material is not properly organized. Their answers expressed that working with so much sheets of paper is a little bit confusing, so they propose to eliminate some of them. Around a quarter of Swedish students agree that content is too much difficult, so they answered that there is too much information to understand in just two hours. In Spain, 17.40% of students would like to eliminate some questionnaires of the evaluation and also to reduce the number of activities (15.22%). Spanish students express that they would like to eliminate some worksheets of the activity. Therefore, the feedback gave for the students from both countries reflected that they would like to eliminate some sheets of paper but for different reasons. Spanish students would like to reduce the activity workload and Swedish proposed to organize the materials a little bit more.

After analyzing the opinions of students about the activity it could be summarized that a great majority of the students from Spain and Sweden agreed that the topic based on a police case is interesting and keep the student engaged to the activity. They also prefer working in groups rather than working individually. Students think that extra information cards are useful to solve the police case. In addition, students feel that there is too much information to learn in a 2h session. It could be interesting to split the activity in two sessions or probably give more time to some groups which need more time to read the information. Moreover, students propose to eliminate some sheets because they feel lost when they have too much papers on the Table. Maybe it could be possible to give some information on Moodle or another digital support.

Table 7: Three aspects that students would like to keep of the RECAL activity.

	Themes	Categories	Answers categories	Percentage (%)
Sweden	Methodology	Organization	4	7.69
		Timing	3	5.77
		Set-up	1	1.92
		No guided activity	1	1.92
		Police case	9	17.31
		Innovation	1	1.92
		Motivation	6	11.54
		Team work	13	25.00
		Competition	2	3.85
	Material	Clues	3	5.77
		Extra info cards	6	11.54
	Contents	Educational	2	3.85
		Knowledge	1	1.92
Spain	**Themes**	**Categories**	**Answers categories**	**Percentage (%)**
	Methodology	Game	21	11.17
		Practical	2	1.06
		Police case	28	14.89
		Organization	7	3.72
		Timing	5	2.66
		Guided	4	2.13
		Evaluation	9	4.79
		Competitively	7	3.72
		Class	7	3.72
		Team work	49	26.06
		Team environment	1	0.53
	Material	Worksheets	12	6.38
		Extra info cards	25	13.30
		Clues	4	2.13
		Resources	7	3.72

Table 8: Three aspects that students would like to change of the RECAL activity.

	Themes	Categories	Answers categories	Percentage (%)
Sweden	Methodology	Instructions	7	18.92
		Order	1	2.70
		Timing	3	8.11
		Chronogram	2	5.41
		Work environment	2	5.41
		Team work	2	5.41
		Competition	1	2.70
		Evaluation	1	2.70
	Material	Worksheets	3	8.11
		Info cards	3	8.11
		Translations	2	5.41
		Organization	1	2.70
		Difficulty	2	5.41
		Simplicity	4	10.81
	Contents	Previous knowledge	3	8.11
	Themes	Categories	Answers categories	Percentage (%)
Spain	Methodology	Police case	4	3.20
		Game	2	1.60
		Flipped class	1	0.80
		Organization	3	2.40
		Timing	15	12.00
		Evaluation	6	4.80
		Team work	4	3.20
		Motivation	5	4.00
	Material	Activities	7	5.60
		Difficulty	4	3.20
		Worksheets	6	4.80
		Extra info cards	13	16.25
		Clues	3	2.40
		Resources	4	3.20
		Design	3	2.40
		Prize	3	2.40
	Contents	Teacher	11	8.80
		Goals	2	1.60
		Previous knowledge	8	6.40
		Information	15	12.00
		Summary	6	4.80

Table 9: Three aspects that students would like to eliminate of the RECAL activity.

	Themes	Categories	Answers categories	Percentage (%)
Sweden	Methodology	Police case	1	5.26
		Autonomous	1	5.26
		Competition	1	5.26
		Evaluation	1	5.26
	Material	Organization	4	21.05
		Clues	1	5.26
	Contents	Instructions	2	10.53
		Teacher	1	5.26
		Difficulty	5	26.32
		Knowledge	2	10.53
Spain	Themes	Categories	Answers categories	Percentage (%)
	Methodology	Evaluation	8	17.40
		Competitively	2	4.35
		Timing	6	13.04
	Material	Number of activities	7	15.22
		Difficulty	2	4.35
		Extra info cards	5	10.87
		Clarity	1	2.17
		Design	7	15.22
		Resources	6	13.04
	Contents	Previous knowledge	1	2.17
		Difficulty	1	2.17

Discussion

Currently, research in science education is increasing worldwide. All members of the education community work together in order to improve citizens' scientific and technological literacy. Many researchers have observed a steady decline of satisfaction and usability toward science in middle and high school, resulting in a decreasing number of students who pursue science at the college level (Gibson & Chase, 2002; Tai *et al*., 2006; Martin *et al*., 2007).

After creating a new educational PBL activity called "RECAL case", the main focus of this study is to analyze the usefulness of RECAL activity. We evaluate the learning achievement of some aspects of genetics by means of a "RECAL case" activity with a sample of Spanish and Swedish pre-service teachers. Turney (1996) show that most people see scientific knowledge as simply irrelevant to their needs and interests. Genetics is an interesting but very hard discipline for students to conceptualize DNA structures, heritability, recombination and some more processes of this field. A good foundation in genetics also requires knowledge and understanding of topics such as structure and function of cells, cell division and reproduction. Studies at the international level report poor understanding by students of genetics and genetic technologies, with widespread misconceptions at various levels (Baars *et al*., 2005). Students often describes the traditional practical exercises as "pointless, repetitive chores", unconnected to real-world applications and without relevance to the overall apprenticeship programme aims (Monks, 2010).

The main goal of this study was to explore whether the use of RECAL activity, contributes to students' knowledge and attitudes towards genetics. We began analyzing prior knowledge of genetics using a 10 basic genetics questions. The results show that there is a slight difference between Swedish and Spanish students in pre-test questionnaire scores. This inequality in knowledge could be explained because the Swedish upper secondary degree curriculum contains a subject that encompasses all sciences. This subject contains knowledge of environmental sciences, biology, chemistry and physics. However, it is very important to note that after taking part of RECAL activity, results of knowledge questionnaire improve in both countries. There are significantly differences in pre and post-test in each country which is decisive to determine the effectiveness of the RECAL activity. Some studies performed in other countries like Israel (Rotbain *et al*., 2006) show that by applying a revolutionary activity, as the beat; that is similar to models typically used in chemistry such as ball-and-stick models, and illustrations models; that including hands-on tasks such as drawing, painting and figure completion, help to improve students' knowledge of genetics**.**

The results obtained in the pre and post test in Spain and Sweden coincide with other studies conducted in other countries. This is the case of a study done in Slovenia (Starbek *et al*., 2010) using a multimedia activity to teach genetics in which students, once made the activity significantly improve their results. Other studies and new methodologies framed within the concept STSE, are beneficial to increase knowledge in various scientific areas, such as the study of Barab *et al*. (2010). In this case, they use a virtual environment gaming to understand different environmental situations. Similar results are also found in the study of Marbach *et al*. (2008), performed with students from Israel learning with different genetic methodology, as computer animation and illustration activities that obtained better results than the control group in which use traditional instruction.

This study was also focused on the analysis of the differences between students who have or have not prior knowledge on biology, we could say that in Spain the evolution of both groups between pre-test and post-test increases with the same trend. The results are positive and indicate that the scores of biology tests achievement increased after students used the RECAL activity and all students have the same increase of knowledge. These results coincide with Klosterman and Sadler (2010) in measured prior knowledge of science into two groups of students from different formations; environmental science and chemistry. The results show that the pre-test of chemistry students from over scientific environmental science students, but once done both activities increase knowledge in parallel. In other ways, in the case of our Swedish students, the trend is different. We could say that their grade of increase of knowledge is in the same way independently of their pre-test mark in both countries.

Regarding the pre-test questions of expectations, it was demonstrates that in both countries students think that they are going to increase the knowledge by means of the activity and they expect to take part on a dynamic and motivating activity. Results from post-test questions of satisfaction and usability shows that vast majority of Swedish and Spanish pre-service teachers agree that they did not have participate on this kind of activity before. Spanish and Swedish pre-service teachers agree that activity main goals were understandable and simples. They also feel that the teacher was a good guide during the development of the activity and wordings were clear and student could understand all it was demanded. The results of team work environment show that students from both countries feel comfortable solving the activity in groups however, Spanish students are the most enthusiastic on working in groups. Other studies also declare that a large majority of students expressed positive feelings about teamwork (Vasan *et al*., 2009). For the questions of the students' assessments of the activity, we have found that an almost all Spanish students and Swedish students agree that Problem-based learning is a good way to learn. Other authors founded that around 84% of students prefer PBL approach over traditional lectures (Abate *et al*., 2000). A 93% of Spanish and an 85% of Swedish students said that most often would like to do this kind of activities. As well as, in previous studies, Israelis students claimed that they would like to have more such activities in other biology topics as well (Rotbain *et al*., 2006). Finally they think that they have increased their knowledge and they would like to recommend the activity to other students.

According to students' opinion answers, it could be concluded that in both countries students agree that best aspect of the activity is working in groups. As well as in Belgium, the most frequently mentioned design variable for students was the tutorial group (Dochy *et al*., 2005). Moreover, a study made in US (New Jersey) declares that a large majority of students expressed positive feelings about teamwork (Vasan *et al*. 2009). Tseng *et al.* (2008) say that collaborative work has to be incorporated because the individual learner is not the only source of knowledge and information. In a second place students said that the topic based in a police case is interesting and keep student engaged to solve the activity. And finally, they feel comfortable solving the police case by means of the extra information cards. On the other hand, students of Spain they feel that there are so much activities to do and so much information to learn in a two hours session. It could be interesting to split the activity in two sessions or probably give more time to some groups which need more time to read the information and to solve the case.

Once the activity RECAL PBL has been carried out by students in which relevant genetic issues are integrated, have the potential of inducing 'HOCS learning' in science, technology, environmental, society (STES)-oriented genetics teaching. The potential contribution of PBL activity to the development of students' HOCS is clearly a related issue. HOCS typically reflects taking new information and combining it with a priori information, or rearranging such information to find possible answers to perplexing situations (Zoller & Pushkin, 2007, Zoller, 2012). After regarding the results of this study which are favorable to make pre-service teachers literate in genetics. Our research group is now devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret other biotechnological issues.

References

Abate, M. A., Meyer-Stout, P. J., Stamatakis, M. K., Gannett, P. M., Dunsworth, T. S., & Nardi, A. H. (2000). Developmentandevaluation of computerized problem-basedlearning cases emphasizing basic sciencesconcepts. *American Journal of PharmaceuticalEducation*, 64(1), 74-82.

Baars, M.J., Henneman, L. & Ten Kate, L.P. (2005) Deficiency of knowledge of geneticsandgenetic tests among general practitioners, gynecologists, and pediatricians: a global problem. *Genet. Med*. 7, 605–610.

Barab, S.A., & Dede, C. (2007) Games and immersive participatory simulations for science education: an emerging type of curricula. *J SciEducTechnol* 16(1):1–3

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D., & Zuiker, S. (2010). Erratum to: Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, 19(4), 387-407.

Bennett, J., Lubben, F. & Hogarth, S. 2006. Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education* 91, 347–370.

Biasutti, M. (2011). The student experience of a collaborative e-learning university module. *Computers & Education*, 57(3), 1865-1875.

Bonal, X. (2002). El balance público-privado en el sistema de enseñanza español. *In Educar* (pp. 011-29).

Carrió, M., Larramona, P., Banos, J. E., & Pérez, J. (2011). The effectiveness of the hybrid problem-based learning approach in the teaching of biology: a comparison with lecture-based learning. *Journal of Biological Education*, 45(4), 229-235.

Dochy, F., Segers, M., Van Den Bossche, P., & Struyven, K. (2005). Students' perceptions of a problem-based learning environment. *Learning environments research*, 8(1), 41-66.

Duncan, D., A. Lubman, S., & Hoskins. (2011). Introductoy biology textbooks under-represents scientific process. *J. Microbiol. Biol. Educ*. 12:143-151. http://jmbe.asm.org/index.php/jmbe/article/view/307.

European Commission (2010). *Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels (Belgium): Directorate General Research, EU.

Fensham, P. J. (2002).Time to change drivers for scientific literacy. Canadian *Journal of Math, Science & Technology Education*, 2(1), 9-24.

Ferrera, J. M. C., López, C. M., & Rodríguez, R. S. (2012). Análisis de los condicionantes del rendimiento educativo de los alumnos españoles en PISA 2009 mediante técnicas multinivel. *Presupuesto y Gasto Público*, 67, 71-96.

García-Zarza, P. (2014). Convergencias y divergencias entre el sistema educativo sueco y el español. Divergences and convergences between Swedish and Spanish educational system. *Revista Española de Educación Comparada*, (23), 203-222.

Garrido, M. F. (2005). Formación basada en las Tecnologías de la Información y Comunicación: análisis didáctico del proceso de enseñanza-aprendizaje (Doctoral dissertation, Universitat Rovira i Virgili).

Gaskell, G., Bauer, M. W., & Durant, J. (1998). Public perceptions of biotechnology in 1996: Eurobarometer 46.1. *Biotechnology in the public sphere: A European sourcebook*, 189-214.

Gaskell, G., Einsiedel, E., Hallman, W., Priest, S. H., Jackson, J., & Olsthoorn, J. (2005). Social values and the governance of science. *Science*, 310(5756), 1908-1909.

Gibson, H.L. & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' satisfaction and usability toward science. *SciEduc* 86, 693–705.

Grinell, S. (1993).Reaching the nonschool public about genetics. *American Journal of Human Genetics* 1: 233–234.

Herger, M. (2014). *Enterprise Gamification - Engaging people by letting them have fun.* EGC Media. p. 32.

Hott, A. M., Huether, C. A., McInerney, J. D., Christianson, C., Fowler, R., Bender, H., & Karp, R. (2002). Genetics content in introductory biology courses for non-science majors: Theory and practice. *BioScience*, 52(11), 1024-1035.

Jennings, B. (2004). Genetic literacy and citizenship: Possibilities for deliberative democratic policymaking in science and medicine. *Good Society Journal* 1: 38-44.

Kılıç, D., & Sağlam, N. (2014). Students' understanding of genetics concepts: the effect of reasoning ability and learning approaches. *Journal of Biological Education*, 48(2), 63-70.

Klegeris, A., & Hurren, H. (2011). Impact of problem-based learning in a large classroom setting: student perception and problem-solving skills. *Advances in physiology education*, 35(4), 408-415.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues-based instruction. *International Journal of Science Education*, *32*(8), 1017-1043.

Lanie A.D., Javaratne T.E., Sheldon J.P., Kardia S.L.R., Anderson E.S., Feldbaum M., & Petty E.M. (2004). Exploring the public understanding of basic genetic concepts. *Journal of Genetic Counseling* 4: 305-320.

Maier, M., Greenfield, D., & Bulotsky-Shearer, R. (2013). Development and validation of a preschool teachers' attitudes and beliefs toward science teaching questionnaire. *Early Childhood Research Quarterly*, 28(2), 366–378. doi:10.1016/j.ecresq.2012.09.00

Marbach-Ad, G., Rotbain, Y., & Stavy, R. (2008).Using computer animation and illustration activities to improve high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, *45*(3), 273-292.

Martin MO, Mullis IVS, Foy P, in collaboration with Olson JF, Erberber E, Preuschoff C, & Galia J (2007). TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades TIMSS &PIRLS International Study Center, Boston: Lynch School of Education.

Monks, A. (2010) Adapted PBL practical exercises: benefits for apprentices, *Journal of Vocational Education & Training*, 62:4, 455-466, DOI: 10.1080/13636820.2010.533789

OECD (2012): *Education at a Glance 2012: OECD Indicators*, OECD Publishing. From: (http://dx.doi.org/10.1787/eag-2012-en).

Pardo, R., Midden, C., & Miller, J. D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, 98(1), 9-24.

Penick, J. E. (2003). Integrated Science: Why Teaching "Science" Is Better than a Discipline-Centered Approach. *Science Education International*, 14(1), 14-16.

Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2006). Effect of bead and illustrations models on high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, *43*(5), 500-529.

Savage, M., Warde, A., Ward, K., & Savage, M. (1993). *Urban sociology, capitalism and modernity* (pp. 184-185). Basingstoke: Macmillan.

Starbek, P., StarčičErjavec, M., & Peklaj, C. (2010).Teaching genetics with multimedia results in better acquisition of knowledge and improvement in comprehension. *Journal of computer assisted learning*, *26*(3), 214-224.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Grounded theory procedures and techniques* (2nd ed.). Thousand Oaks, CA: Sage.

Tai R., Lui C.Q., Maltese, A.V. & Fan, X. (2006). Career choice: planning early for careers in science. *Science* 312, 1143–1144.

Tseng, K.H., Chiang, F.K., & Hsu, W.H. (2008).Interactive processes and learning attitudes in a web-based problem-based learning (PBL) platform. *Computers in Human Behavior*, 24(3), 940-955.

Turney, J. (1996). *Public understanding of science*. The Lancet, 347(9008), 1087-1090.

Vasan, N.S., DeFouw, D.O., & Compton, S. (2009). A survey of student perceptions of team-based learning in anatomy curriculum: Favorable views unrelated to grades. *Anatomical sciences education*, 2(4), 150.

Zoller, U., & Pushkin, D. (2007). Matching Higher-Order Cognitive Skills (HOCS) promotion goals with problem-based laboratory practice in a freshman organic chemistry course. *Chemistry Education Research and Practice*, 8(2), 153-171.

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *J. Chem. Educ.*, 2012, 89 (3), pp 297–300. doi: 10.1021/ed300047v.

General discussion, conclusions and perpectives

General framework

In western societies today, science and technology are cornerstone institutions that affect and sometimes determine important aspects of the daily life of all citizens. Over the last few decades, there has been a revolution in the field of biological research. Genomics and its related technologies (or modern biotechnology) has the potential to become one of the most important scientific and technological revolutions of the 21st century (Kirkpatrick *et al.,* 2002). The rise up of a rapid development of biotechnology and genetic engineering has led a huge gap between what the scientific community understands to be the risks and benefits and what is understood by the society (Gaskell *et al*., 2006). Biotechnology is a relevant topic from the economical and scientific points of view but, at the same time, it has social, ethical and cultural implications which directly concern the whole society. Important issues still remain controversial, for example the applications of Genetic Modification (GM) technology. Surprisingly, the acceptability of these products is based on a perception of health risk rather than on a deep knowledge of the implications and consequences that these products can have (Christoph *et al.*, 2008). From this perspective, society needs well-informed citizens who have to be able to make thoughtful decisions based on scientific conclusions in combination with ethical and moral consideration of the biotechnological issues.

Due to the important impact that biotechnology has on our society, well informed critical citizens are needed. People prepared to make conscious decisions about aspects of biotechnology that relate to their own lives. At this point, teachers play a central role, since they are the main actors in any education system. Thus, the biotechnological literacy of pre-service teachers is an important consideration as they will become an influential collective as future teachers of the next generation of citizens. Previous studies showed that the key factor to success or failure of putting any curricular innovation into practice is the teacher (Mitchener & Anderson, 1989; Tobin *et al*., 1994). It is now generally accepted that to improve learning in our schools we need more and better teacher professional learning (Goodrum, 2006). Some studies have revealed that attitudes towards science (including biotechnology) that teachers have, affect their behavior and influence the way they implement their daily practice of science teaching at school. In particular, pre-existing attitudes and beliefs influence the way that teachers understand what they learn during their training and how they implement it in their daily practices at school (Fetters *et al*., 2002; Lee & Ginsburg, 2007; Roehrig *et al*., 2007). In addition, together with attitudes, knowledge level in scientific topics directly influences the self-confidence and self-efficacy of teachers in their approach to science activities in the classroom (Maier *et al*., 2013). In this sense, the improvement of the knowledge level of pre-service teachers on biotechnology would develop attitudes that promote a deeper reflection on the hazards, benefits and complexity of biotechnology (Klop & Severiens, 2007; Chabalengula *et al.,* 2011). Well informed teachers will be able to handle ethical, social and cultural debates with their students on the implications of biotechnology. Acording to this, Chabalengula *et al.* (2011) argued that if pre-service teachers are well informed, they would possess attitudes that would reflect unbiased and correct information about biotechnology. Elementary teachers may not have to teach complex biotechnology topics in their classroom. However, the more knowledge in biotechnology fundamentals the more self-confidence teachers will have in this subject and, therefore, it can be assumed to increase the chances that more biotechnology topics will sweep into their teaching.

Within this frame, the present Thesis aims to contribute to the biotechnological literacy of future educators. To achieve this purpose, we have performed a deep diagnosis about the knowledge level of preservice teachers on basic concepts of genetics that are the basis of modern biotechnology and its applications. We have also address the assessment of the attitudes towards biotechnology of those future teachers, including both the affective and the behavioral components, and its correlation with knowledge level. Finally, new teaching activities have been developed by applying problem-based learning methodology and STSE approach. Therefore, we aim to promote the use of those practices at both universities and schools, to get closer in some way, step by step, of biotechnological literacy of our society.

Knowledge and attitudes towards biotechnology of pre-service teachers across Europe

In 2010, the European Commission launched the Europe 2020 Strategy that is designed to help the nations of the European Union (EU) to come out stronger economically from the current crisis and to prepare their economies for the next decade's challenges (European Commission, 2010). Biotechnology has been seen as a major driving force in the creation of better health and welfare for European citizens. Toward this goal, the EU has undertaken many initiatives in recent years to stimulate and coordinate biotechnology developments (European Commission, 2012).

In the Eurobarometer surveys, European respondents faced to a group of knowledge questions designed to tap the extent of their knowledge about biology and genetics. The results of knowledge items indicated a general lack of knowledge regarding biotechnology and genetics (Gaskell *et al*., 2006). In Europe, only about one in five adults (20% of population) was qualified as well-informed about biotechnology. Northern and Southern European countries have differences such as cultural, social and economical among others. Sweden is ranked third among the 15 European countries with quite a large population of well-informed public regarding biotechnology only surpassed by Netherlands and Denmark (Gaskell *et al.,* 1998). Spain, on the other hand, is placed as 4th last together with Greece, Ireland and Portugal (Pardo *et al.,* 2002). In terms of attitudes towards biotechnology, Spanish and Swedish citizens are the two most optimistic populations in all EU. However in terms of attitudes towards GM food production and consumption, Spain is ranked among the most optimist countries and Swedish among the more negative ones (Gaskell *et al*., 2010). From this perspective, Sweden and Spain are two interesting countries to be deeper analysed and compared.

As mentioned above, teachers and specifically preservice teachers must be the driving force to overcome the challenge of training next generation of

European citizens in biotechnology topics from a critic and informed point of view. This thesis aimed to analyze the knowledge level and attitudes towards biotechnology of Spanish and Swedish pre-service teachers. To achieve this goal, we have expressly created a new survey that collect socio-demographic information, respondents' knowledge of genetics and some general aspects of biotechnology and respondents' attitudes towards biotechnology.

According to our results, Spanish and Swedish pre-service teachers are aware of the applications of biotechnology but do not have a basic and fundamental knowledge on the biological implications of modern biotechnology on living beings. We identified an important lack of knowledge related to the basic concepts of genetics, in both populations. Concretely, topics concerning DNA structure and cell management of genetic information are not well understood. Questions related to Genetic Modified Organisms (GMO) show the highest proportion of "Do Not Know" answers, indicating that Swedish and Spanish pre-service teachers are conscious of their ignorance about GMO characteristics. This finding is not unique of Spain and Sweden and it is shared in other countries such as Turkey, Slovakia, Slovenia, Lithuania and Lebanon (Darçin & Güven, 2008; Erdogan *et al.,* 2012; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop *et al*., 2007; Sorgo & Ambrozic-Dolinsek, 2009; Usak *et al.,* 2009). In the same way, other studies show that a significant proportion of students leave high school knowing very little about biotechnology, cloning and GM foods (Dawson, 2007).

Interestingly, the majority of pre-service teachers correctly answered questions related to the applications and uses of biotechnology. Comparing to similar studies in other countries when asking about uses of biotechnology, Spanish and Swedish preservice teachers have a higher percentage of correct answers on the same questions than Slovakian (Prokop *et al*., 2007), Turkish (Usak *et al.,* 2009) and Lithuanian (Lamanauskas & Makarskaite-Petkeviciene, 2008) preservice teachers.

Another goal of this thesis was to design and apply a new survey to analyze the attitudes towards biotechnology of Spanish and Swedish pre-service teachers four attitude factors were identified by our new survey in both countries. The exploratory factor analysis of the data from each respective country come up with very similar factor aggrupation of the items. Even though there were little differences of the items assignation in the factors in both countries, the four factors could be commonly described as follows: (i) feelings and consuming intentions towards GMO products, (ii) opinions about Biotechnology applications to medical purposes, (iii) opinions about how scientific and technological advances could affect society and vice versa and (iv) interest in increasing respondents' knowledge about scientific advances and biotechnological applications.

Our results show that both Spanish and Swedish pre-service teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances. It is interesting to point out that our respondents in both countries (more than 80% of them) expressed their desire to have more information and to increase their knowledge in topics concerning GM technology, including GM food. Scientific and biotechnological advances are also interesting topics for our respondents. Only in the case of items related to GMO applications in a global and social context we detected little but significant differences in attitude in both populations. Spanish respondents are little more positive in their attitudes (mean 2.71, SD 0.41) meanwhile Swedish show to be more neutral (mean 2.58, SD 0.33) at this point. In general, European preservice teachers analyzed in this thesis show a neutral or negative attitudes when they are facing issues related to biotechnological applications on food production, use of GMO for commercial purposes and social implications of biotechnology and its applications. Nevertheless they show more positive attitudes when the purpose either of biotechnological applications or GMO uses are applied or directed to improve medical research or healthcare applications. These results point out that our respondents build their attitudes judging the purpose of biotechnology and its applications more than judging "biotechnology" as such.

As mentioned above respondents from both countries do agree to use GMO for medical purposes. We could conclude that the attitudes towards biotechnology applications in healthcare have a positive trend in both countries, so Swedish and Spanish pre-service teachers are optimistic to use biotechnology in new healthcare applications and there no exist statistical significant differences between these countries. In other countries such as

Turkish pre-service teachers only a 46.2% agree to the use of biotechnology in human health applications (Darçin, 2011).

The first two chapters of this thesis were also focused on the analysis of possible correlations between knowledge level and attitudes towards biotechnology, which still remains a controversial issue. Our results from Spain and Sweden have shown a positive correlation between better knowledge and more positive attitudes towards biotechnology. In Spain, this correlation is also valid for the GMO factor, since respondents with better knowledge of biotechnology show higher acceptance of GMO issues. In Sweden, this correlation is valid for biotechnology applications to medical purposes factor and Interest factor. This conclusion about the positive correlation between knowledge and attitudes towards biotechnology has been previously reported by other authors (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Klop & Severiens, 2007; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop *et al*., 2007; Usak *et al*., 2009).

This thesis arises the possibility to continue investigating with the same instrument but assessing pre-service teachers from other countries. It could be interesting to compare students' knowledge and attitudes towards biotechnology of more different countries since this could give us a perception of biotechnology literacy around the world. At the same time, this first part of the thesis permit us to realize that it is necessary to foster biotechnology literacy of pre-service teachers, since they have important misconceptions and wrong ideas that should be solved. It is known that knowledge level in scientific topics directly influences the self-confidence and self-efficacy of teachers in their approach to science activities in the classroom (Maier *et al.,* 2013). In that sense, it is positive to confirm that Swedish and Spanish pre-service teachers strongly agree that they want to increase their knowledge in biotechnology related topics. One effective way to induce a better knowledge and as a consequence more informed decisions of citizens towards new biological sciences and technologies is by promoting biotechnological literacy among teachers. For this reason, is important devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret in a balanced way biotechnological issues.

New educational approach: Creation of new educational material about genetics

One of the most noticeable trends of the last two decades in science curriculum development has been the use of contexts and applications of science as a means of developing scientific understanding. Teaching in this way is described as adopting a context-based or STSE (Science–Technology–Society-Environment) approach. In this kind of approach, contexts and applications of science are used as the starting point for the development of scientific ideas (Bennet *et al*., 2006). Educational tools following STSE approach could include different teaching methodologies oriented to increase student motivation and to help them to structure their knowledge, to develop reasoning processes and to implement self-directed learning skills.

This thesis covers the creation and assessment of a new educational material devoted to the learning of basic concepts of genetics, previously identified by our knowledge questionnaire. Specifically, the learning outcomes of our activity are focused on the concepts of phenotype and genotype, packaging of genetic material inside the cell and genetic inheritance. The abstract nature of genetics may lead to a loss of motivation if learners are not situated in contexts with connections to their everyday life or with problems that have personal or societal relevance (Knipples *et al.,* 2005). The activity was designed according to experimental learning paradigms which suggest that students learn best when they are given the opportunity to acquire and apply knowledge and skills in realistic and relevant settings (Goodwin *et al*., 2012). Thus, our new activity, called RECAL, was designed by combining the STSE approach and PBL educational methodology. The principles of PBL methodology are research, group discussion and the acquisition of new knowledge that will lead to answer the questions that will solve the suggested problem (Carrió *et al.,* 2011). In one side, RECAL activity immerses students in a scientific-based scenario in which they play a role of a scientific assessor. And in other side, players have to develop and use scientific reasoning and evidence-based decision making to solve the given enigmas along the workflow of the game.

One goal of this thesis was to explore whether the use of RECAL activity contributes to students' knowledge towards genetics. To assess the effectiveness of RECAL activity to teach and learn the specific learning outcomes proposed, a comparative study in two countries (Spain and Sweden) was carried out. First of all, we analysed prior knowledge of genetics using ten questions related on basics genetics. The results showed that there is a slight difference between Swedish and Spanish students on the result of pre-test knowledge questionnaire. Swedish students show a slightly high knowledge level at the initial phase of the research, just before the educative intervention was carried out. The difference may be related to the fact that Swedish students have a compulsory science course during upper high school. This course contains knowledge of environmental science, biology, chemistry and physics. However, it is very important to note that after doing the RECAL activity, the results of knowledge questionnaire improve in both countries. The differences between pre and post-test in both countries are statistically significant, so we could determine the effectiveness of the RECAL activity in knowledge improvement. Our results obtained in the pre and post-test from Spanish and Swedish sample coincide with studies conducted in other countries. This is the case of a study done in Slovenia (Starbek *et al*., 2010) using a multimedia activity to teach genetics in which students, once they take part of the activity, their results improve significantly. Other studies and new methodologies framed within the concept STSE, as well as this RECAL activity, are beneficial to increase knowledge in various scientific areas, such as the study of Barab *et al*. (2010). Similar results are also found in the study of Marbach *et al*. (2008), performed with students from Israel learning with a different teaching methodology, as computer animation and illustration activities. In this case, students that performed the computer activity obtained better results than the control group which use traditional instruction.

Another analysis of RECAL activity was focused on the differences in knowledge adquisicion between students who have or have not previous knowledge of biology. As it was expected at pre-test, students with Biology background marked higher than those who had no previously Biological background. In Spain the evolution of both groups between pre-test and post-test increases following the same positive trend. Spanish results coincide with Klosterman & Sadler (2010) who measured prior knowledge of science into two groups of students from different formations; environmental science and chemistry. Results have shown that the pre-test of chemistry students is far from over scientific environmental science students, but once both groups have done activities, the increase of knowledge is in parallel. Instead, Swedish students' case trend is different since Swedish students without biology background have a higher increase in knowledge acquisition after taking part of the activity than the students with biology background. Summarizing, RECAL activity is a suitable learning material to increase the knowledge in genetics, independently if the student have or have not any biological background.

The attitudes of preservice teachers towards RECAL activity were also analyzed both before and after the activity was carried out. Results of the pre-test questions related to expectations of the activity showed that in both countries students perceived that they was going to increase their knowledge by means of the activity and they expected to take part on a dynamic and motivating activity. Additionally, students' satisfaction level and usability of RECAL activity was analyzed at the post-test questionnaire by both a quantitative and a qualitative assessment. Results show that Swedish pre-service teachers are more used to participate in PBL activities than Spanish students. A vast majority of Spanish and Swedish students agreed that the activity main goals were understandable and that the activity dynamics and police case topic used were appropriated and interesting. Pre-service teachers from both countries also agreed that the professor was a good guide during the development of the activity and that the activity was clear and well organized. Most of the students of both countries also believe that the educational material was helpful. In addition, the group working atmosphere was satisfactory, students express their preference to team working and the fact that they have learned from other team members. Although students agreed that the activity is motivating and dynamic, they do not have more interest about genetics and scientific topics after taking part of this activity. Finally, the 95% of Spanish students and 97% of Swedish students agree that problem-based learning is a good way to learn. Other authors found that around 84% of students prefer PBL approach over traditional lectures (Abate *et al*., 2000). The 93% of Spanish and 85% of Swedish pre-service teachers analysed in this study declared that they would like to do this kind of activities more often. In previous studies Israelis students claimed that they would like to have more such activities in other biology topics as well (Rotbain *et al*., 2006). Finally they expressed that they have increased their knowledge towards genetics and they would like to recommend the activity to other students.

According to students' opinion answers, it could be concluded that in both countries students agree that best aspect of the activity is working in groups. As well as in Belgium, the most frequently mentioned design variable for students was the tutorial group (Dochy *et al*., 2005). They expressed that team working is useful to solve the activity. Additionally, students declare that the topic based in a police case is interesting and kept students engaged to solve the activity. And finally, they feel comfortable solving the police case by means of the extra information cards. Exposing pre-service teachers to new teaching and learning methodologies, such as RECAL activity, is one of the main ways in which formal education can be improved. It is interesting to develop more educational materials related to genetics or other topics of the biotechnology field identified in our research.

Conclusions

According to the data obtained in this thesis, Spanish and Swedish pre-service teachers are aware of the applications of biotechnology but they do not have a basic and fundamental knowledge on the biological implications of modern biotechnology on living beings.

Spanish and Swedish pre-service teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances.

Regarding one of the main hypotheses considered in this Thesis which was that the knowledge level of pre-service teachers on biology influences their attitudes towards biotechnology. We have found a positive correlation between better knowledge scores and more positive attitudes towards biotechnology, in both samples Spanish and Swedish pre-service teachers.

Another hypothesis was that learning activities based on STS approach and Problem-Based Learning methodology could be suitable strategies to implement biotechnological literacy at pre-service teachers' training. The following three conclusions were found in order to agree that these learning activities are suitable strategies to implement at pre-service teacher's training.

Knowledge of Spanish and Swedish pre-service teachers clearly rise after performing the educative intervention "RECAL case activity", independently if students have or not biology background.

Opinion of Spanish and Swedish pre-service teachers of satisfaction and usability of "RECAL case" activity shows that a great majority of the students agreed that the topic based on a police case is interesting and keep the student engaged to take part of the activity.

Working in groups rather than working individually is one of the main aspects that Spanish and Swedish pre-service teachers would like to keep on "RECAL case" activity.

Perspectives

This thesis arises the possibility to continue investigating by means of knowledge and attitudes questionnarie with students from other countries such as Canada, England and maybe in near future more countries. It could be interesting to compare students' knowledge and attitudes towards biotechnology of different countries and also of different continents and cultures, this could led to give us a perception of biotechnology literacy around the world. At the same time, this first part of the thesis permits us to observe that it is possible to foster biotechnology literacy of pre-service teachers. As it is now generally accepted that to improve learning in our schools we need more and better teacher professional learning (Goodrum, 2006). Teachers play a critical, central role in the education system. Pre-service teachers are therefore an influential collective because they become teachers of the next generation. Maier says that knowledge level in scientific topics directly influences the self-confidence and self-efficacy of teachers in their approach to science activities in the classroom (Maier *et al*., 2013). In that sense, Swedish and Spanish pre-service teachers strongly agree that they want to increase their knowledge in biotechnology related topics. Therefore, one effective way to induce a better knowledge and as a consequence more informed decisions of society towards new biological sciences and technologies is by promoting biotechnological literacy among teachers. For this reason, is important know devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret biotechnological issues. In this frame it has appeared "RECAL case" activity presented on this thesis. Further research could be done with "RECAL case" activity. First, it is possible to test the activity with pre-service teacher students' from other countries in order to see some differences and also to prove the efficacy of the activity. Second it could be compared with a control group of students who take part in a genetics traditional course. Finally, it could be interesting to develop more educational materials related also to genetics or other topics of the biotechnology field.

References

Abate, M. A., Meyer-Stout, P. J., Stamatakis, M. K., Gannett, P. M., Dunsworth, T.S., & Nardi, A.H. (2000). Development and evaluation of computerized problem-based learning cases emphasizing basic sciences concepts. *American Journal of PharmaceuticalEducation*, 64(1), 74-82.

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D., & Zuiker, S. (2010). Erratum to: Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, 19(4), 387-407.

Bennet, J., Lubben, F., & Hogarth, S. (2006). Bringing Science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, 91, 347-370. doi: 10.1002/sce.20186

Carrió, M., Larramona, P., Banos, J.E., & Pérez, J. (2011). The effectiveness of the hybrid problem-based learning approach in the teaching of biology: a comparison with lecture-based learning. *Journal of Biological Education*, 45(4), 229-235.

Chabalengula, V.M., Mumba, F., & Chitiyo, J. (2011). American elementary education pre-service teachers' attitudes towards biotechnology processes. *International Journal of Environmental & Science Education* 6(4), 341-357.

Chen, S.Y., & Raffan, J. (1999). Biotechnology: Student's knowledge and attitudes in the LJK and Taiwan. *Journal of Biological Education* 34(1), 17-23. doi: 10.1080/00219266.1999.9655678

Christoph, I.B., Bruhn, M., & Roosen, J. (2008). Knowledge, attitudes towards and acceptability of genetic modification in Germany. *Appetite*, 51(1), 58-68.

Darçin, E.S., & Güven, T. (2008). Development of an Attitude Measure Oriented to Biotechnology for the Pre-Service Science Teachers. *Journal of Turkish Science Education*, 5(3), 72-81.

Darçin, E.S. (2011). Turkish pre-service science teachers' knowledge and attitude towards application areas of biotechnology. *Scientific Research and Essays* 6(5), 1013-1019. doi: 10.5897/SRE10.552

Dawson, V., & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology processes. *Journal of Biological Education*, 38(1), 7-12.

Dawson, V. (2007). An exploration of high school (12–17 year old) students' understandings of, and attitudes towards biotechnology processes. *Research in science education*, 37(1), 59-73.

Dochy, F., Segers, M., Van Den Bossche, P., & Struyven, K. (2005). Students' perceptions of a problem-based learning environment. *Learning environments research*, 8(1), 41-66.

Erdogan, M., Ozel, M., Bouiaoude, S., Usak, M., & Prokop, P. (2012). Assessment of preservice teachers' knowledge and attitudes regarding biotechnology: A cross-cultural comparison. *Journal of Baltic Science Education*, 11(1), 78-93.

European Commission (2010). *Europe 2020: a strategy for smart, sustainable and inclusive growth*. Brussels (Belgium): Directorate General Research, EU. Retrieved from:http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

European Commission (2012). *Innovating for sustainable growth: A bioeconomy for Europe*. Brussels (Belgium): Directorate General Research, EU. Retrieved from: http://ec.europa.eu/research/bioeconomy/pdf/201202_innovating_sustainable_growth.pdf

Fetters, M.K., Czerniak, C.M., Fish, L., & Shawberry, J. (2002). Confronting, challenging, and changing teachers' beliefs: Implications from a local systemic change professional development program. *Journal of Science Teacher Education*, 13, 101–130. doi:10.1023/A:1015113613731

Gaskell, G., Bauer, M.W., & Durant, J. (1998). Public perceptions of biotechnology in 1996: Eurobarometer 46.1. *Biotechnology in the public sphere: A European sourcebook*, 189-214.

Gaskell G., Allansdottir A., Allum N., Corchero C., Fischler C., Hampel J., Jackson J., Kronberger N., Mejlgaard N., Revuelta G., Schreiner C., Stares S., Torgersen H., Wagner W. (2006) Europeans and Biotechnology in 2005: Patterns and Trends, Eurobarometer 64.3, http://ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_ final_report-may2006_en.pdf.

Gaskell, G., Stares, S., Allansdottir, A., Allum, N., Castro, P., Esmer, Y. & Wagner, W. (2010). *Europeans and Biotechnology in 2010 Winds of change?*.

Goodrum, D. (2006). Inquiry in Science Classrooms: Rhetoric or Reality? *Australian Council for Education Research*. Retrieved from: http://research.acer.edu.au/research_conference_2006/11

Goodwin, M., Kramera, C. & Cashmorea, A. (2012). The 'ethics committee': a practical approach to introducing bioethics and ethical thinking. *Journal of Biological Education* 46, no. 3: 188-192.

Kirkpatrick, G., Orvis, K., & Pittendrigh, B. (2002). GAME: A teaching model for biotechnology. *Journal of Biological Education*, 37(1), 31-35. doi:10.1080/00219266.2002.9655843

Klop, T., & Severiens, S. (2007). An exploration of attitudes towards modern biotechnology: a study among Dutch secondary school students. *International Journal of Science Education*, 29(5), 663-679. doi: 10.1080/09500690600951556

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues-based instruction. *International Journal of Science Education*, 32(8), 1017-1043.

Knippels, M.C.P.J., Waarlo, A.J. & Boersma, K.T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education* 39 (3), 108-112.

Lamanauskas, V., & Makarskaite-Petkeviciene, R. (2008). Lithuanian university student's knowledge of biotechnology and their attitudes of the taught subject. *Eurasian Journal of Mathematics, Science and Technology Education*, 4(3), 269-277.

Lee, J.S., & Ginsburg, H.P. (2007). Preschool teachers' beliefs about appropriate early literacy and mathematics education for low and middle socioeconomic status children. *Early Education & Development*, 18, 111–143. doi:10.1080/10409280701274758

Maier, M., Greenfield, D., & Bulotsky-Shearer, R. (2013). Development and validation of a preschool teachers' attitudes and beliefs toward science teaching questionnaire. *Early Childhood Research Quarterly*, 28(2), 366–378. doi:10.1016/j.ecresq.2012.09.00

Mitchener, C.P., & Anderson, R.D. (1989). Teachers' perspective: Developing and implementing an STS curriculum. *Journal of Research in Science Teaching*, 26(4), 351-369.

Marbach-Ad, G., Rotbain, Y., & Stavy, R. (2008).Using computer animation and illustration activities to improve high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, 45(3), 273-292.

Pardo, R., Midden, C., & Miller, J.D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, 98(1), 9-24.

Prokop, P., Leskova, A., Kubiatko, M., & Diran, C. (2007). Slovakian Students' Knowledge of and Attitudes toward Biotechnology. *International Journal of Science Education*, 29(7), 895-907. doi:10.1080/09500690600969830

Roehrig, G.H., Kruse, R. A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science Teaching*, 44, 883–907. doi:10.1002/tea.20180

Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2006). Effect of bead and illustrations models on high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, 43(5), 500-529.

Sorgo, A., & Ambrozic-Dolinsek, J. (2009). The relationship among knowledge of, attitudes toward and acceptance of genetically modified organisms (GMOs) among Slovenian teachers. *Electronic Journal of Biotechnology*, 12(3), 1-13. doi: 10.2225/vol12-issue4-fulltext-1

Starbek, P., StarčičErjavec, M., & Peklaj, C. (2010).Teaching genetics with multimedia results in better acquisition of knowledge and improvement in comprehension. *Journal of computer assisted learning*, 26(3), 214-224.

Tobin, K., Tippins, D.J., & Gallard, A.J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 45-93). New York: Macmillan.

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education*, 37(2), 123-130. doi: 10.1002/bmb.20267

ANNEXES

Annexe 1:

Questionnaire of Knowledge and Attitudes towards biotechnology

Biotech XXI: towards a biotechnological literacy of future teachers

Thank you for your collaboration with the International Project entitled "Assessment of attitudes towards biotechnology of future teachers. A collaborative Project between URV-UWO". The aims of this study are to assess the knolwedge and attitudes of pre-service students towards biotechnology and what this could potentially reflect with regards to teaching such information in the future. The same survey will be given to equivalent student teachers in Spain to ascertain if they have the same or different levels of biotechnological literacy.

This is an anonymous survey, and it is divided into three sections:

Section 1 defines the socio-demographic aspects of the participants. Within this section, a question relates to Personal Background in Biology'. This refers to any perception, knowledge, exposure or understanding of biology. For this questionnaire, biology refers to cells, genes, disease, gnomes, organisms evident in nature, products or the human body.

Section 2 assesses biotechnology knowledge through 21 statements where you should answer if the proposed statement is 'True', 'False' or 'Don't know the answer'.

Section 3 assesses your attitudes towards biotechnological issues. In this part, you will be asked to express your views on a scale from strongly disagree to strongly agree.

But the most important aspect is **DON'T feel any panic, this is not an exam!!!**

1.- Socio-demographic profile:

AGE:_______________ PERSONAL BACKGROUND IN BIOLOGY: Yes ☐ No ☐

GENDER: Female ☐ Male ☐

PARENT'S EDUCATION BACKGROUND: Primary school ☐ High school ☐ University ☐

DEGREE/DIPLOMA YOU ARE TAKING: ☐ Pre-school teacher degree ☐ Primary School teacher degree

2.- Biotechnology knowledge:

Read each statement and indicate your response by circling to the right of the statement one indicator (T, F or DK) which relates
closest to your knowledge of the given statement. 'T' refers to your agreement to the statement as being 'True'. 'F' refers to your
disagreement to the statement as being 'False'. 'DK' refers to no opinion for the statement; neither agree nor disagree with the statement

1	In the kidney cells genome you can also find the information about the colour of your hair.	T	F	D K
2	A good hygiene helps to prevent genetic diseases.	T	F	D K
3	Insulin is obtained by the use of genetically modified (GM) bacteria.	T	F	D K
4	Only when we eat GM food we eat genes.	T	F	D K
5	A yogurt is a biotechnological product.	T	F	D K
6	Genetically Modified Organisms (GMO) are larger than normal.	T	F	D K
7	Mutations are only possible by genetic manipulation in the laboratory.	T	F	D K
8	GMO have a high number of toxic substances.	T	F	D K
9	A GMO is always a transgenic.	T	F	D K
10	Bacteria are used in the elaboration of daily products (cheese, vinegar, vitamin C).	T	F	D K
11	It is possible to change the genetic characteristics of a plant to make it more resistant to a given plague.	T	F	D K
12	A high production of vitamins by a fruit is only possible by genetic manipulation of that fruit.	T	F	D K
13	Chemically, the genetic material (DNA) is identical in all the organisms.	T	F	D K
14	Genetic material exchange between different species is only possible by manipulation in the laboratory.	T	F	D K
15	AIDS is a genetic disease.	T	F	D K
16	Microorganisms are used to purify sewage.	T	F	D K
17	In our body there are more bacteria than people in the world.	T	F	D K
18	Children resemble their parents because they share the red blood cells.	T	F	D K
19	Crocodiles have the same genetic material as ostriches.	T	F	D K
20	The most powerful toxic substances are naturally occurring.	T	F	D K
21	Through genetic modification, foods with higher nutritional values can be achieved.	T	F	D K

3.- Student's attitudes towards biotechnological issues:

Read each statement and indicate your agreement level by circling to the scale from strongly disagree to strongly agree. There are no right or wrong answers.

		strongly disagree	disagree	agree	strongly agree
		1	**2**	**3**	**4**
1	Biotechnology makes our lives easier.	1	2	3	4
2	Genetically Modified foods can help alleviate world hunger.	1	2	3	4
3	Science makes our lives easier.	1	2	3	4
4	The application of biotechnology will make the future more dangerous.	1	2	3	4
5	The use of Genetically Modified Organisms to fight against diseases is good	1	2	3	4
6	Biotechnology does not play any role in environmental protection.	1	2	3	4
7	The fast evolution of science threatens humanity.	1	2	3	4
8	A scientific discovery is neither "good" nor "bad", it is how we use it that matters.	1	2	3	4
9	There should be limits to what should and should not be investigated.	1	2	3	4
10	Some people have lucky numbers.	1	2	3	4
11	Genetically altering living beings is like playing God.	1	2	3	4
12	Consumption of Genetically Modified foods is dangerous.	1	2	3	4
13	The genetic modification of fruits and plants to keep them fresh for a longer time is not good.	1	2	3	4
14	I would like to know more about Genetically Modified food.	1	2	3	4
15	The use of Genetically Modified Organisms for medical therapy and the study of diseases is good	1	2	3	4
16	The addition of genes to a plant to make it disease-resistant is unacceptable.	1	2	3	4
17	The use of cloning as a tool to save endangered species is acceptable.	1	2	3	4
18	Genetic manipulation will drive a large number of species to extinction.	1	2	3	4

		strongly disagree	disagree	agree	strongly agree
19	I would buy Genetically Modified food.	1	2	3	4
20	I would feed my children food produced with Genetically Modified bacteria.	1	2	3	4
21	The alteration of the genes in a fruit to make it more tasty is good.	1	2	3	4
22	I would support the use of Genetically Modified Organisms for non-food purposes.	1	2	3	4
23	Genetic manipulation is not ethical.	1	2	3	4
24	The genetic modification of a sheep to produce medicines is not good.	1	2	3	4
25	The genetic modification of a bacteria to produce food is good.	1	2	3	4
26	I would like to have more information about Genetically Modified food.	1	2	3	4
27	I am opposed to the transfer of genes between plants and animals.	1	2	3	4
28	I would forbid the sale of transgenic organisms in my country.	1	2	3	4
29	The laws about Genetically Modified Organisms are strict enough.	1	2	3	4
30	Society should decide what is right or wrong in science.	1	2	3	4
31	I would like to be aware of scientific advances.	1	2	3	4
32	Genetic manipulation should be more strictly regulated.	1	2	3	4
33	If genetically modified food was cheaper, I would buy it.	1	2	3	4
34	If genetically modified food was healthier, I would eat them more often	1	2	3	4

		strongly agree	agree	disagree	strongly disagree
		1	**2**	**3**	**4**
35	If I get a dish in a restaurant made out of transgenic food, I would not eat it.	1	2	3	4
36	Biotechnology is boring.	1	2	3	4
37	Society is well informed about genetically modified products.	1	2	3	4
38	I would like to increase my knowledge about Genetically Modified Organisms.	1	2	3	4
39	I agree with genetic investigation in medicine.	1	2	3	4
40	Biotechnology can improve our lifestyle.	1	2	3	4
41	Scientific investigations should not interfere with religion.	1	2	3	4
42	I agree with genetic transformation in embryos to cure hereditary diseases.	1	2	3	4
43	Biotehnology is evil for today's society.	1	2	3	4
44	The labelling of transgenic products is clear enough.	1	2	3	4
45	Biotechnology is used to produce chemicals in a less polluted way.	1	2	3	4

THANK YOU FOR YOUR COLLABORATION

Annexe 2:

Dossier containing a description, worksheet and solutions of RECAL activity

The Recal Case: a game based on a police investigation

YOU are players and part of a police scientific team. You are going to analyze a variety of evidence, find some clues, and understand forensic genetics. Your job is to help investigators to solve the case.

You have to follow this procedure:

- Read the activities that you are given during the game.
- Answer the questionnaire for each activity
- Analyse the evidence for each activity
- Record the evidence that will help you to find the person responsible.

The main aim of the game is to achieve the **highest score** you can for all the questionnaires. All the information is important if you are to find the person who committed the robbery.

THE RECAL CASE

Mr. Albert Recal was a tailor at the end of the 19th century. He owned a tailor's shop in Stockholm where all sorts of clothes were produced and sold.

In 1980 his great-granddaughter Christina Recal inherited the family business. She was a hard-working woman and she changed the whole business and transformed it into a prestigious brand. She opened several shops around Europe.

Ms. CHRISTINA Recal is now an old woman and a widow, so she usually delegates tasks to her sons.

On 6 December 2014, Christina held a family lunch at her mansion to celebrate her 80th birthday. At 6 p.m., one of the servants realized that her safe deposit box had been opened and was empty. She called the police, who arrived in few minutes.

YOU ARE PART OF THE POLICE FORENSIC TEAM.

Inspector: Adam Axelsson

Investigation file: 62,387

Station: Stockholm 439

Department: Robberies

WORKSHEET 1

Good morning,

I am Adam Axelsson, an inspector from the Department of Robberies in Stockholm. As the person in charge of the Department I would like to verify your abilities in forensic genetics. To this end you will have to respond to several questionnaires before you can be given any evidence. All these questionnaires will help you to solve "the RECAL CASE".

Don't forget that you will be given a point for each correct answer, and the group with the highest score will be awarded the prize as a best police contributor.

You have been sent a link on Moodle to the triangle questionnaire. Do your best to answer it. You also have some extra information cards.*

*The extra information cards that will help you are the cards marked with a triangle. You have 15 minutes to solve it!

1. EVIDENCE REGISTER

It will not be so easy!

As you can see, the thief could be blond or dark haired. So you can discount all redheads and those with white hair.

Every activity has a table in which you should register the evidence that you find in every step. I am sure that you are finally are going to discover all the clues and solve the case.

* Record the evidence, and write down any comments or observations. Remember that this is the most important tool that you have. It is the only way to discount the innocent and find the thief.

Gender	Age	Family relationship	Species	Genetic disease	Hair colour	Skin colour
		Yes		Yes		
		No		No		

Observations: ___________________________________

WORKSHEET 2

You have now satisfactorily completed the first activity. Now it is time for some more difficult activities. Are you ready?

You are going to answer more questions to acquire further evidence.

You have been sent a link on Moodle to the square questionnaire. Do your best to answer it. You also have some extra information cards.*

*The extra information cards that will help you are the cards marked with a square.

You have 15 minutes to solve it!

2. EVIDENCE REGISTER

***** Record the evidence, and write down any comments or observations. Remember that this is the most important tool that you have. It is the only way to discount the innocent and find the thief.

Gender	Age	Family relationship	Species	Genetic disease	Hair colour	Skin colour
		Yes		Yes		
		No		No		

Observations:___________________________________

WORKSHEET 3

Did karyotype analysis give you the correct results? Does that mean that you are experts? Not yet. You need to answer more questions and solve more puzzles if you are to find the thief.

You have been sent a link on Moodle to the square questionnaire. Do your best to answer it. You also have some extra information cards.*

*The extra information cards that will help you are the cards marked with a square.

You have 15 minutes to solve it!

3. EVIDENCE REGISTER

***** Record the evidence, and write down any comments or observations. Remember that this is the most important tool that you have. It is the only way to discount the innocent and find the thief.

Gender	Age	Family relationship	Species	Genetic disease	Hair colour	Skin colour
		Yes		Yes		
		No		No		

For which members of the family will you request further analysis? Why?

Observations:____

WORKSHEET 4

We are getting to the end of the case. Now we are going to discover which investigation team is the best in the class. But you still need to get some more points if you are to get the correct result.

You have been sent a link on Moodle to the star questionnaire. Do your best to answer it. You also have some extra information cards.*

*The extra information cards that will help you are the cards marked with a star.

You have 15 minutes to solve it!

Solutions

Worksheet 1

Students have to analyse two pieces of evidence: a blond hair and a dark hair. They have to record the thief's phenotype. So we can discount the members of the family whose hair is red or white.

Worksheet 2

Students have to compare three karyotypes.

The three main things that the students have to find are the following:

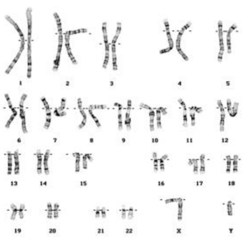
The dark hair and blond hair are from males, as can be seen from the sex chromosomes (XY). Compare this with the grandmother's karyotype (XX).

The blond hair is from the family's dog because it has a different number of chromosomes.

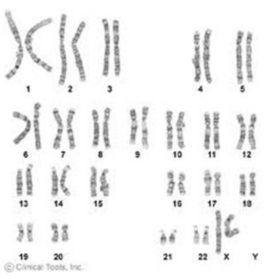
Finally it is really important that students should notice that the thief does not have a Down's syndrome phenotype.

From this evidence it can be concluded that the thief is a man, he has dark hair and he has not got a Down's syndrome phenotype.

Grandmother's karyotype



Karyotype (dark hair)

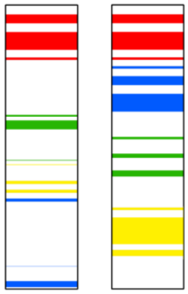


Karyotype(blond hair)

Worksheet 3

Students have to compare two DNA profiles. The grandmother and the thief have a similarity of 25% (red bands are equal) (three bands out of twelve).
So the conclusion is that only the genome of a grandson can have a similarity of 25% with the grandmother's genome.

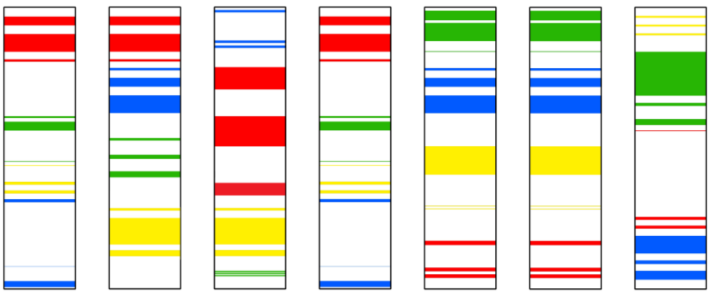
Karyotype of the dark hair / Grandmother's karyotype



Worksheet 4

Petter is the thief because he has the same DNA profile as the dark hair found in his grandmother's bedroom. David and Max are monozygotic twins because their DNA profiling is identical. Anders doesn't belong to the family because he has no genetic similarity with his grandmother.

Karyotype of the dark hair / grandmother's karyotype (all grandsons are Ralph; Petter; David; Max; Anders) and not the grandson Markus who have a Down's syndrome phenotype.



Conclusion: Petter is the thief.

Annexe 3:

Questionnaires of the RECAL activity

Questionnaires used during the activity. Correct answer of each question is marked in bold.

Questionnaire 1

1. Which of the following characteristics is a phenotype?

   a) Your grandmother's age.
   b) The characteristic features of a person with Down's syndrome.
   c) Undyed hair
   d) An outside temperature of 2ºC.

2. Does the size of a living being depend on its amount of DNA?

   a) Yes, bigger living beings have more DNA.
   b) No, DNA is not chemically equal in all living beings so we cannot compare different species.
   c) Yes, smaller living beings have more DNA.
   d) No, the size of living beings is not determined by the quantity of DNA that they have.

3. Which of these samples can be used in a genetic study?

   a) Tip of the hair (the root is not needed).
   b) Any body cell.
   c) Fingerprint.
   d) None of the above.

4. Can we distinguish different species by analyzing their DNA?

   a) Yes, they can be distinguished by the chemical composition of their DNA.
   b) Yes, they can be distinguished by the number of chromosomes in their genomes.

c) No, all living beings have the same DNA sequence. The only difference is how each species uses this information.
d) No.DNA by itself does not reveal the phenotype, which must be known if different living beings are to be distinguished.

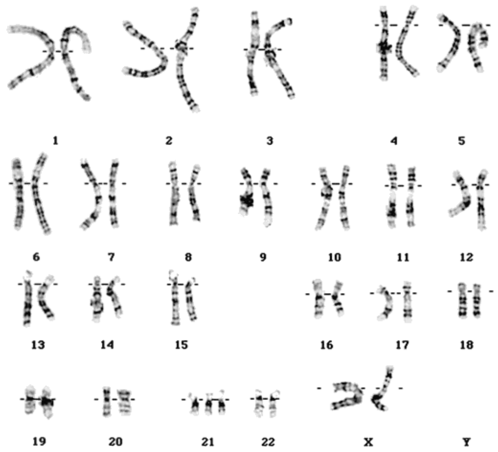
5. Nucleic acids (DNA and RNA) include all the information of a living being but you know ….

   a) All living beings have genetic information in the form of nucleic acids.
   b) The genetic information in plant and animal species takes the form of nucleic acids but this is not the case in microorganisms.
   c) There are nucleic acids and other kinds of molecule which store genetic information.
   d) Each species has its own special molecule in which genetic information is stored.

Questionnaire 2

6. A potato and a frog

   a) have the same number of chromosomes, but different genetic information.
   b) have a different number of chromosomes because the frog is more evolved than the potato.
   c) have a different number of chromosomes. There is no relation between the size of a species and the number of chromosomes it has.
   d) have the same number of chromosomes, because all species have 46 chromosomes (23 pairs).



The Figure below shows a human karyotype. All the homologous chromosomes are numbered, but the sexual chromosomes are labelled X and Y.

This karyotype has two bands or stripes for each pair of homologous chromosomes (each band represents a chromosome). The X chromosome also has two bands but the Y chromosome doesn't have any.

7. Down's Syndrome is a genetic disease that affects an entire chromosome. It is easy to observe in this Figure. Which chromosome is affected by this syndrome?

   a) The Y chromosome because it is not there.
   b) Many of them are because they are bent.
   c) Chromosome 9 because one band is shorter than the other.
   d) Chromosome 21 because there are 3 chromosomes.

8. Could you say if the karyotype of the Figure is a male or female?

   a) No. More evidence is needed to identify the gender.
   b) It is a male because it has two X chromosomes.
   c) It is a female because it has two X chromosomes.
   d) It is a female because it has three chromosomes at position 21.

9. Can a karyotype reveal differences between a Caucasian and an African woman?

a) Yes, a karyotype provides all phenotypic information.
b) No, because all women who do not have a genetic chromosome disease have the same karyotype.
c) No. We could not identify which karyotype belongs to which woman.
d) Yes, because the Scandinavian karyotype has three chromosomes at position 21.

Questionnaire 3

10. On the basis of karyotype evidence we could work out that the person who has committed a crime has

a) blond hair.
b) dark hair.
c) either blond hair or dark hair (a karyotype doesn't allow us to distinguish).

11. On the basis of Karyotype evidence we could work out that the person who has committed a crime is

a) a man
b) a woman
c) either a man or a woman (a karyotype doesn't allow us to distinguish).

12. Could we dismiss family members who have Down's syndrome?

a) Yes
b) No

13. On the extra information card (square) called "Do all living beings have the same karyotype?" could you say what the blond hair has come from? (See the table on the extra information card.)

    a) A cat
    b) A monkey
    c) A dog
    d) A mouse

14. What can we say about the DNA transmission?

    a) Little genetic variations are heritable.
    b) We can identify the degree of relatedness between two family members by means of DNA profiling.
    c) The genome is almost identical in all humans.
    d) All of the above are correct.

15. Which of the following sentences about genetic heritability between family members is correct?

    a) A grandson shares 25% of his DNA with his paternal grandfather and 50% with his mother.
    b) We cannot know how the inheritance of genetic information works because it is random.
    c) A grandson has 80% of his father's DNA and 20% of his paternal grandfather's.
    d) The genome is almost identical in all humans so we cannot know how the genetic inheritance from family members is distributed.

Questionnaire 4

16. On the basis of dark hair DNA profiling we can deduce that the thief is Christina's:

    a) Son-in-law
    b) Son
    c) Grandson-in-law
    d) Grandson
    e) House servant

17. If twins are

    a) identical they are dizygotic.
    b) identical they are monozygotic and their genome is the same.
    c) not identical they are dizygotic and their genome is the same.
    d) Options b and c are correct.

18. Chromosomes

    a) are an organized way of storing two DNA strands.
    b) determine the phenotype.
    c) are lipid cellular membranes that wrap DNA.
    d) are a group of cells that contain DNA.

19. A karyotype analysis

    a) shows how many chromosomes a living being has.
    b) shows the genetic diseases that affect a gene.
    c) shows the genetic diseases that affect a chromosome.
    d) Options a and c are correct.

20. DNA profiling analyzes some genome regions to obtain bands. If 25% of bands are identical in two people,

    a) they are father and son.
    b) they are grandfather and grandson.
    c) they are monozygotic twins.
    d) they are mother and son.

Resolution Questionnaire

On the evidence sheet 4 shows the DNA profiling of suspects. At this point we have found that the suspects are Christina's dark-haired grandsons.
Clearly, by comparing the DNA profiling of suspects with the DNA profiling of evidence we will be able to identify the guilty person. But this comparison provides further information.

Do not forget that each correct response is an additional point towards being awarded a prize as the group's best police contributor.

21. Who is guilty?

    Ralph, **Petter**, David, Max or Anders

22. Some of the suspects are adopted? Who?

    Ralph, Petter, David, Max or **Anders**

23. Some suspects are monozygotic twins?

    a) Ralph and Petter
    b) David and Max
    c) Max and Anders
    d) Ralph and David

Annexe 4:

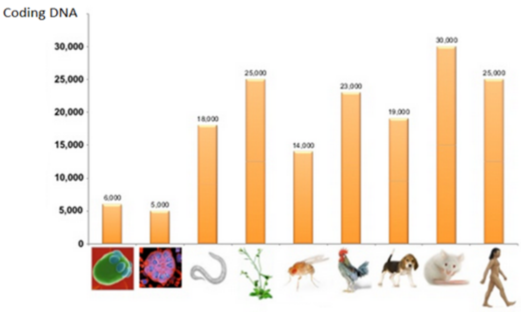
Extra information cards of the RECAL activity

Phenotype?

A phenotype is the result of the expression of an organism's genes, the influence of environmental factors and the interactions between the two. It is the composite of an organism's observable characteristics or traits.
For example: In the picture you can see that the colours of roses are different phenotypes.

DNA: biological information storage

- DNA (DeoxyriboNucleic Acid) is a molecule that encodes the genetic instructions used in the development and functioning of all known living organisms and many viruses. It is made up of two biopolymer strands composed of simple units called nucleotides. There are four kinds of nucleotide (A,T,G and C).



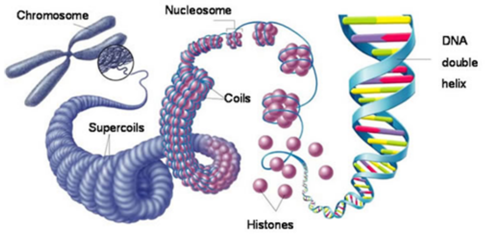
http://es.slideshare.net/lizbethfdz/presentacion-lcg-04112011-10018243

DNA-chromosome relation

DNA strands are very long (the 3.400 Mb in humans can be up to 3 meters long).

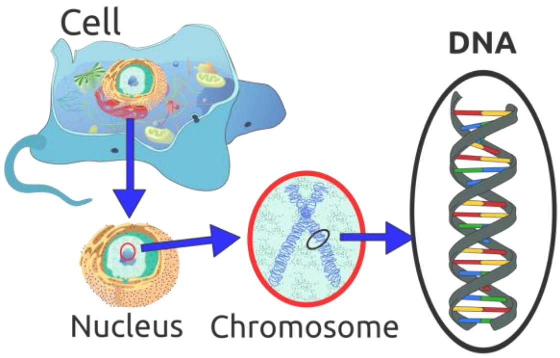
The strands form packages by coiling together numerous times to take up as little space as possible (remember that DNA is found in the cell nucleus). This is known as DNA super coiling.

The supercoiled DNA structure is the chromosome. Humans have 23 pairs of chromosomes to store the 3,400 Mb.



http://www.goldiesroom.org/Note%20Packets/14%20Mitosis%20and%20Asexual/00%20Mitosis--WHOLE.htm

Where is DNA found?

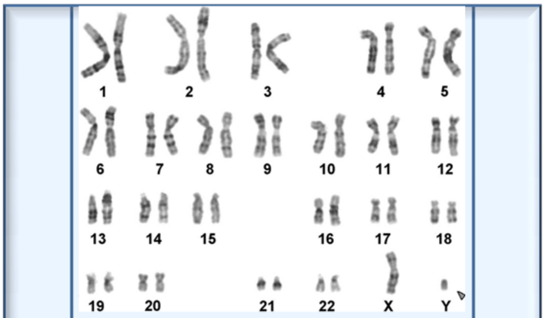


DNA is found inside the cells of living beings.

Also, if there is a nucleus in the cell, DNA will be found. We can obtain DNA from every cell in our body.

What is a karyotype?

- Every species has a specific number or chromosomes, which are of different lengths and structures. A **karyotype** is an analysis which shows the complete set of chromosomes in a species or individual organism.



Human Karyotype

What differences are there between genders?

- The human gender is determined by a specific pair of chromosomes (X and Y). The **male gender** is represented by XY and the **female gender** by XX.

Human Karyotype, male

Do all living beings have the same karyotype?

- The number, shape and size of chromosomes are different in each **species**. The number of chromosomes has no relation to the complexity of a species (see table).

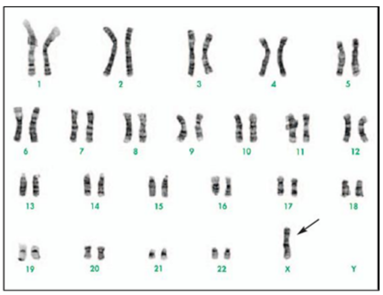
Common Name	Species	Diploid number	Common Name	Species	Diploid number
Animals (2n)			Plants (2n)		
Human	*Homo sapiens*	46	Corn	*Zea mays*	20
Monkey	*Macaca mulatta*	42	Potato	*S. tuberosum*	48
Dog	*Canis familiaris*	78	Green algae	*A. mediterranea*	20
Cat	*Felis domesticus*	38			
Mouse	*Mus musculus*	40	Fungi (2n)		
Frog	*Rana pipiens*	26	Yeast	*S. cerevisiae*	32
Fruit fly	*Drosophila melanogaster*	8	Fungi (1n)		Haploid number
Flatworm	*Planaria torva*	16	Mold	*Penicillium species*	4

Can karyotypes be used to diagnose genetic diseases?

Some genetic diseases affect an entire chromosome and they can be seen with a karyotype. Others are the result of a single mutated gene. In some genetic diseases, there are extra or missing chromosomes.

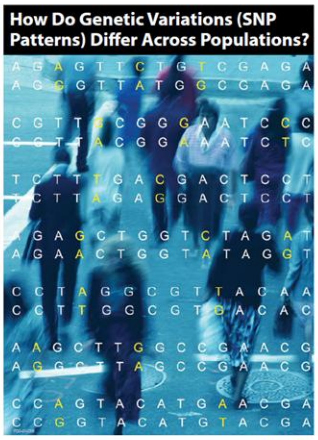
XYY Syndrome

Turner Syndrome



All living beings have the same information in the DNA?

The human genome is almost identical (99.9%) in all human beings.



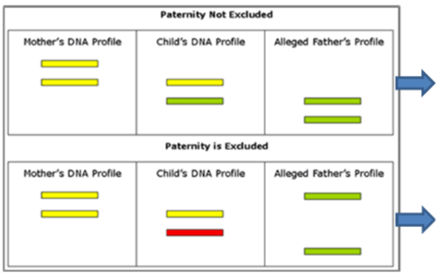
Slight variations in DNA sequences have an impact on our body responses. These variations help us to identify relations between members of the same family because genetic variations are heritable.

Scientists have long recognized that, despite physical differences, all human populations are genetically similar.

U.S. Department of Energy Genome Programs, http://genomics.energy.gov

What is genetic profiling?

- Genetic profiling is a technique that can be used to identify individuals by their respective DNA profiles. DNA profiling is used in, for example, parental testing and criminal investigation.
- DNA is obtained and analysed from blood, skin or sperm samples.



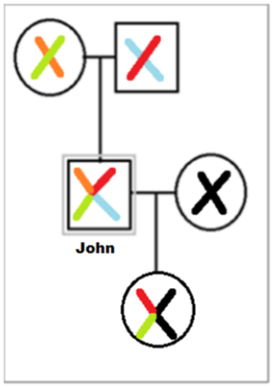
YES, he is the father. We can see that the son and his father have the same green part. The son receives half his genetic information from his father.

NO, he is not the father. The father's and son's genetic information bear no similarity.

How can characters be inherited from parents and grandparents?

The joining together of an ovule with sperm produces a baby (John). So each ovule and sperm have half the information of his parents. As you can see in the figure. John' s daughter will receive half the information from her mother and her father.

What is the percentage of genetic information shared between John's daughter and her grandparents?



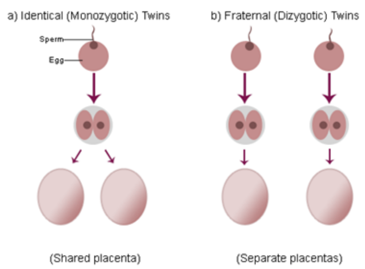
John's Family

○ Female

☐ Male

There are different kinds of twins?

- Twins can be **monozygotic**, meaning that they develop from one zygote that splits and forms two embryos. Two embryos share the same placenta.
- Twins can be **dizygotic**, meaning that they develop from two eggs, each fertilized by separate sperm cells. Each embryo has its own placenta.



- Do you know which kind of twins are identical?

Annexe 5:

Evidences of the RECAL activity

Evidence 1

Information of interest:

The police officer who has been on the scene gives us some information.

- The thief is a family member.
- Two hairs have been found as evidence are the keys to the case.
- Nobody's hair is coloured.

The two hairs found have the follicle attached. So epithelial cells, which contain DNA, can be obtained. Hair is not a tissue, so it is not made up of cells and no DNA can be obtained from it. There are 32 people in the house: 16 females, 16 males and 1 dog. Of these 6 are blond, 4 have gray hair, 21 have dark hair and 1 has red hair.

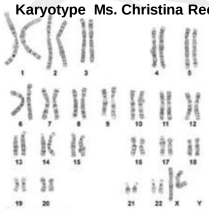
Evidence 2

The laboratory has provided three karyotypes of the hairs that have been found.

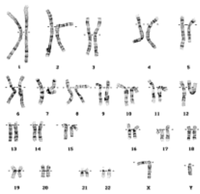
- 1 karyotype of grandmother's hair (control)
- 1 karyotype of blond hair
- 1 karyotype of dark hair

Information of interest:
The police officer who was at the scene tells us that two family members (Markus and Lisbet) have a Down syndrome phenotype. So they can be discounted. (Remember to record this data on the evidence register.)

Karyotype Ms. Christina Recal



Karyotype dark hair



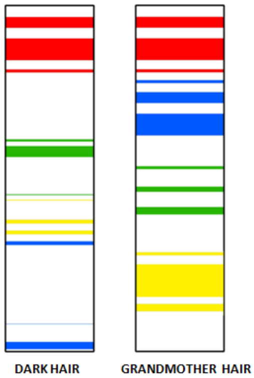
Karyotype blond hair

Evidence 3

Two genetic profiles have been obtained:

- 1 of the grandmother.
- 1 of the suspect's dark hair.

Now find some other features of the thief.

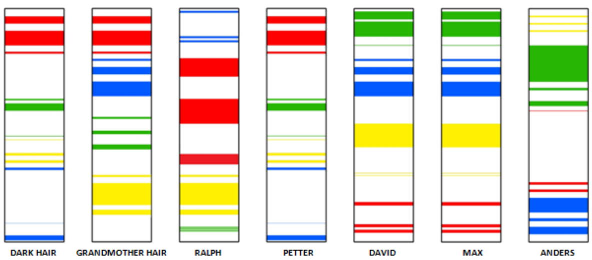


Evidence 4

The evidence shows that the suspect is a dark-haired grandson.

The dark-haired grandsons are: Ralph, Petter, David, Max and Anders. We have discounted Markus (Down syndrome).

Here are the DNA profiles of the dark-haired grandsons.



Annexe 6:

Pre-test for the validation of RECAL activity

CODE:...................... AGE:……………….. GENDER: Female…… Male….

BIOLOGY BACKGROUND (High school) (Yes/No):………………….

PARENTS EDUCATIONAL LEVEL: University…… High school…. Primary school….

WHICH UNIVERSITY DEGREE ARE YOU STUDYING?.......................................

INITIAL QUESTIONNAIRE

Please mark the correct answer with a cross depending on whether you think the sentence is True (T) or False (F). If you do not know the answer ,mark Don't Know (D.K.)

1	The phenotype is independent of genetic information.	T	F	D.K
2	All living beings have the same number of chromosomes.	T	F	D.K
3	DNA molecules are the same in all living beings.	T	F	D.K
4	Chromosomes are made up of cells.	T	F	D.K
5	We can distinguish two women by the information that we get from a karyotype.	T	F	D.K
6	We can obtain information about species, gender and some genetic diseases by means of a karyotype.	T	F	D.K
7	Human beings have more DNA because they are more evolved.	T	F	D.K
8	A son looks more like his father when he receives a higher percentage of genetic information from him.	T	F	D.K
9	Men have one chromosome that is the same as in women and another that is different..	T	F	D.K
10	A boy has 23 pairs of chromosomes. His father transmits to him one chromosome of each pair and his mother the other.	T	F	D.K

OPINION: Please answer the following questions using the scale (strongly disagree, disagree, agree and strongly agree). It is important to answer all the questions.

	Strongly disagree	disagree	agree	Strongly agree
I have great expectations about this new activity.				
I think that this activity is going to improve my knowledge.				
I think that this activity is going to be dynamic and motivating.				

Annexe 7:

Post-test for the validation of RECAL activity

CODE:...................... AGE:……………….. GENDER: Female…… Male….

BIOLOGY BACKGROUND (High school) (Yes/No):…………………

PARENTS EDUCATIONAL LEVEL: University…… High school…. Primary school….

WHICH UNIVERSITY DEGREE ARE YOU STUDYING?.......................................

FINAL QUESTIONNAIRE

Please mark the correct answer with a cross depending on whether you think the sentence is True (T) or False (F). If you do not know the answer ,mark Don't Know (D.K.)

1	The phenotype is independent of genetic information.	T	F	D.K
2	All living beings have the same number of chromosomes.	T	F	D.K
3	DNA molecules are the same in all living beings.	T	F	D.K
4	Chromosomes are made up of cells.	T	F	D.K
5	We can distinguish two women by the information that we get from a karyotype.	T	F	D.K
6	We can obtain information about species, gender and some genetic diseases by means of a karyotype.	T	F	D.K
7	Human beings have more DNA because they are more evolved.	T	F	D.K
8	A son looks more like his father when he receives a higher percentage of genetic information from him.	T	F	D.K
9	Men have one chromosome that is the same as in women and another that is different..	T	F	D.K
10	A boy has 23 pairs of chromosomes. His father transmits to him one chromosome of each pair and his mother the other.	T	F	D.K

OPINION: Please answer following questions using the scale (strongly disagree, disagree, agree and strongly agree). It is important to answer all the questions.

Previous background in biology:

	Strongly disagree	Disagree	Agree	Strongly agree
I had a background in biology before starting the activity.	1	2	3	4
I had already participated in an activity like this (based on solving a case in a collaborative way).	1	2	3	4

The activity itself (timing, cards, teacher, etc.):

	Strongly disagree	Disagree	Agree	Strongly agree
The main goals were understandable and simple.	1	2	3	4
The activity dynamics were appropriate and interesting.	1	2	3	4
The police case used was appropriate.	1	2	3	4
Wordings were clear and I could understand all that was asked.	1	2	3	4

I understood all the questions at the end of each activity.	1	2	3	4
The organization was clear and ordered.	1	2	3	4
The teacher / professor was a good guide during the activity.	1	2	3	4
I had enough time to finish the activity.	1	2	3	4
The resources that we had during the activity were enough to solve the police case.	1	2	3	4
I think that all the educational materials were useful.	1	2	3	4
I used the educational material at the right moment.	1	2	3	4
I managed to acquire all the information that I didn't know using the Extra information cards.	1	2	3	4
The extra information cards encouraged me to continue solving the police case.	1	2	3	4

Working environment (group):

	Strongly disagree	Disagree	Agree	Strongly agree
The group working atmosphere was satisfactory.	1	2	3	4
I would have preferred to do the activity on my own.	1	2	3	4
I had some problems with other team members.	1	2	3	4
I learned from other members of the team when I had doubts.	1	2	3	4

Motivation:

	Strongly disagree	Disagree	Agree	Strongly agree
This activity has raised my interest in genetics and biotechnology.	1	2	3	4
This police case has encouraged me to study scientific topics.	1	2	3	4
I think that this activity is motivating and dynamic.	1	2	3	4

Student assessment of the activity:

	Strongly disagree	Disagree	Agree	Strongly agree
I think that this problem-based activity is a good way to learn.	1	2	3	4
The research that we did to solve the police case was useful because we learned.	1	2	3	4
This activity made me learn new knowledge.	1	2	3	4
It was difficult to solve all the activities of this case.	1	2	3	4
I would like to do this kind of activity More often.	1	2	3	4

Future applications of the activity:

	Strongly disagree	Disagree	Agree	Strongly agree
This activity fulfilled my expectations.	1	2	3	4
I think that I have improved my knowledge.	1	2	3	4
I am going to recommend this activity to other students.	1	2	3	4

I think that I will be able to apply all the knowledge acquired in the future.	1	2	3	4

Complete the table:

3 aspects that you would like maintain	3 aspects that you would like eliminate	3 aspects that you would like change