BIOTECHNOLOGY PEDAGOGICAL KNOWLEDGE THROUGH MORTIMER'S CONCEPTUAL PROFILE

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Abstract

In this study the authors try to ascertain the knowledge base of high school teachers related to the topic of «biotechnology», one that provides opportunities for students and teachers to explore and critically debate dilemmas and bioethical issues. The main outcome of this research is the use of the Content Representation frame of Loughran, Mulhall and Berry answered by Mexican teachers and their examination through Mortimer's conceptual profile model. It will be shown that there are differences in expressions and ways of thinking between four experienced chemistry and biology teachers of the high school and the undergraduate levels. Therefore, Pedagogical Content Knowledge (PCK) can be used to classify, construct and represent the epistemological aptitudes of each professor by means of their conceptual profiles.

Keywords

Biotechnology, Pedagogical Content Knowledge, Content Representation, Conceptual Profile.

Introduction

The general assertion guiding this research is:

High school teachers Biotechnology's PCK can be documented using the Content Representation (CoRe) of Loughran *et al.* (2004) and it may be utilized to find, categorize, characterise and discuss their pedagogical thinking and epistemological aptitudes by means of Mortimer's (1995) conceptual profile model.

The first step of this research consisted in reaching consensus amongst the professors about the central ideas or concepts involved in teaching biotechnology at high school level and documenting afterwards the CoRe with the frame of Loughran *et al.* Secondly, four conceptual profile zones were defined in accordance with the guidelines proposed by Mortimer: perceptive/intuitive, contextual, empiricist, and rationalist. Finally, these zones were used as criteria to classify each phrase provided by each professor in the CoRe framework, from which four different conceptual profile graphs were constructed by plotting the percentage of times that each profile zone appears. According to the authors, such conceptual profile graphs reveal the epistemological aptitudes and pedagogical thinking of each individual teacher; thus, they offer an enlightening way of classifying the professors' knowledge base from which their teaching characteristics can be analyzed and discussed. Finally, a set of Pedagogical and Professional Experience Repertoires (PaP-eRs) were joined by documenting three classes given by one of the teachers in high school and four sessions of another professor at the college level (Loughran *et al.*, 2001). A recent article uses the same methodological frame (Padilla *et al.*, 2008).

Biotechnology, an important multidisciplinary topic for this Century

Modern biotechnology has a large impact on society and requires informed decision-making and critical attitudes towards it amongst the public. It has already introduced profound changes in different fields such as agriculture, paleontology, industrial chemistry, medicine and forensic science. Indeed, the rapid growth of biotechnology during the recent decades has produced relevant advances in the field of medicine (e.g., recombinant insulin and DNA tracing), in the sequencing of the full genome of several living beings, and in the food production sector with genetically modified organisms, the last one a topic that reveals a lot of controversy and deals with complaints from the general public (Simonneaux, 2001; Zohar and Nemet, 2002; Sadler and Zeidler, 2004).

Biotechnology and genomics are set to become one of the most important scientific and technological revolutions of the twenty-first century. These are examples of 'modern science' which provide teachers with a context to show how teams of scientists, technologists and social scientists work together (France, 2007). As such, it is important that the general public understands the main concepts of these emergent topics, because citizenry must be better prepared with information and debate about the most critical biotechnology topics, especially those related with bioethics.

Several recent studies have examined secondary school and university students' understanding of, and attitudes towards, modern biotechnology (Bal, Samanci, and Bozkurt, 2007; Klop and Severiens, 2007; Sáez, Gómez-Niño, and Carretero, 2008). People will need such knowledge in their daily lives as members of the society to make personal and social choices about issues related to science and technology (Martínez, Gil, and Osada, 2003).

It results necessary to develop teaching and learning sequences for those topics in the different levels of education (Venville and Treagust, 2002; EIBE, 2007), to organize in-service courses for teachers, to implement the materials in schools, as well as to carry out more related research.

Methodology

Pedagogical content knowledge

Shulman introduces PCK as the knowledge:

> which goes beyond knowledge of subject matter *per se* to the dimension of subject matter knowledge *for teaching*. I still speak of content knowledge here, but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability.
>
> Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations –in a word, the ways of representing and formulating the subject that make it comprehensible to others. (1986, p. 9)

PCK has become a way of understanding the complex relationship between teaching and content through the use of specific teaching approaches for specific reasons.

Shulman (1987) defined PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 15). In other words, "teacher practical knowledge" builds bridges between subject matter concepts and pedagogical ideas.

Magnusson, Krajcik, and Borko (1999) propose that PCK has the five components shown in Table 1:

Table 1. Components of PCK according to Magnusson, Krajcik, and Borko (1999).

A. Orientations toward science teaching
B. Knowledge and beliefs on science curriculum
C. Knowledge and beliefs on student's understanding of specific science topics
D. Knowledge and beliefs about assessment in science
E. Knowledge and beliefs about instructional strategies for teaching science

The methodology developed by Loughran *et al.* (2004) to uncover, document, and portray science teachers' PCK comprises two tools: Content Representation (CoRe); and, Pedagogical and Professional experience Repertoires (PaP-eRs). Together, these tools are designed as both a methodology for discerning teachers' PCK as well as a way of portraying that knowledge to others.

CoRes

Four teachers were selected, two of them working in high school and the other two in college level education. Teachers' personal interviews were developed to orientate them to elaborate what Loughran, Mulhall and Berry (2004) call individual CoRe for the teaching of Biotechnology in High School. The first action to attain these CoRes is asking each interviewed the central ideas for teaching the topic. Searching for a homogeneous CoRe for all teachers, instead of having a different set of central ideas for each one, it was set a consensual procedure of repeated interviews to reach a common set of central ideas for teaching biotechnology at this level. To do so, the authors first asked the following to the teachers:

> Please, select a set of two to four topics that will be called 'central ideas for teaching biotechnology'. We use the term 'central ideas' to mean those concepts that are at the core of understanding and teaching the topic; they are those that belong to the disciplinary

knowledge which you usually use to section the syllabus. The clue is that those ideas sharply reflect the most important ones of biotechnology.
An example of a set of four central ideas in the theme of environmental chemistry could be something like this:

1) Atmospheric chemistry and acid rain
2) Ozone hole
3) Water and liquids contamination
4) Solid wastes

After having four sets of central ideas, the researchers constructed a plausible consensual set of ideas that jointly contemplated those mentioned by the teachers and interviewed them again to see if this new set would satisfy them. Some of the teachers made new propositions so a new set of ideas was constructed, and over and over again until in the third round a complete set of consensual central ideas was obtained. The result of this consensual procedure is shown in Table 2.

Table 2. Consensus central ideas for teaching the topic of biotechnology at high school level.

A. Historical outlook of biotechnology (with the origin of fermentations) and its importance.
B. DNA structure (The basic genetic material of the different organisms is the same for all of them).
C. What is genetic engineering? (From DNA to recombinant proteins).
D. Biotechnological applications towards drug and food production (Genetically modified organisms).
E. Ethics and consequences (Where does genetic manipulation lead us?).

After attaining these central ideas, all teachers received a questionnaire to write the answers (for each of the consensus central ideas) of the eight questions included in Loughran *et al.*, (2004) CoRe frame (see table 3).

The authors want to remark that each one of the questions of the CoRe is related to each one of the five elements of PCK proposed by Magnusson, Krajcik, and Borko (1999). The result of this comparison is expressed also in table 3.

Table 3. Loughran *et al.'s* (2004) original questions for each of the central ideas that constitute the Content Representation (CoRe). The second column establishes the relation between the frame of Loughran *et al.* (2004) with the Magnusson elements of PCK (see table 1 to reveal the meaning of the letters).

Loughran *et al.*	**Magnusson *et al.***
1. What do you intend the students to learn about this idea?	A
2. Why it is important for students to know this?	A
3. What else do you know about this idea? (That you do not intend students to know yet).	B
4. Difficulties/limitations connected with teaching this idea.	B, E
5. Knowledge about students' thinking, which influences your teaching of this idea.	C
6. Other factors that influence the teaching of this idea.	--
7. Teaching procedures (and particular reasons for using these to engage with this idea).	E
8. Specific ways for ascertaining students' understanding or confusion around this idea (Include probable range of responses).	D

Conceptual Profile Model

Mortimer (1995; Pp. 273-274) introduced a new way to interpret the learning process, a model for analysing conceptual evolution in the classroom: The Conceptual Profile Model (CPM).

It suggests that there may be different ways of thinking in different domains, each one represented by a CP zone, ranging from common-sense to scientific ideas. Learning science does not involve the replacement of common sense ideas by scientific ones, but rather the slow and progressive change from one CP zone to another one with a more complex level of knowledge. From this point of view, learning requires students to change their profile, which is what Mortimer means by "conceptual change": The CP change.

There are hierarchies amongst the different conceptual profile zones, by which each successive zone is characterised by having categories with more explanatory power than its antecedents. Mortimer forecasted the use of this model to characterise a pattern of teaching emphasis manifested in a given moment by a specific teacher that fully exhibits his/her commitments. He says:

> I believe that it is possible to use this theoretical framework to analyse the teaching process for this and for other concepts, which could generate future research.
> (Mortimer, 1995; Pp. 284).

Convinced of this proposal, the authors have used the CPM to epistemologically characterize the teaching of the four persons interviewed to get their CoRe, and revising the answers given to each of the framing questions of the CoRe we have defined a set of four profile zones with the following characteristics:

Perceptive/intuitive: These ideas correspond to everyday notions, strongly rooted in common-sense reasoning. These are ideas that could result as subjective, without a structure or systematization of information. The ideas resulting from a personal reflection are included here, such as simple everyday observations (i.e., the turning sour of a wine), or processes that apparently occur alone, in a spontaneous way, without external interference (as fruit ripening).

Contextual: These kinds of notions are constructed by individuals according with the social and historical context they experience; concepts or processes such as “yogurt production” or “bread or cheese fabrication”. It is vague the borderline between this zone and the perceptive/intuitive one. From a general point of view, the idea of biotechnology is related with naturally occurring microbiological phenomena observation. Although bacteria cannot be seen, this zone has an implicit microscopic component. Context profile zone it also involves ideas with an ethical sense without a formal scientific approach. Here belong practical ideas that are mentioned without a clear relation between phenomenon and theory.

Empiricist: This conceptual profile zone includes the notions of biotechnology that imply the use of empirical scales or those that express the conditions for a biotechnology process to occur. The necessary conditions to the action of some microorganism are considered in the case of traditional biotechnology or the insertion of some vector in the modern one. The use of an instrument results as a clear empiric and positive effect, even though the theory of operation of the instrument is partially unknown. At the beginning their conception of the biotechnology process is absolutely macroscopic, but immediately they turn to a microscopic explanation through the cells of the microorganisms that achieve the transformation (Simonneaux, 2000). In relation to the ethical aspects, in this zone the benefits and risks of biotechnology are discussed but without a deep insight in its moral consequences.

Rationalist: Ideas in this zone emphasizes on the foundation and theories of biochemistry to explain biotechnological phenomena, as well as the necessity to include an ethical analysis to discuss its possible consequences and the use of argumentation as a way to involve all of the students in the topic. Rationalist zone of the conceptual profile embraces the ideas of an atomic-molecular approach (nanoscopic) after having passed, through the empiricist zone, on account of the microbes level (microscopic). At the end, biotechnology is presented as a whole conceptual network: the macroscopic and microscopic elucidations are congruent with the nanoscopic one, and there exist a coherent and balanced approach amongst the three levels of explanation, and also between theoretical and empirical details. Also in this zone historical, philosophical and social aspects related with biotechnology are considered.

Constructing the conceptual profile graphs

Each one of the matrix elements of the professors’ CoRes were carefully read line-by-line by the authors to analyse its content and classify it inside a given CP zone. That task could be done with an average of thirty sentences for each teacher. The results are shown in table 4. A conceptual profile graph was constructed plotting the percentage of phrases inside each one of the profile zones (see table 5).

Table 4. Number of times for each teacher that sentences of the CoRe frame was classified as belonging to a given CP zone.

	PERCEPTIVE/ INTUITIVE	CONTEXTUAL	EMPIRICIST	RACIONALIST	SUM
Teacher 1	5	8	7	8	28
Teacher 2	2	11	7	7	27
Teacher 3	12	3	3	9	27
Teacher 4	3	9	10	13	35

Table 5. Percentage of sentences of the CoRe frame for each teacher classified as belonging to a given CP zone.

	PERCEPTIVE/ INTUITIVE	CONTEXTUAL	EMPIRICIST	RACIONALIST
Teacher 1	44.4	11.1	11.1	33.3
Teacher 2	7.4	40.7	25.9	25.9
Teacher 3	17.9	28.6	25.0	28.6
Teacher 4	8.6	25.7	28.6	37.1

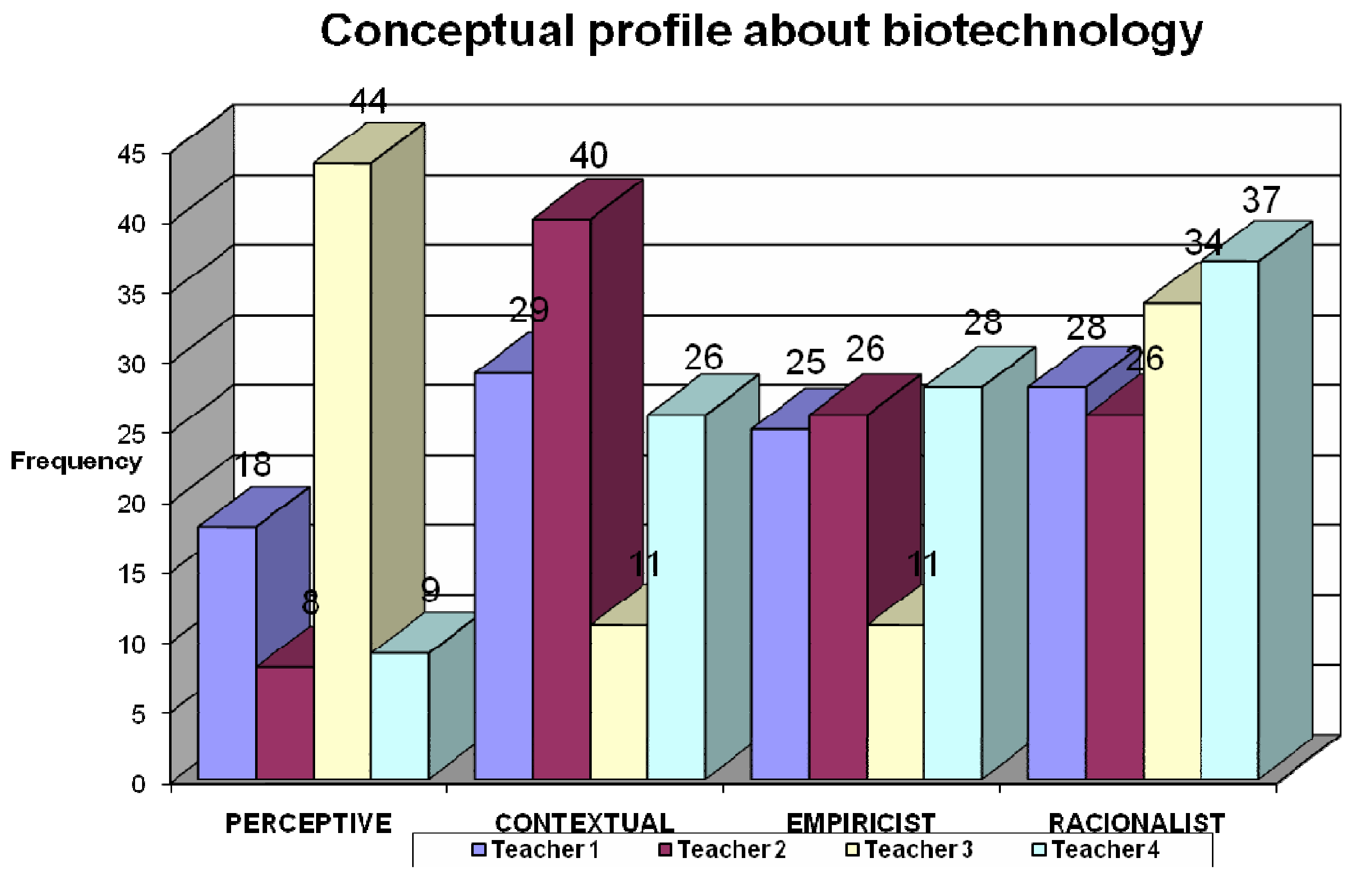
The conceptual profile graphs of the results of table 5 are shown in figure 1, at the next page of this document.

The PaP-ers collected

After concluding the CP graphs exercise, the authors attended and videotaped the classroom of two of the teachers (1 and 4 in figure 1) with a similar CoRe performance to complete the Loughran *et al.* documentation of PCK, one of them during three classes of a Biology course in high school and the other during four classes of a Biotechnology one at the final phase of undergraduate level. Results were presented as a written description or a narrative, at the style of an ethnographic research. Atkinson & Hammersley (2007) comment on this methodology that:

> ethnography usually involves the researcher participating, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, and/or asking questions through informal and formal interviews, collecting documents and artifacts —in fact, gathering whatever data are available to throw light on the issues that are the emerging focus of inquiry (P. 13).

Figure 1. Conceptual profile graphs for the four teachers.



Although in our case it was not "an extended period of time" it was enough to realize some of the objectives, didactic and assessment strategies used by the two teachers. We cannot say that it was at ethnographic research but it had the recommended feature of Atkinson & Hammersley (2007) as "People's actions and accounts are studied in everyday contexts, rather than under conditions created by the researcher".

If a representation of PCK is to help teachers to recognize, articulate and develop their understanding of that content, then clearly it must be based on an understanding of what it is about the content that the teacher knows (and has come to understand) in order to purposefully shape the pedagogy and the associated approach to student learning. As a classroom window, a PaP-eR has the advantage of being set in a context where the learners are interacting with the subject matter.

In the appendix of this paper the authors have included a short piece of the narrative of the first class of the Biology course in high school and of the last class of the Biotechnology course at the penultimate semester of undergraduate level. The authors also classified into Mortimer's conceptual profile zones the phrases pronounced by both teachers in their classes. It was found some meaningfully differences with the distribution of the CoRe sentences belonging to the central ideas C and D of table 2 related to "Genetic Engineering" and "Biotechnological applications" with those of the PaP-eRs, as can be seen in table 6. The main differences appear in Mariana (Teacher 1 before), where she had almost 30% of the sentences classified as perceptive/intuitive, but in the classroom she used only 3%, with a more intense dedication to the contextual and empiricist CP zones. In the case of Roberta (Teacher 4 before), there was less differences, except that she uses much more on the rationalist zone, that is, she mentions a more information on genetics and biochemistry in the class, compared with that of the CoRe.

Table 6. Comparison between the distribution of sentences amongst CP zones inside central ideas C and D of the CoRe frame (related to "Genetic Engineering" and "Biotechnological applications" that were the general topics of their classes) for Mariana and Roberta with the distribution obtained in their PaP-eRs.

	PERCEPTIVE/ INTUITIVE	**CONTEXTUAL**	**EMPIRICIST**	**RACIONALIST**
Mariana CoRe (C+D)	29.4	23.5	35.3	11.8
Mariana PaP-eRs	3.1	39.	47.6	10.3
Roberta CoRe (C+D)	0	20.5	58.5	21
Roberta PaP-eRs	0.4	15.2	47.7	36.6

We decided to write a PaP-eR that reflects the thinking of Roberta while giving her class. To do so, we asked her to write a sentence each time she wanted to explain the reasons behind her saying. We call that PaP-eR "What does Roberta think" and is full with ideas such as:

> I try to board each topic from the general to the particular because some of the concepts that are supposed to be known by the students are partially buried in their background knowledge.
> Something that I have observed, and in fact happened to me as a student, is that we have the tendency to mentally organize knowledge in separate compartments, according to the discipline; and this knowledge is seldom connected with each other.
> Biotechnology is a multidiscipline, because it not only involves knowledge related to biology or technology, but also other from engineering, analytical chemistry, physical chemistry, etc.
> Revisions like those of the foundations of a discipline imply hard work; it is necessary to do it, otherwise the topic on the use of such molecular tools could not be understood.

Analysis

It can be argued if the percentage of times a teacher's response is allocated into a specific CP zone typifies a pattern of thought, a premeditated emphasis or avoidance that represents a characteristic of his/her classes. It can be seen in figure 1 that the CP graph of teacher 2 has a maximum in the contextual zone, mainly due to the Science-Technology-Society focus of her/his teaching. Teachers 1 and 4 have a similar CP with an increasing magnitude as the profile zones grows in complexity, which resembles an interesting pedagogy. Finally, teacher 3 has a CP graph with high perceptive and rationalist profiles, with a "U" shape, highlighting the intuitive and extensive introduction to the topic and the final formal boarding of it. The rationalist heights of the four teachers are equivalent, showing that no matter their teaching differences all of them conclude with the scientific nanoscopic-microscopic-macroscopic equilibrium needed for the biotechnology topic.

A comparison with the results of Moreland, Jones and Cowie (2006) has confirmed their classroom-based research to describe seven constructs that have to be challenged by teachers when teaching an interdisciplinary subject such as biotechnology:

1) Nature of biotechnology and its characteristics;
2) Conceptual, procedural, societal, and technical aspects;
3) Knowledge of the curriculum, including goals and objectives as well as specific programmes;
4) Knowledge of student learning in the subject;
5) Specific teaching and assessment practices of the subject;
6) Understanding the role and place of context; and
7) Classroom environment and management in relation to the subject.

With the CoRe's expressions of our four teachers, but mainly with the PaP-eRs developed, the authors can add the following five constructs to complete a set of twelve:

8) Ethics knowledge and its discussion as an inescapable and fruitful approach (maybe included in the second construct of Moreland, Jones and Cowie, see also Conway, 2000; Sadler and Zeidler, 2004);

9) Argumentation to present evidence and how this evidence fits with explanations (Simonneaux, 2001; 2002; Jiménez, Bugallo, and Duschl, 2000; Zohar and Nemet, 2002);
10) History as a needed tool to set a convenient context to the scientific topics (Mysliwiec, 2003; Gericke and Hagberg, 2007).
11) Modelling as a necessary strategy in science teaching. Models can refer to ideas, objects, events, systems or processes (France, 2000; Venville and Treagust, 2002; Gericke and Hagberg, 2007).
12) High quality visual presentations of the topic as a needed tool (Su, 2008).

Likewise, in relation to point (9), Anat Zohar and Flora Nemet (2002, P. 57) in their work with high school students on fostering students' argumentation skills in the context of learning genetics found:

> Students in the experimental group scored significantly higher that students in the comparison group in a tests of genetic knowledge. An assessment based on both written tasks and discourse analysis also revealed several major findings about argumentation skills. The analysis of written tasks showed an increase in the number of justifications and in the complexity of arguments. Students were also able to transfer reasoning abilities taught in the context of bioethical dilemmas to the context of everyday life.

Conclusion

There is no doubt that biotechnology is a topic on the borderline of knowledge that has become one of the most delicate and important by public perception. It represents a real challenge to journalists and teachers to offer public and particularly students the daily news related to this topic. That is why one must count with the knowledge base of the best teachers, because this documented knowledge could be very useful for novice teachers to improve their didactic strategies, metaphors, analogies, examples, simulations, and so forth. The discussion of the CoRes of exemplar teachers in workshops dedicated to teachers' training could be a useful and practical recommendation of this work (Zeidler, 2002).

As the authors have demonstrated through this study, Loughran *et al.*'s (2004) methodology for capturing PCK offers an interesting way of documenting and portraying the construct and, as also illustrated here, Mortimer's CPM (1995) looks to be a useful tool for sorting the epistemological and ontological claims of individual teachers. Both methods can be used to efficiently characterize PCK and can therefore be useful in discussing divergent ways of teaching.

The CoRes of the four interviewed teachers are different, when contrasted amongst the four conceptual profiles zones developed in this study. This does not imply that one of them is better than the others; conceptual profiles cannot represent a value judgement. They utilise with different emphasis STS interactions; unalike definitions of biotechnology; didactic strategies transformed by their experience; independent beliefs and attitudes on the affective domain of teaching.

We also conclude with the five additional constructs found when analyzing those reported by Moreland, Jones and Cowie (2006): Socio-scientific issues as a way to stimulate students' development of reflective judgment (Zeidler, *et al.,* 2005; Zeidler, *et al.,* 2009); Argumentation as dialogic weapon of interaction, essential element of learning and teaching in the 21st Century (Driver, Newton and Osborne, 2000; Osborne, 2007); The historical development of scientific concepts as a way to present the Nature of Science and to give a good context idea of them (Boeck, 2007); Modeling as a necessary methodology for presenting the development of science, because the interdependence of models and explanations in science is both evident and strong (Gilbert, Boulter and Rutherford, 1998); Information and Communication Technologies as a need in this genetic information age, innovative applications of technology provide rich, authentic tasks that challenge the sorts of integrated knowledge, critical thinking, and problem solving (Quellmalz and Pellegrino, 2009; Mayadas, Bourne and Bacsich, 2009).

What lies at the heart of contemporary society –the process of knowledge generation– places an emphasis on the higher order thinking skills of constructing arguments, asking research questions, making comparisons, solving non-algorithmic complex problems, dealing with controversies, identifying hidden assumptions, classifying, and establishing causal relationships (Zohar, 2006).

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Appendix. Small pieces of Pedagogical and Professional experience Repertoires

Mariana (M.), the high school teacher

Topic: Genetic Engineering of the Biology course in the third semester of high school in 'Colegio de Ciencias y Humanidades', National Autonomous University of Mexico.

The first class starts with a Power Point presentation prepared by M. The first slide shows three questions:

> Is it possible to modify a gene in an organism?
> What is a genetically modified organism? Give examples.
> Is there a mechanism to modify genes? Explain.

After letting the students to exchange their ideas for five to ten minutes, M. ask for answers. The whole group has an answer of "yes" for the first question, so then she asks:

M.: "How have you been informed that indeed genes of a living being can be modified?"

Silence is the answer, so she encourages them giving some options and she asks for answers individually. Then some of the students say "by TV", others "by magazines", and someone dares to mention "by intuition". One student comments that vegetables are progressively larger. In that moment M. introduces the "natural selection" in contrast to the "artificial selection". She explains that the latest is a process developed by humans to select beings, trying to keep characteristics of their interest. She mentions some examples, as that of caws producing large amounts of milk, and how cattlemen are interested in preserving that characteristic to the caws progeny; or the way in which the varieties of corn have been obtained. M. says that humans have modified direct and indirectly organisms since ancestral times, through artificial selection, but she explains that this manipulation is not one related with genes. The direct manipulation of genes is something that started in the 1970's and that is generalized today. This field is relatively new and has the objective of knowing and modifying the genetic information of organisms. This kind of manipulation is known as genetic engineering.

Then M. ask for answers to her second question: "what is a transgenic organism?" The student's answers are as follows:

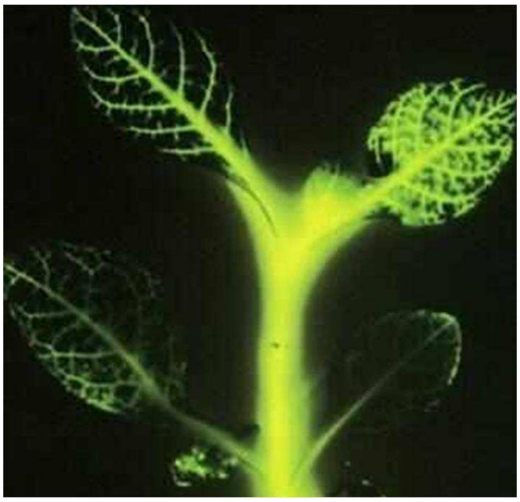
> These are organisms which genes have been modified.
> They are organisms with their genes changed to modify their characteristics.
> These are organisms genetically remodelled.

M. accepts her student's answers and she specifies that it is possible to genetically modify an organism, which then is known as transgenic, because genes of another species have been inserted in its genome: "What could be an example of a transgenic organism?"

Students mention some vegetables, Ninja turtles and clonation. After exchanging some smiles with the boy that mentioned 'Ninja turtles' she says "Those are fictitious animals created by the imagination of children. You are not a child, but now you are behaving as one". Clonation says M. is a process different to transgenesis, trying to answer to a student that asks: "Is it possible to select all the characteristics of a baby?"

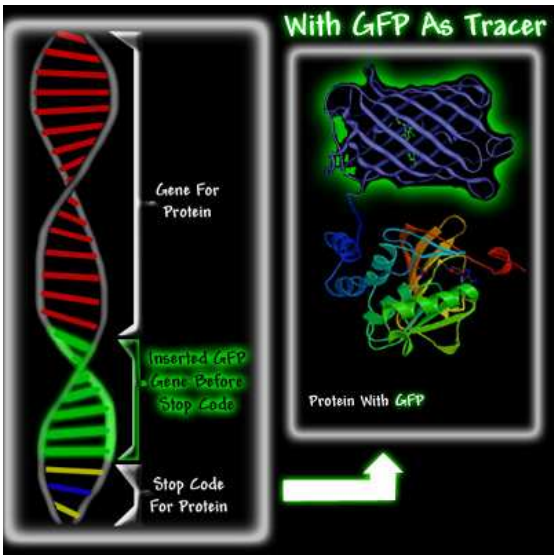
Nevertheless, some vegetables are transgenic organisms. Then she shows a slide with a genetically modified tobacco plant made bioluminescent with the insertion of a gene of a green fluorescence protein (GFP, shown in figure 2).

Figure 2. A bioluminescent tobacco plant, example of a transgenic organism. The 2008 Nobel Prize in Chemistry honors Osamu Shimomura, Martin Chalfie, and Roger Y. Tsien for the discovery and development of green fluorescent protein (GFP). Engineered variations in GFP result in a rainbow of fluorescent proteins.



So now, we go to the third question, says M.: “How genes can be modified?” Then M. does not wait for an answer and shows a slide with the two helicoidally plaited DNA chains in which a GFP gene has been introduced (see figure 3).

Figure 3. M. shows a green portion of DNA that has been inserted in the DNA of the organism. This portion corresponds to a GFP gene that DNA uses to codify for a GFP (in the upper part to the right of the diagram), which makes the organism bioluminescent.



The class continues with the mention of restriction enzymes that cut the DNA in specific sites and can be also used to insert genes of a different organism inside the genome of the original one. M. talks also about plasmids, small DNA rings, vectors that introduce the genetically modified portion as a way to answer the question on a mechanism to modify genes... and so on.

Roberta (R.), the college professor

Final section on the subject: Enhancement, isolation and preservation of industrially relevant microorganisms, taught at the Biotechnology course during the eighth semester of undergraduate studies on Food Chemistry at Chemistry College, National Autonomous University of Mexico.

… Suddenly, R. says:

R.: Before we begin. If somebody asked what do you think about transgenic plants, and he would tell you they have genes that make them antibiotic resistant, you'd probably say "only a lunatic may think such thing" or you would be suspicious. But now you know antibiotic resistance is part of the procedure to obtain a construction. Frequently those selectable markers, such as antibiotic resistance genes, were not removed in the past, because nobody thought they could become such fuzz. This is why nowadays other types of markers are utilized….

The professor goes on explaining that under controlled conditions and using competent cells, the probability for the technique to work is very little. However, certain organizations, such as Greenpeace, claim that because transgenic food contains genes codifying for antibiotic resistance or toxins that serve as insecticide, this food is toxic. In this issue, they are unwilling to further discuss the evidence. The professor explains in the case of the toxins, that they only affect lepidopters. In the gut membranes of lepidopters, there are specific receptors for the toxins, which upon binding to the receptors cause the formation of pores in the membranes. Mammals' membranes do not possess the receptors and thus the toxins cannot possibly affect them. The professor explains that when humans or cows eat transgenic maize, nothing will happen to them. The professor adds that regarding antibiotic resistance, the environmentalists often argue that by eating food containing antibiotic resistance genes, the bacteria in the gut will become resistant, and that some of these bacteria are pathogenic. However, she clarifies, everything we eat is digested, for example, eating carrots means also eating carrot DNA, and our color never changes to orange. She explains the entire DNA we eat is turned into little pieces of nucleotides and the probability for the genes codifying antibiotic resistance to remain intact is very tiny. However, assuming that this fragment does remain intact, she asks what would be the probability for this fragment to enter an incompetent host cell, considering that under favorable conditions and with competent cells the probability is very low. She says it is more likely that a sequence of several amino acids remains, which is not easily digested by our proteases, and if this sequence enters the blood stream it may trigger an allergy. Nevertheless, there is food such as strawberries, eggs and other that have not been subjected to any genetic modification and still are able to trigger allergies in certain people. She recommends being objective when making judgements and says:

R.: This doesn't mean I am in favor of transgenic products; it is just that science says one thing. Now, if for us it is convenient or not for political, economic, social or ethical reasons, that is another thing. But the technical issues are those we just discussed. You have to be responsible and think about these things so you can reach to your own conclusions.

The professor mentions an example related to food production, saying that a protein from a polar fish that has anti-freezing properties was isolated. This protein was thus utilized for the production of ice creams, turning them softer and creamier. Later, she tells it was attempted to produce this protein at industrial scale through molecular biology techniques. However, some countries did not accept an ice cream formulated with transgenic products.

Another example she mentions is regarding to wine production; if the yeasts that are involved in wine production were genetically modified, in such a way that they could also utilize the grape skin for fermentation, the yield would improve. However, she repeats that just like in the previous example, it is not easy to introduce a transgenic microorganism; in fact many countries, especially from Europe, categorically refuse. Likewise she mentions other examples and at the end she says:

R.: Well, here we finish with the subject, remember we just discussed the least you need to know so that when you read something you can understand it, or when you have to make a decision or give an opinion, you do it in an informed way. Now, if you would like to learn more on the subject there is an optional course you may take…