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Biological education, ethics and society

We are currently going through our fourth significant cultural revolution... Astronomers such as Copernicus and Kepler "expelled" us from the centre of the universe while Lamarck and Darwin convinced us that we are a mere historical product of Life on Earth. Einstein, Max Planck and Niels Bohr completely changed our references in terms of space, time and matter. And now, contemporary biologists are destabilizing our conception of humankind by simultaneously transforming our genome, our environment and the ways in which we reproduce.

These are the cover stories in print and on air: should we develop GMOs, loosen restrictions on stem cell research, introduce various modes of cloning, either for reproductive or for therapeutic purposes, etc? Such debates challenge us as biologists, since the potential consequences are considerable, both in terms of ethics and in terms of citizenship. Yet, as a community, we do not give enough importance to such issues. Conferences abound, with lively debates on such decisive questions. Unfortunately, too few biologists take part.

What about the economic entanglements surrounding the genome? The growing therapeutic use of our bodies as spare parts? Our selfishness with regard to the biodiversity of developing countries? Or, more generally, the ecological and health consequences of some kinds of research? Simply advocating the "precautionary principle" as a slogan, without defining it further or grounding it in specific situations, must make us realize its limitations and highlights our incompetence.

Debates and Citizenship

In the Life Sciences, the cell was taken to pieces and many of its mechanisms understood. Genes and DNA were analyzed. Few years ago, the human genome was almost entirely decoded. Every day, new horizons open in medicine and other branches of the life science. Of course, everything went too fast, much too fast. And all this knowledge remains very inadequately disseminated. Over the past 20 years, all surveys have shown the extent to which the public is removed from scientific knowledge.

Evaluation of student knowledge

Several evaluations have been carried out, several on students at the beginning of the university (Giordan, de Vecchi 1987, Bayerhuber, Brinkman, 1998). Every time, we find a lot of misconceptions in the student minds. The links between chromosome, gene and DNA seem not to be established (Fig.1).

Fig. 1. Misconceptions of students (end of secondary school) on gene (*in red*)

The concept of cell is misunderstood by most of the general public (Giordan 1998, Fig. 2).

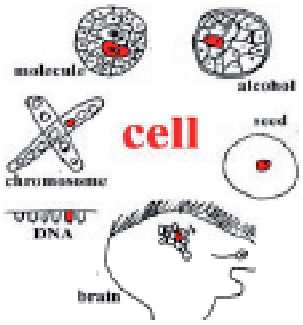


Fig. 2. Cell misunderstood (*in red*) in general public

The same conceptions identified in very young children are found unchanged in College after 1, 2, 3 courses during the secondary schooling, as the example below on the nutrition demonstrates (Giordan, de Vecchi 1987, Clément et al 1991, Fig. 3).

Fig. 3. Nutrition conceptions at different school levels

And this is not our most serious problem. The image of the sciences has deteriorated, while the irrational spreads through our society. Science is no longer automatically associated with the idea of progress. On the contrary, it generates fear. A survey recently conducted in Europe shows that while Europeans are prepared to accept therapeutic innovations, their doubts with regard to other applications should not be taken lightly.

Worse, numerous scientific practices, beginning with genetic manipulations, are vigorously rejected by certain categories of the population. And the most virulent detractors of GMOs do not come from the most conservative groups in our society, but from progressive circles and environmentalists.

Biological progress has been accused of triggering unemployment or accused of being at the origin of dramatic problems that threaten our planet (climate changes, holes in the ozone layer, etc.) and our health (mad cow disease, the contaminated blood scandal in France). Moreover, the scientist is no longer the "father" of the people or the "saviour of mankind". Particle physicists, molecular biologists and geneticists all appear on the television as "cold" researchers, dehumanised, avid for power, in the service of multinationals.

As a community of biologists, we must prioritize the teaching of biology in schools and its popularization in the media. The education we offer in schools, colleges and universities is in need of a major rethinking.

Biological Education and Popularization

Biological curricula

Most of the secondary school curricula in the world propose a multitude of non-situated details. Information is broken down into bits, without landmarks, references to our present society or any other perspective. Biology is taught in and of itself without any link to the ethical issues involved (Engleman, 2001). Furthermore, students are bored by frontal teaching or ritualized practicals.

Several areas of work are becoming urgent. It is important to renew our students ' interest in biology. In particular, by making their lessons more meaningful. Thought is fed by experience. Awareness only grows from wonder and can be extended by a multitude of questions, the desire to learn, even understand. A large place must be given to the acquisition of investigative approaches in biology (see Fig. 4). How to change attitude toward biological knowledge? How to increase curiosity? How to develop receptivity to actual questions?

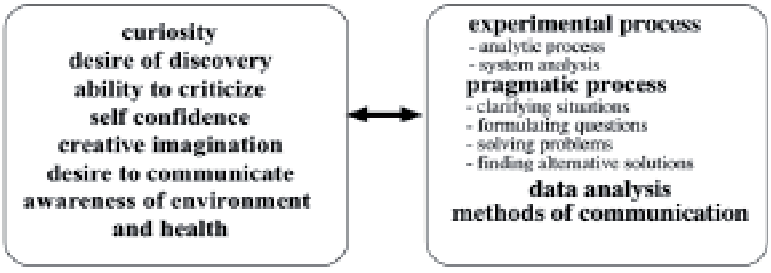


Fig. 4. Parameters for investigative approaches in biology

Also, it is important to pinpoint key landmarks which would help students find their way among the big issues of our time. Transmitting experiences and perceptions of the world is an iffy business. A few "organising concepts" would allow learners to link and situate various data (Fig. 5).

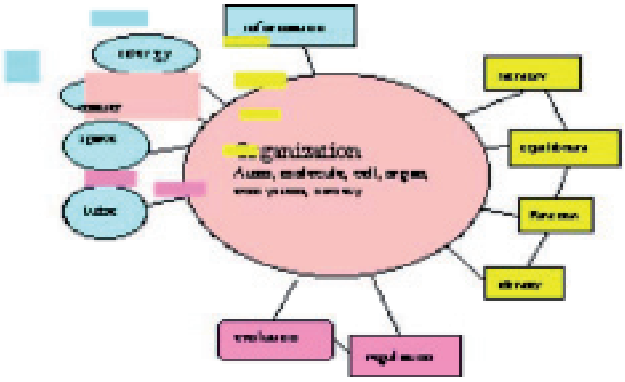


Fig. 5. Organizing concepts in Biology

Finally, it is important to integrate the underlying ethical and social issues when presenting each area of biology. However, when teaching ethics, first and foremost we intend to teach questioning, avoid ready-made certainties and leave room for many possible answer.

Educational strategy

As biologists, we have to "transform" our knowledge and also our scientific approach to take into account the pupil knowledge, the general public understanding. Not to stay at the level of the learner, but to increase or develop their conceptions* (Fig. 6)

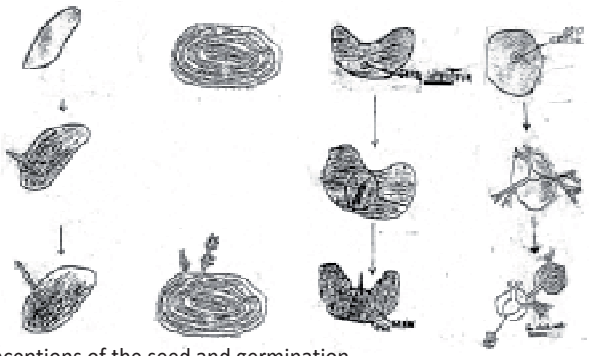


Fig. 6. Student conceptions of the seed and germination

First column: the plant is produced by the interaction of matter of the seed and water
Second column: the plant is already present in miniature inside the seed
Third column: there is a seed inside that produces the plant
Fourth column: It must meet two seeds to produce the plant

* To know more about the new didactical approach, see papers on *allosteric learning model* on the web site : http://www.ldes.unige.ch/ang/edito/septembre2005/septembre2005.htlm

That pedagogical evolution in biological education is to be introduced at school, at university and in museum (Fig 4.)**. At the same time, it's also a question of putting your finger on the situations, arguments, and documents that can overlap with learners' thoughts to make them progress. A system of multiple interrelations must be set up between learners and the object of knowledge. The probability of learners discovering the whole set of elements capable of transforming their questions or furthering the construction of networks is practically zero (Giordan, Girault 1996, eds. see Fig. 7).

At the current stage of research, it is possible to pinpoint these elements in some specific subjects. A networks of parameters and constituent constraints can equally be advanced. Its objective is to decode bit by bit, and in the light of specific knowledge, various types of learning in the form of a "nuanced", systemic and multi-stratified entity, where self-regulating loops and levels of integration are put to the fore.

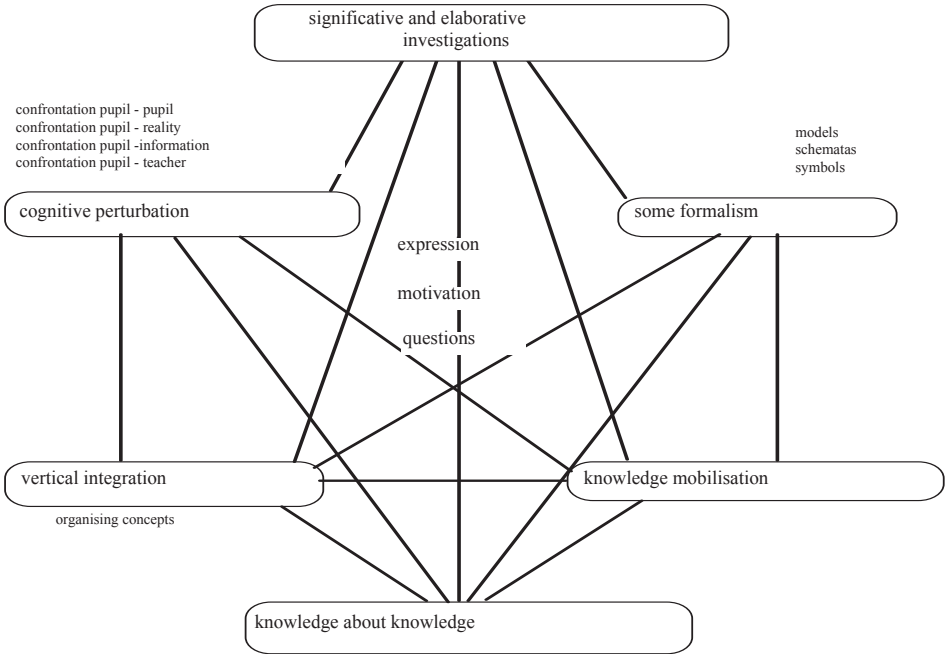
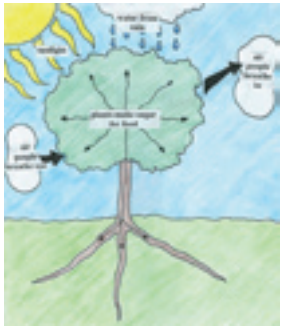
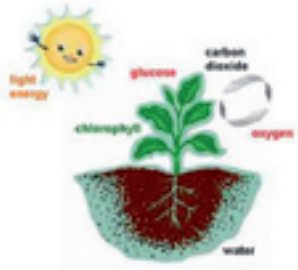


Fig. 7. The parameters of an allosteric environment

At the beginning of any learning, a certain degree of dissonance perturbing the cognitive network formed by mobilized conceptions is indispensable. This perturbation creates tension, which disrupts or displaces the fragile balance that the learners' brains have put in place. This dissonance creates progress; without it learners have no reason to change their ideas or way of doing things, and even less reason to be concerned with the exposition's theme. They must find an interest in it, a sense in the project or the knowledge at hand.

** In parallel, other avenues have been explored, as computer learning (Potyrala 2007).

Tab. 1. Learning strategy on Plant nutrition (photosynthesis)

1. Initial conceptions of the pupils	2. Educational Objectives (end of compulsory school)	3. Allosteric strategy
– "*plants are nourished (essentially) in the soil by their roots*" – light = *"a fortifier" or "a vitamin"*. It *"acts through its heat"* – carbon gas = *"harmful product"* somehow involved with breathing 	*The plant does not nourish itself, but can manufacture its own matter from simple elements by combining water and gas, thanks to the energy from light.*	Major deconstruction work has to be carried out parallel to the construction work: > perturbations: plants without soil, hydroponic cultures, aerial tropical forest plants, water lentils, wretched things under glass. They can lead students to reflect on what "happens" with plants that grow without soil (hydroponics). "*What and how do they eat?"* They may be working on duckweed or branches of misery that grow directly in water. But these arguments are not sufficient in itself for them to accept that the plant does not "eat" its substance in the soil ("*they eat in the water*"). The plants of tropical forests that grow directly overhead on the flanks or in the flats nylon are even more interesting. > real confrontations (learner-reality confrontations, learner-learner confrontations). In particular, they lead them to test their ideas throug h experiments or observations (changes in various experimental factors: light, temperature, CO2 concentration, mineral alt s, etc..). They lead to a reformulation of the problem (that means: "food"?) Or / and to consider other relationships (food-energy relationship). > schemas and models make it easier to develop the new concept. chlorophyll/ light energy carbon dioxide + water →→→→→→→→ sugar (glucose) + oxygen  > "thinking aids" (conceptograms) help to progressively regroup the different items of information and put them in perspective and introduce new real investigations (*"what is the light?" "is it a tonic?")*. These activities lead to the identification of elements involved in nutrition (or growth) of the plant, most often to reformulate the problem (*"what means food for a plant?")* Or / and to consider other relationships (*"is there a relationship between food and energy?").* Patterns, global models allow to relate the various parameters, they facilitate the development of the new design. > moments of mobilization will be necessary afterwards. It is necessary to provide situations where the learner can use his or her new knowledge (e.g. the role of photosynthesis in food webs, crop yields).

Later, learners must find themselves confronted with a certain number of significant elements (documentation, experimentation, argumentation) that challenge them and lead them at once to take a step back, and to reformulate their ideas or debate them. In the same way, a certain degree of limited formalism (symbolism, graphs, schemata or models), some kind of thinking aids, must be integrated in their approach. I might add that a new formulation of knowledge doesn't replace the old unless learners find an interest in it and learn to make it function. At these stages as well, new confrontations with adapted situations, with selected information can be profitable in permitting the mobilization of the knowledge.

Lastly, knowledge about knowledge is also desirable. It permits learners to situate the procedures, to step back from them, or to clarify the field to which the knowledge will be applied. For each of them, our micromodels are as many tools for deciphering constraints, and forecasting situations, activities, and teaching practices favouring learning, as shown in Table 1.

Popularization of biology

New activities can be imagined to contact people who are afraid of the fast development of biotechnologies, such as "miniU" (mini-university), miniLab" (mini-laboratory), "Feast of the Science" or "Night of the Science", organized outside the schools and outside the laboratories…

This sort of evenments can present "consultations" with biologists, workshops, productions, theatres.

Through these events, the priority is to change the relation between researchers and the public. Researchers have to be taught to lend an ear to people's concerns. They must abandon the idea that they can change the image of science simply by disseminating information. The gap is too great. Scientific education, its programmes and pedagogical methods, will have to be rethought – especially in secondary school. Popularization in science also requires new strategies. In this field there is a bigger, more significant obstacle. Behind the fear of GMO, mobile telephones and biotechnologies lie deeper questions, questions of "of society". They involve notions such as "progress", "expertise" and the "principle of precautions", which are subject to diverging visions and interpretations. These issues are recurrent and generic and therefore should be treated as such.

Conclusion

With *allosteric situations*, the whole question of teaching or popularization becomes clearer. New functions for biology teachers or mediators have thus been corroborated. Their importance lies no longer a priori in their lectures or demonstrations. The efficacy of their action is always situated in a context of interactions with the learners' conceptions and didactical strategies. First and foremost, is their role in regulating the act of learning, their capacity to engage the students or general public, to provide orientation, or to impart aids in sensibilization or conceptualization.

At the same time, it seems important to increase researchers' awareness of these issues, and to train them "to engage the public". 90% of scientists have never received training in communication, media or knowledge of segments of the general public. Very few of them have had an hour of formation in science and ethics or in

science and society. The youngest researchers are key targets, so as to take this direction into account early in their career.

It is vital to accompany them:

– in making material that can give them arguments and ideas of situations they can create,
– in inventing new ways of engaging the public (theatre, role game, consultation point, assessment).

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Biological Education, Ethics and Society

Abstract

Questions about living organisms are never neutral, and there can be no single answer. What is possible to do with biotechnology? Who should decide? Without biological references, individuals are just as illiterate today as they were last century if they couldn't read.

The biological community must have clear projects. First, we must question ourselves – as some already do – regarding biology's place in society. Criticizing some biological practices, seeing how its approaches are becoming social challenges, considering the way in which the market, or policies, determine research, does not mean having an anti-scientific attitude. Instead, biologists must engage in such a questioning approach. If not, what is the purpose of knowledge without meanings?...

Finally, how to introduce a biological education and mediation in link with society and ethics. The "solution" is not only additional classes, more concepts, or more public information regarding the contents and methods of research. What appears to be a possible key, is to trigger openness and availability in each individual's mind, and to foster their curiosity for that which is not obvious, for problems.

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