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THE CHALLENGE OF CONTEMPORARY SOCIETY ON SCIENCE EDUCATION: THE CASE OF GLOBAL WARMING

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Abstract
The big problems that contemporary society needs to address (e.g. climate change) challenge our traditional idea of education and require to revise the goals of science education research. Such problems are indeed so complex as to require a wide range of competencies to be engaged in producing and implementing solution strategies. Science education is forced to take into account the many dimensions that characterize contemporary science and to face the task of bringing together the potential of all the different perspectives (Tasquier & Nonni, 2011). An example of this kind of research, concerning environmental problems, will be briefly described and its first encouraging results illustrated.

1. A research on teaching about complexity
The Global Warming (GW) issue is a problem which existed from more than twenty years. However, it is difficult to capture a deep interest and attention by the general public due to its complexity and the interweaving between different levels/dimensions: scientific, cultural, psychological-behavioral, political-economic and ethical.
From the perspective of Science Education the environmental issues require a rethinking of scientific content and a review of the traditional curricula because of *i)* the inter-disciplinary nature of the topic; *ii)* the disciplinary problems linked to the construction of some important Physic concepts (i.e.: transparency, absorption, emissivity); *iii)* the effect and the role of the scientific controversy/debate.
From the perspective of Sociological/Behavioral research, the environmental issues require to investigate the emotional attitude of citizens with respect complex issues, like global changes, that have important impact future (Pongiglione, 2011).
A research has been started at the Physics Department, University of Bologna, supported by the CIRE (Interdepartmental Center for Educational Research), aiming at designing a teaching proposal on GW based on the contributions of different fields of research (Tasquier & Pongiglione, 2011).

2. First results of the research project
The research work carried out so far has been divided into three phases, that will be described in details in the paragraphs below:
a) To identify the main emotional, cognitive and cultural barriers that prevent the individuals from engaging in actions that can limit GW (contribution from psychological/behavioral research);
b) To identify operational criteria for rethinking the disciplinary contents coming from the analysis of barriers (joint contribution of different fields of research);
c) To make explicit the criteria by applying them to simple models of explanation of GW (contribution of Science Education research).

a) Identifying emotional, cognitive and cultural barriers
The first phase consisted in the analysis of some important European reports (IPCC, 2007; Norgaard, 2009) where some behavioral barriers, which come from the way people perceive the risk of GW, can be identified. We summarized the research results in three kind of barriers that are described below.

i. *Not individual but collective.* The lack of understanding of some basic climate dynamics can cause the climate problem to be perceived by people as concerning only a global and not an individual level: the individual does not take its role as "causal agent" in the interaction between man and nature.
ii. *Too big or too small.* Two opposing perceptions of the risks associated with climate change can both cause reactions of "denial" of the problem. If risks are seen as too big, the individual

feels he can do nothing about them and therefore does not care; if risks are seen as too small, the individual feels to be entitled to neglect them. The uncertainty that characterizes some aspects of the scientific debate, produces disorientation, loneliness and sense of guilty.

iii. *Too far.* To individuals it is not clear what are short-term and what are long-term risks: the present generation feels to be called to "pay" for a probable good of the future generations.

The research in social/behavioral science shows that there is an emotional attitude which manifests itself in divided feelings as guilt, confusion, frustration. Faced with the complexity of the debates on environmental issues, like global warming, people have a different kind of "fear" than respect to cataclysms or disasters. This kind of fear acts at a deeper level and causes people to keep a safe distance from the issue of climate priorities. The unknown, the uncertain, the complex, the debated, all generate a sense of disorientation and a feeling of inability to act (Pulcini, 2009).

b) Defining operational criteria for disciplinary reconstruction

The second phase consisted in defining some operational criteria to guide the process of discipline reconstruction that can allow science education to contribute to overcoming the emotional/cognitive/cultural barriers:

i. As far as the barrier *Not individual but collective* is concerned the corresponding criteria is to make the role of the individual explicit - what interaction between man and nature - in the modeling of global warming.
ii. For the barrier *Too big or too small* the criteria is: to make it explicit, in the modeling of global warming: what is shared and what is under discussion; examples of causal connections, typical of complex systems, between man-nature-technology and examples of feedback to show that small causes can have large effects and back again.
iii. For the barrier *Too far* the criteria is: to place, the examples already treated, on a time scale, typical of an evolutionary approach to complex systems, to reflect on possible future scenarios (i.e.: the melting of glaciers).

c) Applying the criteria to the GW model

The third phase consisted into applying the criteria to a simple model of GW explanation (Rizzi, 2011), where the main role is played by the *coefficient of absorption in atmosphere (a).*

In the model we have chosen it is possible to apply criterion *i)* because it is possible to recognize the central role of human action in the variation of the parameter *a*.

It is also possible to apply criterion *ii)* because it is possible to show examples of causal links and feedback mechanisms (i.e.: If *a* increases → then T increases; if T increases → the glaciers are melting; if the glaciers are melting → *a* increases).

As far as criterion *iii)* is concerned the model offers the possibility to raise the issue of the predictive character of the models that study the evolution of complex phenomena, like the melting of glaciers.

3. Future developments

This synthetic description is intended to highlight the importance and the potential of a reflection on the changing role of Science Education to face big problems that society needs to address.

The results already obtained support the hypothesis that addressing the issue of GW from different perspectives may help to develop teaching materials on this topic able to convey the message that:

- The scientific controversy does not concern the existence or not of GW, but it concerns the predictions of the models in terms of consequences of the GW;
- The models of GW cannot show a power of prediction in classical terms (like in Classical Mechanics) because the phenomenon is intrinsically complex and multi-dimensional.

To introduce the epistemological dimension, in particular epistemology of complexity seems potentially able to provide students with cultural tools to rationally navigate in the jungle of ideological wars about environmental issues.

This is an important goal for Science Education in the challenge of finding an effective perspective, not only for teaching Physics, but also for educating young people to Scientific Citizenship.

The future research development includes design of a teaching proposal for introducing GW as a topic in physics teaching at higher secondary level, integrated in a wider teaching path about

Thermodynamics, already produced and tried out by the Physics Education research group of the Bologna University (Tasquier, 2009; Levrini et al., 2010).

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