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How to help pupils to build up scientific problems in biology lessons

Patricia Schneeberger, Yann Lhoste, Brigitte Peterfalvi

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Science learning and Citizenship

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This ebook contains fourteen parts according to the strands of the ESERA 2011 conference. Each part is co-edited by one or two persons, most of them were strand chairs. All papers in this ebook correspond to accepted communications during the ESERA conference that were reviewed by two referees. Moreover the co- editors carried out a global reviewing of the papers.

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HOW TO HELP PUPILS TO BUILD UP SCIENTIFIC PROBLEMS IN BIOLOGY LESSONS

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Abstract: Our research aims at highlighting the conditions that allow the pupils to build up scientific problems during sessions including moments of debate in biology lessons. Our project is in line with the researches conducted in biology didactics on the role of linguistic interactions in scientific learning. In this study, we try to clear up the strategies used by teachers to change pupils' understanding of biological phenomena and encourage their involvement in the building up of a scientific problem. Our research data were collected in a 6th grade class and in a 10th grade class. Through examples observed in these classes, we have examined the way teachers manage a discussion about pupils' different attempts at explanations and how they lead them to change their points of view. In this contribution, two biological topics are concerned: the recycling of the organic matter in ecosystems (6th grade class); the supply of dioxygen in the body (10th grade class).

Keywords: linguistic interactions, problem building, enunciative posture, professional gesture, inducer of problematization

1. INTRODUCTION

Our research aims at highlighting the conditions that allow the pupils to build up biological problems during sessions including moments of debate in the classroom.

We try to clear up the strategies used by teachers to change pupils' understanding of a biological phenomenon and encourage their involvement in the building up of a scientific problem.

In our analysis of the teacher's activity, we have tested Fabre's and Musquer's hypothesis (2009a, 2009b), especially their idea of "*inducer of problematization*". In spite of the wide variety of inducers of problematization implemented by the teachers, we found similarities between the two analysed sequences. In this paper, we study some of those similarities. This study allows a better understanding of the process of problematization.

2. RATIONALE AND PURPOSE

In French secondary school, science teachers are encouraged (by recommendations from their hierarchy) to organize their teaching around a scientific problem but most often they present the problem to the class and the pupils have to try to solve it. In this case, the question of the construction of the problem is avoided and its role is often underestimated

A specificity of our approach is related to the articulation between the theoretical framework of problem building - elaborated by Fabre and Orange (1997), CREN laboratory, university of Nantes - and a socio-historical approach of learning, which considers that school must allow pupils to rebuild knowledge available in culture and the ways of thinking, speaking and acting associated with this knowledge (LACES laboratory, University of Bordeaux: Ponce & Schneeberger, 2002 ; Lhoste, 2008; Rebière, Schneeberger & Jaubert, 2009; Schneeberger &

Vérin, 2009). More precisely, we assign a decisive role to the pupils' problem building in the construction of biological knowledge.

The teacher's role is complex because he or she must encourage pupils to move from a position rooted in everyday life to a scientific approach. At the same time he or she must ensure a psychological continuity and he or she must also impulse an epistemological rupture between the first questions and the biological problem. Many studies conducted by researchers in biology didactics try to understand how the teacher manages to introduce a scientific problem to the class and to what extent it is possible to associate the pupils in the process of problem building in biology.

With reference to a rationalist approach, we argue that the main goal of science-teaching is to enable pupils to abandon common-sense reasoning and to develop a scientific approach of the understanding of biological phenomena. Such an improvement is possible only if teachers set up adequate teaching situations, which implies obeying specific conditions which characterize the scientific activity. We propose to investigate these conditions, particularly those that promote the pupils' involvement in a scientific problem building.

3. THEORETICAL BACKGROUND

During our research, we used the concept of "inducer of problematisation", developed by Fabre and Musquer (2009a, 2009b). These authors assume that various kinds of "inducers" can act to stimulate specifically different cognitive operations involved in a process of problematization.

Figure 1 is a model of the process of problematisation according to Fabre (2009) completed with inducer of problematisation (Fabre & Musquer, 2009a, 2009b)

Various kinds of "inducers" can act to stimulate specifically different cognitive operations involved in a process of problematisation.

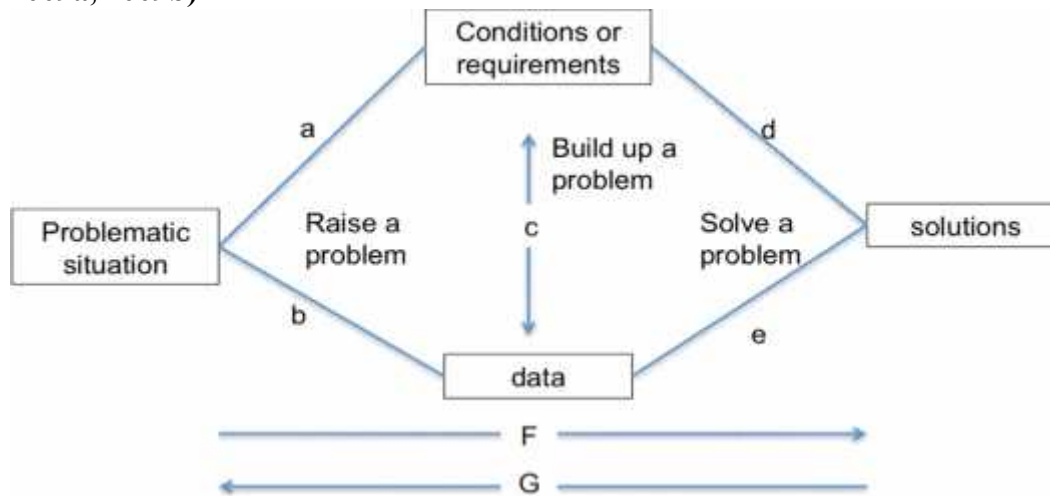
Macroinducers are directly connected to the situations and to the tasks proposed by the teaching devices :

- F: inducer F leads to building potential solutions
- G: inducer G leads to consider solutions, whether possible or not, in a critical way, by reconsidering the problem

Other inducers, less obvious, are linked to the teacher's oral interventions during the debate :

- inducers helping to pose the problem, with more or less specification of the conditions (type a) or the data (type b)
- inducers aiming at the expression of hypotheses or critical analyses of solutions according to the conditions (type d) or the data (type e)
- inducers aiming at connecting the conditions and the data of the problem

Figure 1. Model of « inducer of problematisation » (according to Fabre & Musquer, 2009a, 2009b)



4. DATA & METHODS

Using examples observed in classes of different levels on various biological topics we have examined the way teachers manage debate from different pupils' attempts at explanation and how they lead them to change their points of view (Schneeberger et al., 2007; Schneeberger & Lhoste, 2010). More precisely, we study how the teacher acts in order to make the pupils consider the problem as their own. For this purpose, we examine how the problem, as the teacher formulated it in his or her preparation papers, is introduced to the class, how the discussion before and after its formulation contributes to make pupils understand its meaning as a real problem. We search what conditions the pupils have to build up before understanding the meaning of the question and how the teacher acts to make it effective.

Our research data were collected in a class of 11-12-year-old pupils (6th grade) and in a class of 15-16-year-old pupils (10th grade) whose teachers are associated with the researches conducted by our teams. The data collection took place during sessions including moments of scientific debate in class.

The corpus includes various data

- the teachers' preparatory work;
- the transcripts of the video recordings of the session;
- the transcripts of the teachers' interviews (self-analysis)
- the pupils' written tasks

Two topics were studied during the sessions.

- The 6th grade pupils (11-12 years old) study the recycling of organic matter in ecosystems. This lesson aims at explaining the origin of mineral salts in the soil in order to enable the pupils to connect the presence of mineral matter in the soil with the decomposition of organic matter thanks to the action of the decomposers.
- The 10th grade pupils (15-16 years old) study the supply of dioxygen in the body during physical effort. This lesson entitled "The functioning of the human body" aims at initiating the pupils to the concept of integration of the functions of the human body, as the official French education curriculum specifies: "the contents of this chapter constitute a first approach of the concept of regulation".

4.1. Extracts from the French curriculum

Table 1. The content of the French curriculum

6th grade	10th grade
<p>“Origin of the matter of living beings” (2008)</p> <p>This lesson aims at introducing the pupils to the recycling of the organic matter in ecosystems, so as to take it into account with the objective of sustainable development.</p>	<p>“The functioning of the human body” (2001)</p> <p>This lesson aims at introducing the pupils to the <i>concept of integration</i> of the functions of the human body. The contents of this chapter constitute a first approach of the concept of <i>physiological regulation</i>.</p> <p><i>The chosen topic is the study of the variations of the cardiovascular parameters in the human body during physical exertion.</i></p>

Our study is a qualitative study. The transcripts of the two sequences were analysed by focusing on what could characterize problem formulation in biology teaching.

Table 2. The two studied classes

6 th grade class	10 th grade class
<p>11-12 years old, 13 students</p> <p><i>10 cm of leaves gather on the soil every year, but after 100 years we don't walk on 10 m of leaves</i></p> <p>Explain what happens to the dead leaves.</p>	<p>15-16 years old, 30 students</p> <p><i>During a physical effort more oxygen is provided to the muscles whereas the oxygen rate in arterial blood remains the same.</i></p> <p>Explain how the muscles are supplied with dioxygen when the consumption increases.</p>

Our analyses mainly focus on one lesson in each class.

4.2. Methodology

Our methodology includes two steps :

1/ A “microscopic” analysis of every script :

- Identification of moments considered as important with regard to an epistemological point of view.
- Coding of previous interventions with an identification of the different inducers

2/ A comparison between different sequences about different topics observed in classes of different levels

5. RESULTS

5.1. A common characteristic

The analysis of the transcripts of the two sequences has allowed us to identify common points which could characterize problem formulation in biology teaching.

The analysis of the transcripts of the two sequences has allowed us to identify common points which could characterize problem formulation in biology teaching. Indeed, in both cases, the formulation of the paradox (where the problem is) does not appear immediately, contrary to what is implied in the examples of problem situations given by some authors (De Vecchi). Instead, it requires the construction of ideas without which the problem does not make sense for pupils.

6th example

In the sequence of the sixth grade class (recycling of organic matter in ecosystems), in order to formulate the paradox as such (20cm of leaves fall down every year, but after 100 years we don't walk on 20m of leaves), the pupils must have some idea of the conservation of the quantity of matter.

6th grade

After 100 years of deposits of 20 cm of leaves a year, the thickness of the ground has not increased while it should be 20 m thicker.

Condition to raise the problem : the idea of conservation is accepted by the pupils

Before formulating the problem to deal with, and just after having done it the teacher (Corinne) does not prompt pupils to enunciate this condition of the conservation of the quantity of matter straight away, but she leads them to reason in a way that includes this idea. This way, the pupils are enabled to understand the paradox as such (35-36). When the specific problem is formulated, the reasoning the teacher aims at encouraging implies that the idea of conservation is accepted by the pupils.

- 35 Teacher: Yes / but once they're on the ground it's no longer living matter / all that can become dead organic matter in the end // the question is what what becomes of that dead organic matter /once it's there (put the « dead MO » label on the poster)
- 36 Pupil: It decays
- (...)
- 42 Teacher: Yes / we should walk on dead leaves 20m deep
- 43 Pupil: Ah //
- 44 Teacher: Dead leaves 20m high / that's nearly as high as that building / so when you go for a walk in the forest do you really walk on dead leaves 20m deep ?
- 45 Pupil: Well no / xxxx / it's transformed/ xxxx
- (...)
- 107 Pupil: Baptiste says it's because of animals / animals make it get smaller
- (...)
- 113 Pupil: So Baptiste you said a while ago what animals do
- 114 Pupil: They eat them
- (...)

- 131 Pupil: But they'll decay anyway xxxx
 (...)

136 Teacher: What sort of earth does it become //

137 Pupil: Maybe some sort of a fertilizer
 (...)

150 Teacher: Stop stop stop / I'll write that/to help plants grow / if your fertilizer helps plants to grow / what does it mean ? / What makes plants grow ? / You know that

151 Pupil: It 's mineral matter

152 Teacher: Here we are / Baptiste says it's mineral matter // good, but what are dead leaves ?
 (...)

170 Pupil: Well / when they decay / they become // they become / as I said before / they become another / another matter / and that mixes with the air

171 Teacher: Well / Gwénaél says when they decay / they become another matter // all right / so it 's not the same, is it?/ it turns into another / a another matter / because Hugo said a while ago / he said it scatters / Gwénaél says it gets very small // but does it disappear?

172 Pupil: Well, no

It was only later, when she asked the pupils to look for solutions, that the teacher attempted to make the pupils clarify the idea of the conservation of the quantity of matter (171).

Thus the teacher helps the pupils to think in a way that implies this idea. Then the paradox becomes a paradox for them. Furthermore the teacher's interventions aimed at keywords such as "organic," "mineral," "dead matter" in order to initiate the idea of recycling. What is brought up is not directly the idea of the conservation of quantity of matter, but an idea of "becoming useful", which anticipates the expected solution. The category "[organic] dead matter", brought by the teacher led to the notion of a continuum between organic and inorganic matter in the foreshadowing of the cycle she wanted the pupils to build. Paradoxically, we can see that when the pupils tried to formulate the paradox using an example close to everyday life, their oral interventions involved an abstract model of the transfer of matter between plants, animals, soil, using scientific terms (mineral matter, organic matter), a model that they had been taught before. Thus, the notion of discontinuity which is the core of the scientific problem became a central idea in the discussion. The paradox was not formulated with scientific words (dead leaves, etc ...), but with arguments involving quantification, and the pupils attempted to match the two languages (dead leaves, dead organic matter).

10th example

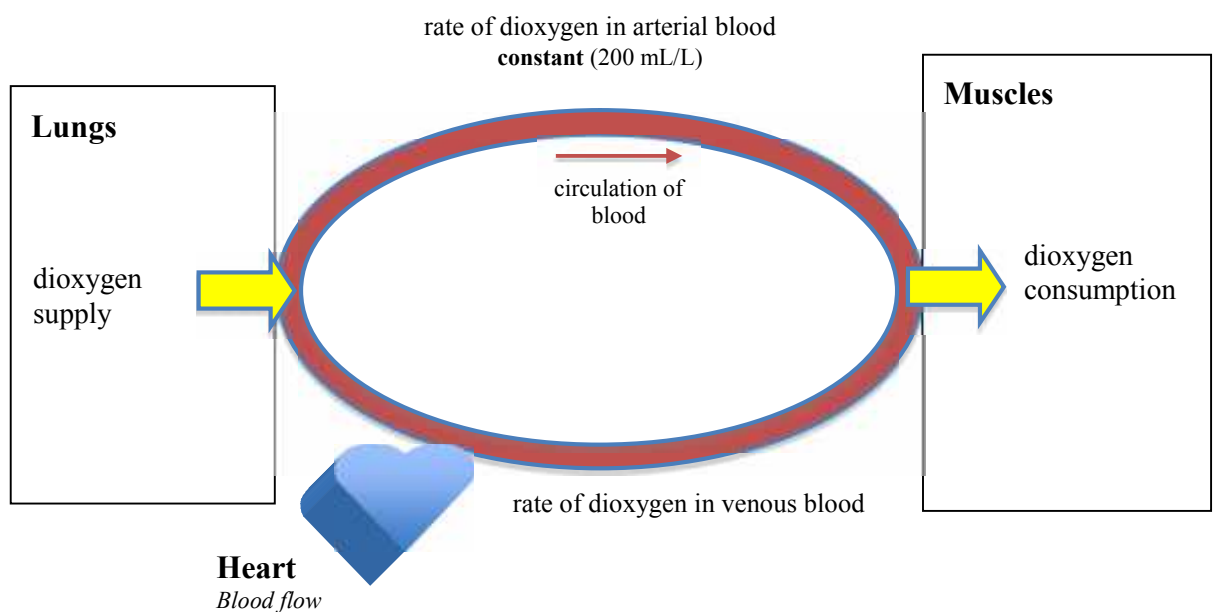
In the case of the other sequence (10th grade), in order to explain the paradox (*more dioxygen is provided to the muscles whereas the dioxygen rate in arterial blood remains the same during a physical effort*), some conditions are also required in order to be able to formulate the problem. The teacher managed to formulate the scientific problem (the paradox defined in section 1) when the pupils seemed to recognize it as such, because different conditions concerning the approaches of the relationships between data (including operating conditions) were identified by them. In the proposed situation, procedural operations are required because the relevant data to take into account in the biological problem studied (dioxygen consumption, dioxygen supply) are not direct data: in order to measure them, one must have the concentrations of dioxygen and use a multiplicative factor: $\text{dioxygen consumption} = (\text{rate of dioxygen in arterial blood} - \text{rate of dioxygen in venous blood}) \times \text{blood flow}$.

10th grade

more dioxygen is provided to the muscles whereas the dioxygen rate in arterial blood remains the same during a physical effort

Condition : different conditions concerning the approaches of the relationships between data (dioxygen supply / dioxygen consumption)

Figure 2. The relationships between dioxygen consumption and dioxygen supply in the body

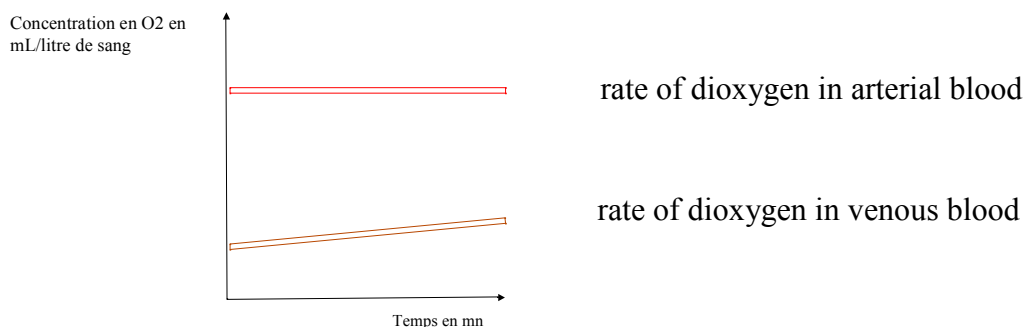


So, learning does not consist in a simple way: from the pupils' experience to more "scientific" formulations. Instead, to make the problem meaningful for pupils, links are required between experiences and models, with the purpose of building a scientific point of view.

5.2. Macro and micro-inducers

In the sixth grade sequence, we could say that, at a macro level, all the teacher's interventions represent a macro-inducer of position of the problem which occurs when she speaks of dead leaves in forests. That is what she wrote in her preparation paper, before the lesson. But before doing so, in each intervention (micro-inducers), she tried to make sure that the pupils build up the conditions so that the problem became a problem for them.

In the tenth grade sequence, the pupils must consider two curves at the same time (showing them the difference between the rate of dioxygen in arterial blood and the rate of dioxygen in venous blood) but they do not do it spontaneously. Usually, they first focused on a single curve. The micro inducers of the teacher this time aims at leading the pupils to take into account the two curves, and at focusing on their distance.

Figure 3. Production of one the group of students

Pupil: I don't understand how there can be more dioxygen at the end than at the beginning

Teacher: What matters is not each separate curve, but both considered at the same time / together it's the gap(s) / difference(s) between them / The same blood ran through the muscles

So there seems to be a link between macro-inducers of the formulation of the problem with micro-inducers involved in the building up of the conditions which make this formulation possible. These conditions may also be conditions of solutions of the problem.

In both cases, the formulation of the paradox is possible thanks to an articulation between macroinducers and microinducers :

- Macroinducteurs G (in connection with the general organization of the sequence) in this case a criticism of pupils' answers
- Microinducers (a, b) (in connection with linguistic interactions).

6. CONCLUSION AND IMPLICATIONS

In this study, the methodology based on the comparison between two sequences using the model of inducers of problem building leads us to find similarities and differences.

The formulation of the problem is possible only if some necessary conditions have been constructed beforehand. So, not only the problem's solution has to be built, but also its formulation. Our "microscopic" analysis shows an articulation between these conditions and the identification of data to allow the pupils to build up the problem (theoretical data in the 6th grade, empirical data in the 10th grade).

We bring to light some differences.

In the 6th grade, the pupils' phrasing is not in accordance with scientific discursive community: they use scientific terms and everyday terms without making any difference between them.

In the 10th grade: pupils' phrasing is in accordance with scientific discursive community, but they have to improve their conceptual apprehension of experimental data.

Experienced teachers know that and do not start with giving the problem to be solved straight away, but first use macro-inducer of problem formulation articulated with micro-inducers so as to make the problem appropriatable by pupils. When training teachers, it could be useful to explain these articulations.

Our research has implication in two different fields:

Concerning research field, our results lead to a criticism of theoretical models of problem building and inducers of problematisation.

Concerning teachers' training, our results lead to identify didactical skills teachers must develop in order to help pupils to build up scientific problems.

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