# TRENDS IN BIOLOGY EDUCATION RESEARCH IN THE NEW BIOLOGY ERA

A selection of papers presented at the Vth Conference of European Researchers in Didactics of Biology (ERIDOB), September 21st - 25th 2004, Patras - Greece

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TRENDS IN BIOLOGY EDUCATION
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A selection of papers presented at the Vth Conference of European Researchers in Didactics of Biology (ERIDOB), September 21st - 25th, 2004, Patras-Greece

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CONTENTS

## THE V^TH ERIDOB CONFERENCE

# TRENDS IN BIOLOGY EDUCATION RESEARCH IN THE NEW BIOLOGY ERA

## PREFACE

The dramatic development of Life Sciences during the last two decades has enhanced the links between biology and medicine, pharmaceutics, informatics, technologies and environmental sciences. A New Biology has evolved, especially in the field of molecular biology and gene technology, offering a great potential of improving human life and health. These recent achievements seem to affect all areas of life, from the individual to the biosphere and individuals are increasingly being asked to express opinions or make decisions on issues that have a biological cognitive background. In an information-based society, it is particularly important to provide young people with adequate knowledge and reasoning skills for developing a critical understanding of science and technology, that is to educate students as tomorrow's citizens capable of expressing scientifically informed opinions about everyday life.

New advances in understanding the role of genes and gene control, genomics and proteomics, also affect traditional fields of biology such as ecology and evolution, integrating the gene level to the organism and population level and leading to the development of new biological domains such as molecular ecology. At the same time, the basic cognitive core of biological sciences, structure and function of the organism at all levels, the history of living organisms on earth, and the unique role of each of them in the biosphere remain essential elements of biological scientific literacy.

If we are to meet the need for both well-trained specialists and a well-informed and educated public, we actually need high quality biology education. However, the speed and impact of recent developments, while exciting, present us with some serious challenges as biology educators. One of these is confidence in our own subject knowledge, when these rapid development leads to the re-evaluation of previously valid conceptualizations, the emergence of new terminology and even whole new areas of biology. A second challenge is the need to integrate a consideration of social and ethical issues into our teaching of biology. Finally, we need to refine and develop our understanding of the relevant pedagogy if we are to teach these new areas of the biology curriculum effectively. Consequently, high quality research in biology education is of strategic importance in developing good educational practices that can successfully meet the dual aims of the biology curriculum.

The bi-annual European Researchers in Didactics of Biology (ERIDOB), first established in Kiel (Germany) in November 1996, has made a major contribution to biology education research. Participants, who are drawn from International as well as European countries, are all research active and this conference provides a unique opportunity for discussion, reflection and exchange of methodological practices between experienced researchers and newcomers and also between different research cultures and traditions.

At the Vth Conference of European Researchers in Didactics of Biology (ERIDOB) held in Patras, Greece (September 21st - September 25th 2004) almost a hundred researchers from 17 countries met to discuss their work, presented in 31 papers and 43 posters. This volume contains a collection of these papers, selected after independent review by two members of the academic committee of ERIDOB and subsequently revised. These papers have been grouped into 6 sections that reflect the research strands covered during the conference and identify the actual Trends in Biology Education Research.

The first section, entitled "Learning Biology: Students' conceptions and conceptual change", includes seven contributions that deal with students' conceptions about various biological topics such as ecology, animals, life cycles, human reproduction and birth, growth and cell division, evolution. Conceptions are studied with the aim of providing a useful background for organizing teaching & learning environments (Jelemenská, Sander and Kattmann; Nyberg; Zogza and Christopoulou) or evaluating their effectiveness (Dirk Krüger, Jennifer Fleige & Tanja Riemeier), as well as for gaining a better understanding of the ways in which students reason about living organisms and explain the evolutionary process (Papadopoulou and Athanasiou; Lakka and Vassilopoulou; Selles, Boulter, Tunnicliffe and Reiss).

The second section, "Reasoning: Scientific Thinking and Argumentation", includes four contributions dealing with various aspects of students' argumentation. These papers focus on the use of argument in peers' discourse as a shared process of knowledge and meaning construction in genetic engineering (Ergazaki & Zogza) and cell biology (Diaz De Bustamente & Jimenez- Aleixandre) as well as in individual explanations within ecological comparisons (Hammann), or explore educational settings that train students in reasoning and arguing about new biological advances such as GMO's (Simonneaux and Simonneaux).

As the influence of information technology on the educational practices has increased, so has the interest of researchers in the study of educational settings that integrate information technology. This has led to the third section, "Teaching Biology in Technology-Supported Educational Environments", which includes six contributions. Three of these highlight the impact of web-based educational environments on learning genetics (Waarlo and Smeenk; Gelbart and Yarden) and evolution (Wallin and Andersson), while one explores the effectiveness of the problem-solving strategies developed within such environments (Pedaste and Sarapuu). Finally, one paper concerns the influence of a multimedia curriculum guide on scaffolding students' learning through research articles (Falk, Brill and Yarden), and one studies the influence of different reasoning processes in expressive and exploratory synchronous environment on the development of students' representations in genetics (Pata and Sarapuu).

The fourth section focuses on "The Impact On Teachers Of New Approaches To Biology Education" and brings together papers that consider biology education from the teachers' perspective, particularly the response of teachers to new or unfamiliar approaches - the way that teachers get involved in teaching methodologies that are considered successful on the basis of experimental educational research (Bandiera and Bruno), how teachers cope with a new curriculum that teaches biology through the use of real world contexts (Lewis) and a report on teachers' view of learning and assessment of laboratory work (Ottander).

The fifth section, entitled "Developing Attitudes and Opinions: Interest and Motivation for Biology", includes three papers that explore how students' interest in biology is related to their out-of-school experiences (Uitto, Juuti, Lavonen and Meisalo), how students' aesthetic appraisal of "creepy" organisms can be modified through changing pespectives (Retzlaff-Fürst) and finally how a debate on medical applications of genetic engineering can affect opinions expressed by students (Oueslati and Simonneaux).

Finally, in the sixth section, "Environmental and Health Education", two separate fields, which are strongly connected to Biology Education, are brought together. Two of the section's papers relate to Environmental Education, exploring issues that concern the extra-curricular sustainable development education in Germany (Bögeholz), as well as analyzing the explanations used by primary school students when interpreting environmental disturbances (Gómez, Sanmartí and Pujol). The two remaining papers refer to Health Education issues, such as students' representations about their body and sexual development (Zimvrakaki and Athanasiou) and students' value awareness and purchase intentions in the field of nutrition (Schlüter, Köpke and Bayrhuber).

The Editors

# SECTION 1

# LEARNING BIOLOGY: STUDENTS' CONCEPTIONS AND CONCEPTUAL CHANGE

# TOWARDS A BETTER UNDERSTANDING OF ECOLOGY. RESULTS OF TWO STUDIES CONDUCTED WITHIN THE FRAMEWORK OF THE MODEL OF EDUCATIONAL RECONSTRUCTION

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## Abstract

In biology teaching, ecological subjects play an important role in order to deal with nature in a responsible way. Empirical research has shown that even after school instruction, students do not understand essential ecological concepts. The main reason for this is that preconceptions which influence learning are not taken into account in the construction of curricula. In this paper, we combine findings from two independently designed studies which have main objectives in common. In both studies the focus is on students' conceptions of ecological terms and phenomena – ecosystem, balance and change in nature. The studies are conducted within the framework of Educational Reconstruction, where three components of research are linked together: "scientific clarification", "comprehension of students' perspectives" and "construction of instruction". In accordance with the aim to capture the structure and quality of students' conceptions, qualitative methods are used. The results of both studies indicate that students tend to refer to more or less constant properties, in particular those which are visible for them in everyday world. Processes are rarely their concern. Therefore, the scientific conceptions of ecosystem, unbalance and dynamics of biodiversity would be difficult for them to understand. For a better understanding, the dimensions of both space and time should be included in curricular design.

## 1. Introduction

*"Persons using the term 'ecosystem' are considered scientific experts. But opinion differs about what this term really means"* (Jax, 1994).

In biology teaching, ecological subjects play an important role in order to deal with nature in a responsible way. Empirical research has shown that even after school instruction students do not understand essential ecological concepts such as food chain, cycle of matter and ecological niche (Pfundt & Duit, 2002). According to the research on conceptual change, the difficulties in understanding scientific concepts are not caused by insufficient knowledge. They arise from students' everyday conceptions which are different from the scientific ones.

Another obstacle in teaching ecology, which hardly has been taken into account, is the fact that even in ecological science itself, there are great uncertainties as to how certain facts, concepts and terms should be understood adequately. This situation is even mirrored in

school-books where the same terms are used in different ways. To improve biology education it is therefore necessary not only to comprehend students' perspectives. The clarification of scientific subject matter is of equal importance, because the significance and meaning of the content of instruction cannot be treated as given.
Therefore we combine in our studies empirical comprehension of students' conceptions with the scientific clarification of central ecological concepts and theories. The aim is to construct learning environments by systematically relating both conceptual areas to one another. On this basis, the approach from everyday conceptions to a scientific view should be made easier.

In this paper we report findings from two independently designed studies which have main objectives in common. In both studies the focus is on students' and scientists' conceptions of ecological terms and phenomena. One of the studies deals with the concept of ecological units, in particular ecosystem, whereas the other investigates the understanding of nature, in particular the conceptions of ecological balance and change. The topics of research are as follows:

- Conceptions with regard to "community", "ecosystem" and "earth as an ecosystem" and the differences between these conceptions
- Ontology and epistemology of ecological units
- Conceptions of nature with focus on balance, stability and processes (e.g. succession)
- Ethical points of view and their relation to conceptions of nature

Furthermore, we seek to comprehend the ontological and epistemological status of the ecological units and the role of understanding nature in ethical decisions.

In this contribution, the results of the two studies will not be reported in detail, but common conceptions of the students with regard to ecological phenomena will be demonstrated. These conceptions will prove as essential for the understanding of the ecological contents of both subjects and, moreover, for successful instruction and meaningful learning of ecology. Because the focus is on the ecological subject of matter, other aspects of our research questions like the ethical dimension or the ontological and epistemological status will not be considered in this paper.

## 2. Previous research

Although the number of studies which investigate students' previous conceptions of biological phenomena increased continuously (Pfundt & Duit, 2002), the research in the domain of ecology is insufficient, especially with regard to our field of interest. There hardly exist any studies which give detailed information about how students think about units in nature or balance and change in nature. There are only some investigations concerning the concepts of food chain, ecological niche and ecosystem (Munson, 1994; Leach et al., 1995; Grotzer & Bell Basca, 2003). Some of their results (Adeniyi, 1985) indicate that students use concepts like ecosystem, community and population synonymously. The investigation of

Engstroem (1981) reveals that balance in nature is concerned as a law of nature; Schaefer (1973) reports that conceptions of "balance" have connotations of static and harmony. The studies are mostly concerned with isolated concepts and many of them are oriented towards factual knowledge. The conceptions of the students are often regarded as inadequate. Besides, there is hardly any discussion of the question of how to deal with such conceptions as preconditions in learning processes or how students' conceptions can be related to scientific statements.

## 3. Theoretical framework and methodology

In our research projects, we value students' previous conceptions in their own significance. According to a constructivistic epistemological position, there is no "true" content structure of a particular content area. Systematic and unbiased research is necessary in order to understand students' conceptions adequately. Both studies reported here are based on the Model of Educational Reconstruction (Kattmann et al., 1997), which offers a theoretical framework for planning and conducting educational research. The studies relate students' conceptions systematically to scientific concepts so that mutual relations can be analysed. The aim is to find a more appropriate basis for teaching. Consequently, the research design consists of three modules: scientific clarification, empirical investigation of students' conceptions and construction of instruction.

The research projects deal with scientists' and students' ways of understanding – not with the quantity of specific conceptions. This is the reason why qualitative methods are applied. For the empirical investigations of students' conceptions about ecological units, a combination of problem-centred interviews and "concept net" (a special kind of concept map) has been applied. The interview guideline includes questions concerning the units of nature, described from a local (e.g. a forest) to a global perspective, the meaning of terms like community, ecosystem and earth as an ecosystem. After three months, a concept net was created in a second interview with the students. The "concept net" was structured while the student's understanding of the technical terms of the subject (community, ecosystem, earth as an ecosystem) was checked explicitly. The study was conducted in Germany and in Slovakia. Hence, the study obtained information based on a broad variety of everyday life experiences.

The empirical investigation of students' conceptions about nature used group discussions in combination with problem-centred interviews. The former is concentrated on ethical conflicts in the field of nature which affect students' fields of interests (e.g. construction of an amusement park vs. protection of an eco-sys-tem) (Billmann-Mahecha et al., 1998). The latter deal in more detail with ecological phenomena. The interview guideline includes questions, pictures and drawings with regard to, for example, succession, living in a community and forest-development after a fire. The combination of these different methods and interventions makes it possible to analyse concepts of nature as well as ethical arguments.

In both studies the interventions of the interviewer were not directed to a scientifically correct answer, but to the personal explanations and understandings of the student. All responses to an intervention were treated as valid articulations of a personal perspective rather than simply right or wrong answers. In our empirical studies, we worked with 16 to17 year-old students.

The problem-centred interviews and the "concept nets" are evaluated by means of the qualitative content analysis (Mayring, 2003), which was adapted for educational research (Gropengießer, 2001). By means of this method, the material ascertained in the interviews is condensed, interpreted and analysed in a systematic and verifiable way. The recorded material is processed and analysed in a number of steps:

- Word for word transcription
- Editing (transformation of utterances into grammatically correct statements, dissolution of the dialogue)
- Condensation (combination of almost identical statements )
- Explication (intense interpretation of the statements, characterisation of the mental constructs, explanation of the underlying conceptions and assumptions of the origins)
- Structuring (formulation and identification of the different elements of the conceptions).

It should be noted that transcripts were analysed independently by at least two researchers to ensure reliability and validity.

The group discussions are analysed with an adapted sequence-analytic procedure (Lamnek, 1998). The methodological details are not presented in this paper, because we do not intend to report results from the group discussions.

The method of qualitative content analysis (Mayring, 2003) is also applied to the scientific clarification. This means that scientific literature which represents the latest developments of research on the topic is analysed together with historical theories. On the one hand, this helps to clarify and distinguish between different scientific theories and on the other hand, it serves a better understanding of students' conceptions (Gropengießer, 2001).

After all interviews and the selected scientific literature have been analysed by the qualitative content analysis, the conceptions gained within the structuring will be compared.

## 4. Results of both studies: Common conceptions

Comparing our results, we identified three aspects that are common to the students' conceptions of the respective topics. These common aspects are: "Orientation towards the visible", "preservation of life" and "one-sided relationships". We want to show that these aspects are of fundamental importance for understanding the topics ecosystem and balance in nature. The results will be presented by giving examples from both studies and emphasizing their common aspects. The quotations merely illustrate these conceptions. The interpreted conceptions are derived from the entire interview and not only from the short passages cited here.

### 4.1- Orientation towards the visible

In our interviews, community and ecosystem are mostly considered synonyms in the sense of habitat. On this basis, Martin develops a criterion for differentiation:

*"Communities form the ecosystems and this whole earth. For example, the forest is a community; the meadow is another community and a field is yet another one. But together they form the ecosystem of a climatic zone. … In my opinion, the ecosystem is a larger region"* (Martin, 17 years old).

Martin, for example, shows that students orient themselves towards the visible, namely properties of the landscape – such as plant formations or other characteristics when talking about community and ecosystem. Accordingly, community and ecosystem are distinguished on the basis of their size: The forest is the community, whereas the climatic zone is the ecosystem. Thus, the size is the decisive factor for discriminating the areas.

In the study concerning the concept of nature, we intend to discover, besides other things, if conceptions of balance are of importance for students. During the interview different interventions are presented to the students, on the basis of which they are asked to explain, for example, why different organisms can exist together in a habitat or what happens in an area left on its own. Even without the interviewer mentioning balance, students often introduce this conception themselves, as the following quotations show:

*"The organisms can exist in this island, because there is always such an ecological balance […]"* (Alan, 16 years old).
*"If the Yellowstone Park was left on its own, the organisms would change over the long term, but apart from that, these balances will be maintained and probably that's where matters will rest"* (Ben, 17 years old).

These examples illustrate that students are convinced that biological balance occurs in nature and always returns after disturbance. In their conception, balance is a fundamental characteristic in nature; it is regarded as the *normal* or *natural state* in a community.

This conception of balance as a normal state seems to closely associate with the every-day perception: In our spatial and temporal perspective, we do perceive a constant, unchanging nature. Obviously, the things visible every-day play a role in both studies. Due to the perceptible spatiality, ecosystem and community are distinguished by their size. This conception is based on the orientation towards the visible just like the perception of balance as a normal state.

4.2- Preservation of life

Students associate not only spatiality (spatial delimitations) but also relationships with community and ecosystem. They are regarded as dependencies on fundamentals of life. Under this aspect, the terms “ecosystem” and “community” are used synonymously.

*“Community. There should be relations between the components of the community - e.g. food chain […]*” (Tom, 17 years old).
*“With an ecosystem I associate a system of nature which builds up out of itself […] That’s actually like “eating and being eaten” […] and practically never ends thus protecting the ecosystem”* (Anne, 17 years old).

Students associate “processes” with “fundamentals of life”: Organisms can only survive, if the fundamentals of life are constantly available. For example, Anne postulates the constant availability of food: The “eating and being eaten” practically never ends. In the local perspective, mainly the biotic relationships are important.

It is interesting, however, that students consider the earth as an ecosystem in the global perspective to be dependent on “matter”. On the basis of a continuous production of oxygen and “nutrients” by plants and animals, there is a cycle of matter. This cycle again serves the preservation of life.

*“The ecosystem and the whole earth [as ecosystem] are made in a way that life is preserved. Plants produce oxygen [for animals and humans] and by the decomposition of animals and plants nutrients are produced for plants*” (Martin, 17 years old).

The notion of preservation is articulated also with regard to balance in nature. Examining the students’ conceptions of balance concerning the exact definitions of balance, they differ at a first glance:

*“Ecological balance means to me that there are always enough plants available for living, that no party, if I may say so, gains the upper hand, something like that*” (Alan, 16 years old).
*“Balance means that all species principally get on well together, that the populations are stable, that no species predominates in the forest and causes damages among other species*” (Oliver, 17 years old).

The conception of a balance can refer to well-balanced predator-prey relations, to a certain hierarchical order among organisms or to a complete cycle of matter.

A common aspect of all conceptions is that a balance ensures the survival – of all organisms involved, of local ecosystems or the ecosystem earth. This is particularly evident when unbalance is considered:

*“The consequence of a lost balance is the state called “collapsed ecosystem”. Then everything is simply destroyed, the forest dies, all animals are endangered*” (Oliver, 17 years old).

This example shows that balance stands for the preservation of life, whereas an unbalance is not only regarded as a change, but as the danger of destruction. We therefore point out that a common and central aspect regarding “ecosystem” and “balance” is the conception of preservation of life. Balance stands for survival in nature. Referring to the understanding of ecosystems, relationships are considered to be dependencies on fundamentals of life. From the local perspective, preservation of life refers to the availability of food, yet, by contrast, it is associated with cycles of substances from the global perspective. Students often believe that life remains unchanged without exterior influences.

### 4.3- One-sided relationships

When talking about changes of ecosystems, students consider them to be causally related to changes of climate. For students, organisms and climate form a unit, the ecosystem. The relationships between climate and the organisms are mainly understood one-sidedly: A change of climate leads to a change in the species composition (or species have to adapt to the climate) and changes in the species composition are emphasised as changes of the ecosystem. Catastrophes such as meteorites striking the earth are assumed to cause changes of the climate. Organisms - with the exception of humans - have no influence on the change of climate. Since the change in the species composition involved a change of the ecosystem, ecosystems are considered to be temporally limited.

In connection with successions, students tend to assume that organisms follow the environmental conditions: Organisms colonise under certain prevailing conditions - plants first, followed by animals. Living conditions are not assumed to be changed by the activity of organisms in the course of time. This becomes evident by the fact that students believe organisms from an early stage of development to be still present at a later time.

This demonstrates that students have a one-sided view of organism-environment relationships. They generally do not hold the idea that the activity of organisms retroactively influences the (abiotic) environment essentially.

## 5. Discussion

### 5.1- Comparing students’ conceptions with experts’ conceptions

Comparing students’ conceptions with the scientific ones (Table 1), we find not only differences but also similarities. Obvious similarities appear when even scientists use (unconsciously) an everyday perspective.

The orientation toward the visible, for example, which is important with regard to defining ecosystems as topographical units, is represented in the work of Eugen P. Odums (1999), one of the most influential ecologists since the 1950s. To define an ecosystem in this way, will be problematic if you want to clarify food webs: Are organisms whose distribution exceeds the topographical unit, part of this ecosystem? (Jax, 2002). The conceptions are contradictory. Furthermore there is a problem in terminology. Michael Begon et al. (1996) reject the criterion of spatiality to define an ecosystem and, moreover, ask if we need the term “ecosystem” at all. Because of this, decisions on how to teach this subject are difficult to reach.

Other ecologists lay stress on processes to define ecological units. The reciprocal action between biotic and abiotic elements of an ecological unit is seen as a prerequisite of their development (Tansley, 1935). The unit is outlined by relations. With regard to earth history, it is interesting that living beings are considered as the important factor which has changed the abiotic environment on a global scale (Lovelock, 1991). The term "bioplanet" has the meaning that the activity of organisms creates living conditions on earth (Kattmann, 1991; Kattmann, 2004). Students relate "preservation of life" to cycles of matter: the relationships in nature are understood in an everyday framework as "needs". The term "ecosystem" is associated with flows of matter and energy in the expert's view.

The change of living conditions by organisms is also important in the scientific explanation of the process of succession. In the perspective of the scientists, succession is a process which is based on the mutual relationship between the living organisms and the abiotic environment.

The actual expert perspective regarding balance also differs from the students' conception. At present, ecological theories proceed on the assumption that a balance in ecological systems is rather an exception, while unbalance represents the normal state. More attention is paid to the consideration of the heterogeneity of ecological systems, as well as the consideration of spatial (and temporal) scales. Examples of this approach are the conceptions of patch dynamics or mosaic cycles. The decisive factor is that disturbances - by wind, waves, digging animals - receive a theoretical status in order to explain patterns and processes of ecosystems, for example patch dynamics or the preservation of species diversity (Begon et al., 1996).

This view on balance and unbalance, or change in nature, has to be acknowledged when one has to decide on strategies to protect nature. In general, students' conceptions about balance in nature are closer to the classical ecological conceptions than to the modern ones. In the view of classical ecology, an ecosystem is characterised by an ecological balance or else every ecosystem will reach the state of balance. Therefore, balance is regarded as the normal state of nature. Thienemann, for example, an influential ecologist in Germany, refers to the usual properties of a landscape to demonstrate the existence of balance (Thienemann, 1956). It is similar to how the students orient towards the visible.

Table 1. Students' conceptions and clarified scientific conceptions of "ecosystem" and "balance in nature"

| **Students' conceptions** | | | **Clarified scientific conceptions** |
|---|---|---|---|
| Size as difference between "community" and "ecosystem" | "Food chain"- "community"<br><br>"Circle of matter" - "ecosystem" | Adaptation to environment | Earth is a bioplanet<br>Flow of matter and energy<br>Unbalance as the normal state (patch-dynamics, diversity of species)<br><br>Disturbance as important factor |
| Balance as normal state | Balance take care of preservation<br><br>Unbalance destroys nature | Organisms follow abiotic conditions | |
| *Orientation towards the visible* | *Preservation of life* | *One-sided relationships* | |

### 5.2- Conclusions for teaching ecology

The comparison makes it obvious that the perspectives of the students - the orientation towards the visible, the notion of preservation life and one-sided relationships - lead them to a different understanding of "ecosystem", "balance" and "unbalance" than the one of the (present) scientists.

The question arises as to how to overcome these discrepancies with respect to teaching biology by considering students' conceptions, which is indeed the central idea of educational reconstruction. It is essential to select and structure the contents in such a way that they are not only learnt by heart but are grasped in the literal sense.

We propose to introduce spatial and temporal changes of perspectives into teaching ecology. This change of perspectives may contribute to a better understanding of "community" and "ecosystem" and the recent scientific view of unbalance, but in different ways as explained hereafter.

#### 5.2.1- Conceptual change concerning the concept of balance

A *spatial change* of perspective may have a relativizing effect on conceptions of balance. Such a change from a large-scale view -that rather corresponds to an every-day view- to a small-scale view, draws the attention away from the apparent constancy and the directly visible and towards the dynamic processes and their causes, for example, local extinction by disturbances and recolonization of populations. In the school context, concepts like the mosaic-cycle model instead of the classical conception of climax should be taken into consideration. Successions - on a small scale so to speak - should be of more significance in teaching. At the same time, this concept offers the opportunity to scrutinize the conception of balance as survival and unbalance as destruction by discussing the importance of disturbances for species diversity.

Considering the small-scale dynamics in the form of successions, conceptions of one-sided organism-environment relations can also be expanded into mutual relations, as autogenic processes are brought to light.

Orientation towards the currently visible, which may lead to the assumption of balance, can be relativized by a *temporal change* of a perspective exceeding the students' normal perception of time: for example, by demonstrating on the basis of long-term successions that ecosystems follow each other. Also, a review of the history of the earth may show that unbalance does not necessarily mean destruction, but has rather provided the conditions for present-day life on earth. Therefore, it is not balance that preserved - and will preserve - life on earth.

**5.2.2- Conceptual change concerning the concept of ecosystem**

As pointed out before, students understand community and ecosystem synonymously. By orientation towards the visible, the units are defined spatially. The ecological processes are looked upon as preserving life. The change of perspectives - from a local to a global view - makes the perception of some other aspects possible. In the global perspective, the ecosystem can be well characterised by the flow of matter. But this bears the question of spatial definition. Considering the global flow of matter, the independence of smaller ecosystems becomes relative.

The one-sided conception of the dependency of organisms on climate and other abiotic conditions can be revised best in the context of the history of the earth, if the global change of conditions caused by living beings is demonstrated. In this context, one can start with the conception of students who articulate that the production of materials by plants, which are necessary for life, may be a precondition of further development of animals. In this way the production of organisms will change the abiotic environment. The organisms will develop by adaptation to the changing environment.

This conception can be illustrated again with a quotation of Martin:
"*Somehow [the ecosystem] developed and the development happened in a way, that it was preserved [on earth]. I. e., that the plants have developed, they have produced air and the air has been consumed by the animals. If plants would produce sulphur, then animals would have been developed adequately*" (Martin, 17 years old).

A first step into the direction of change of perspectives is to introduce the context of earth's history into biology lessons. Confronting the students with the bio-historical causes of the present conditions of our life will likely lead the students to a meaningful understanding of unbalance and of the global ecosystem of bioplanet earth (Sander et al., 2004).

The guidelines we suggest for teaching have to be proved by empirical studies. But there are convincing indications that the model of educational reconstruction builds a framework for planning learning pathways which lead students to the scientific view (Riemeier, 2005).

Therefore we regard the model of educational reconstruction as a valuable fundamental structure in bringing together issues to improve the learning of biological topics.

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# PUPILS' RESPONSES TO CUES FROM THE NATURAL WORLD: A CROSS-CULTURAL STUDY USING MULTIPLE ANALYTIC PERSPECTIVES

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## Abstract

This paper presents an in-depth analysis and comparison of the understandings of 10-11-year-old pupils in a suburban school in Rio de Janeiro, Brazil with a similar school in suburban Bracknell, in southern England. An open-ended interview with a photographic probe was used in both schools. Both classes were preparing for a visit to a zoo. An analysis system using systems theory to develop 8 levels of biological organization was used to analyze all the interviews both in England and Brazil to show the breadth of responses to the objects from a biological perspective. The interviews using the photographs were further analyzed to show aspects of models and human features and influences, to provide an in depth interpretation of the knowledge and experience expressed by both sets of pupils. The results of the three analyses were used to characterize the understanding in the different contexts and to make descriptive comparisons. There are strong similarities between the case studies in Brazil and in England. The Brazilian students showed a slightly more integrated biological view of the objects in the natural world and more frequent emotional and anthropocentric views as well as a different pattern of responses to particular objects.

## 1. Introduction

When children study both biology and environmental topics either in school or in out-of-school contexts, they encounter objects in the natural world that are presented to them as representations visually or verbally, or they encounter them as real objects in their natural settings (in the wild, in zoos or botanic gardens), or as part of museum exhibits. In responding, children use their own knowledge and experience to express their understandings. Such understandings do not just involve cognitive aspects but also social and cultural experiences in which children have taken part. When they think about the natural world, all these experiences come to bear. So, in analysing what children say about the various objects we shall be using multiple perspectives to try and grasp this broader aspect of children's understanding of the natural world. Our research in England, whose initial methodology was reported on at the IVth ERIDOB conference, has shown that these expressed understandings differ in various out-of-school contexts and when alternative representations are used (Boulter et al., 2003a).

Since the beginning of the project, it was our intention to collect data from children in Rio in order to explore the differences in children's understanding of the natural world in these two contexts of the suburbs of a large city in Brazil and England. When the analysis system had been established, the data from the schools in Rio became available and it was analyzed in a similar way to the English data. The Brazilian and English researchers not only cross checked the analysis but carried out visits in both directions. This enabled us to consider comparing the schools in Rio with the most comparable schools in England. In this paper, we have made a comparative case study of year 5 classes in suburban Rio in Brazil and Bracknell in England. In Rio, the teacher described his school as middle class taking its intake from an area about 30 km from the city centre. It took pupils from 11-17 and he taught the biology and science and the classes were of mixed ability with equal numbers of boys and girls. The Bracknell School is a combined Infant and Junior-school taking pupils 3-11, so the case study class is at the top of the school. In a recent report the school was classified as a "good school". The area is middle class and most pupils live near the school. There are equal numbers of boys and girls.

Our hypothesis was that the learning revealed by a young person's expressed understanding will differ for subjects whose understanding has been deepened through their experience in different cultures, such as that in South American Brazil or Southern England. As far as we were aware, this had not been investigated to date.

## 2. Objective and research question

To summarize, our objective in this paper is to compare, using multiple analytic perspectives, the nature of the knowledge in the expressed understandings of pupils in suburban Rio and Bracknell near London, when presented with photographs of objects from the natural environment as interview probes in school. We aim to show the implications for science teaching, which may assist teachers' thinking about teaching biological aspects of the environment. Our research question was: *'What can we say about the nature of children's expressed understandings of the natural world in Rio and Bracknell using our methodology and data?'.*

## 3. Design and methodology

### 3.1-The sample, the objects and the interviews

We selected a class of 10-11-year-old pupils in Rio which was similar in background and ethos to the class in suburban Bracknell. They were both planning an out-of-school visit to the zoo. The teacher was asked to select a sample of 6 pupils to provide three boys and three girls and a range of ability. Each pupil was interviewed individually by the researcher about each object in school.

Eight objects were decided upon through consideration of those objects with which the children would be likely to be familiar in these suburban settings and were also likely to be seen on the forthcoming zoo visit. We also decided that the objects should be such that it would be possible to consider them relating to each other in various ways e.g. as a food chain, as competitors or as components in an ecosystem. The objects were a daisy, grass, a tree, a pigeon, a squirrel, an ant, a pond and a cloud. At the pilot stage, it was decided to replace the squirrel with a species of monkey in Rio as they hold comparable positions in the food chains. The golden lion monkey and a tamarin (spider monkey) were tried as alternatives to the squirrel. It made no difference to the children's responses. Both are wild and pupils are well aware of them. The amendoeira tree was chosen to replace the oak as it is both common and deciduous, and the golden lion monkey was chosen to replace the squirrel. All the interviews were audio-recorded and transcribed.

### 3.2-The choice of a photographic probe

Photographs of the eight objects were used as probes in the interviews which were as open-ended as possible. The use of photographs suited the aims of the research since it enabled us to elicit the children's knowledge not only of the object but also the situations in which they are found and encourages pupils to express their knowledge of the levels of biological representations and how they are related to each other. Our previous work (Boulter et al., 2003b) showed that photographs enable all the aspects of biological levels of organization to be systematically explored.

## 4. The Analysis of the transcribed data

### 4.1- Analysis of levels of organization

Our first level of analysis uses a hierarchy of levels of biological organization and enables us to catch pupils' understandings of the complexity and embedded nature of the objects, the breadth of their understanding. This interpretative framework is based on a systems view of the levels of biological organization (Gulyaev & Stonyer, 2002). For our purposes we looked at hierarchies of objects (Laszlo, 1972) that are based on scales of size and mass and pass from atoms to ecosystems with organisms in between. The first (lowest) elements in the hierarchy are the building blocks for the next and so on. The components at any one level are united at the next level by means of a fundamental interaction such as interbreeding (organisms making up a population) or the cycling of nutrients (communities making up an ecosystem). The highest elements are thus connected to the lowest and depend on them so that, for instance, an ecosystem depends upon the presence and properties of atoms. In a hierarchy, new properties emerge at each level and as Laszlo points out (1972: 97) *"each subsystem finds constraints imposed on its behaviour by the higher"*.

For each interview and for each object, the number of times that each level ('ecosystems', 'communities', 'populations', 'organisms', 'organ systems and organs', 'tissues', 'cells and organelles', 'atoms and molecules') was mentioned, was noted and totaled for the object, for the pupil and for the school class. This enabled us both to gain insights into the range of levels used by particular groups of pupils with particular probes and to address the research question in a quantitative manner. The levels analysis was completed on all the data collected from the selected schools in outer London and Rio.

As the project had developed we came to realize that, although the analysis of the levels of organization gave us a good indication of the integration of the object into the hierarchy of natural things in the pupil's thinking, it left out features we were interested in. In particular, we wanted to understand more about how the pupils described the objects as entities with parts and properties that related to other objects.

### 4.2- Analysis of expressed models

Previous work by Buckley and Boulter (1999), Gilbert and Boulter (2000) and Boulter and Buckley (2001) on expressed models was used as a basis for the development of a set of categories to look at the objects as entities. A similar categorization had been used to analyze student teachers model building on field trips (Boulter & Buckley, 2001) and had proved an effective way of analyzing the content of student talk and posters.

The expressed models of the objects were therefore analyzed by categorizing the naming, physical features, behaviour, mechanisms, interrelationships and habitats expressed (Appendix 1). As before, the totals for each category were totaled.

### 4.3- Analysis using human features

These two analyses did not cover the third area in which we were interested, that of how the pupils saw the objects in relation to themselves as human beings, their human experience. So, we also applied a categorization of human features to the same data. This analysis arose from repeated re-readings of the data, allowing the categories to emerge within the frame of human experience. The categories include the source of the knowledge, feelings, human actions and influences, direct experience and cultural and anthropocentric features (Appendix 2).

The analysis of the data in these three ways through levels, modeling and human features allows us to describe the characteristics of children's expressed understandings and compare the responses of pupils in Rio with those in Bracknell. It allows us to consider and compare the expression of the knowledge of the embedded levels, the objects as entities and the experience of the objects from a human perspective. This multiple analysis allows for a richer description of what the children said.

## 5. The characteristics and comparison of children's expressed understandings

### 5.1- What the levels analysis tells us

The levels analysis reveals some interesting characteristics and differences, as shown in Table 1 where figures in each box are totals for the six interviewed pupils. The interviews in Bracknell elicited more coded comments in the interviews than in Rio (288 versus 147). Despite of attempting to make our interviewing technique as similar as possible to prompt the pupils in a similar fashion, there are differences in expectations likely in pupils for what is expected in the interview.

The organism and organ levels were the most commonly mentioned. This finding has been seen throughout our work: pupils when asked about these objects in the natural world naturally tend to focus on naming the organism and the parts they can see. In Rio, community levels were mentioned much more often (19) than in Bracknell (7).

The population level was mentioned more often in Bracknell (47) compared to Rio (7). The reason for the high levels of population comments in England was largely because of the responses of the English children to plant probes, when they tended to talk about how these plants lived together in a place and with other organisms.

The ecosystem level was infrequently mentioned in England (twice) and more often in Rio (7 times). It does seem from this, that the Brazilian children may have a slightly better grasp of the interconnectedness of the natural world. Tissues and cells were not mentioned in either context. Molecules were mentioned only twice in the English context. At age 11, children do not mention these lower levels of organization. This may be connected to the lack of ecosystems comments which when present tend to involve *lower* levels in their explanation e.g. the water cycle.

Table 1. Levels analysis for the interviews

| | School Year 5 Meadvale (photographs/UK) | | | | | | | | | School Year 5 Gaya (photographs/ Rio) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | e | c | p | o | or | t | cl | m | | e | c | p | o | or | t | cl | m | |
| Daisy | 0 | 1 | 15 | 12 | 14 | 0 | 0 | 0 | **42** | 0 | 1 | 1 | 10 | 18 | 0 | 0 | 0 | **30** |
| Grass | 0 | 2 | 12 | 10 | 9 | 0 | 0 | 1 | **34** | 1 | 3 | 0 | 9 | 6 | 0 | 0 | 1 | **20** |
| Oak tree/ Amendo-eira | 0 | 2 | 2 | 13 | 28 | 2 | 0 | 2 | **49** | 0 | 0 | 0 | 8 | 13 | 0 | 0 | 0 | **21** |
| Pigeon | 0 | 0 | 7 | 13 | 21 | 0 | 0 | 0 | **41** | 3 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | **10** |
| Squirrel/ monkey | 0 | 1 | 4 | 12 | 19 | 0 | 0 | 0 | **36** | 0 | 9 | 0 | 15 | 13 | 0 | 0 | 0 | **37** |
| Ant | 0 | 0 | 7 | 21 | 15 | 0 | 0 | 0 | **43** | 2 | 0 | 5 | 6 | 10 | 0 | 0 | 0 | **23** |
| Pond | 0 | 1 | 0 | 34 | 2 | 0 | 0 | 1 | **38** | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | **6** |
| Cloud | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | **5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | | | | | | | | | | | | | | | | | | |
| *Ecosystem (e)* | 2 | | | | | | | | | 7 | | | | | | | | |
| Community (c) | | 7 | | | | | | | | | 19 | | | | | | | |
| Population (p) | | | 47 | | | | | | | | | 7 | | | | | | |
| Organism (o) | | | | 116 | | | | | | | | | 53 | | | | | |
| Organ (or) | | | | | 108 | | | | | | | | | 60 | | | | |
| Tissue (t) | | | | | | 2 | | | | | | | | | 0 | | | |
| Cell (cl) | | | | | | | 0 | | | | | | | | | 0 | | |
| Molecule (m) | | | | | | | | 6 | | | | | | | | | 1 | |
| | Total: 288 | | | | | | | | | Total: 147 | | | | | | | | |

## 5.2- What the models analysis tells us

The models analysis, summarized in Table 2 - where figures in each box are totals for the six interviewed pupils - shows that the English students made more comments coded as models comments overall (544 as opposed to 324). This is partly explained by the English students commenting more on the physical features of the objects (231 as opposed to 108) and also making more comments about their relationship with other objects (77 as opposed to 38). This is not unexpected in relation to the previous analyses. Looking at the specific comments a number of interesting comparative points can be made.

Both sets of students easily name all the objects and most produce a category, such as insect. Two objects in Brazil, the tamarin and the amondoeira tree and three in England, the oak tree, the red squirrel and species of ant were named at the species level. No types of clouds were named at all by these 11-year-olds.

Both sets of pupils name similar parts and properties of those parts such as size, shape and color. In neither case are the ways in which the parts relate mentioned very often, especially in the Brazilian case. So, for instance, pupils talk about stems and roots and flowers of the daisy but not about how they connect together.

Similar behaviors of eating, growing, moving and looking after young are mentioned by both groups. No mechanisms were coded for either group of students, although when English children talked about the behaviors of clouds they seemed to come near to telling why they behaved the way they did. This seems to show that pupils at this age can describe the behaviour of the whole organism, but have difficulty in seeing what the function is of the various parts and how they connect and work together to form a functioning organism.

Table 2. Models analysis for the interviews

| | School Year 5 Meadvale (photographs/UK) | | | | | | | School Year 5 Gaya (photographs/ Rio) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Object | n | p | b | m | i | h | | n | p | b | m | i | h | |
| Daisy | 9 | 31 | 4 | 0 | 1 | 13 | **58** | 7 | 20 | 1 | 0 | 3 | 7 | **38** |
| Grass | 6 | 26 | 8 | 0 | 7 | 13 | **60** | 6 | 10 | 2 | 0 | 4 | 11 | **33** |
| Oak tree/ Amendoeira | 10 | 47 | 12 | 0 | 8 | 2 | **79** | 3 | 18 | 12 | 0 | 0 | 7 | **40** |
| Pigeon | 9 | 38 | 13 | 0 | 6 | 12 | **78** | 8 | 11 | 6 | 0 | 7 | 14 | **46** |
| Squirrel/monkey | 7 | 27 | 22 | 0 | 11 | 9 | **76** | 9 | 24 | 18 | 0 | 5 | 12 | **68** |
| Ant | 17 | 32 | 21 | 0 | 7 | 11 | **88** | 7 | 17 | 9 | 0 | 3 | 13 | **49** |
| Pond | 9 | 11 | 1 | 0 | 34 | 9 | **64** | 6 | 2 | 1 | 0 | 16 | 8 | **33** |
| Cloud | 7 | 19 | 7 | 0 | 3 | 5 | **41** | 5 | 6 | 0 | 0 | 0 | 6 | **17** |
| | | | | | | | | | | | | | | |
| *Name (n)* | 74 | | | | | | | 51 | | | | | | |
| | | | | | | | | | | | | | | |
| Physical features (p) | | 231 | | | | | | | 108 | | | | | |
| Behaviour (b) | | | 88 | | | | | | | 49 | | | | |
| Mechanism (m) | | | | 0 | | | | | | | 0 | | | |
| Interrelationship (s) | | | | | 77 | | | | | | | 38 | | |
| Habitat (h) | | | | | | 74 | | | | | | | 78 | |
| | Total: 544 | | | | | | | Total: 324 | | | | | | |

Both sets of pupils see humans as the most significant relationship that an object has with other objects. These may be negative, e.g. causing disease, or positive, e.g. producing oxygen for us to breath. Brazilian students see risks of extinction for the tamarin and fewer interrelationships in general especially for the tree and pond. Both sets of pupils talk about the habitats that relate mostly to human settlements, though wild places are spoken about. Most often, the places are connected to home and family. In England, the pupils mention different countries. This is probably related to the presence of a more multicultural mix in the English class with pupils whose parents came from Europe and India. School grounds are significant to English pupils who mention them often.

### 5.3-What the human features analysis tells us

In the human features analysis shown in Table 3 - where figures in each box are totals for the six interviewed pupils - more comments were coded in Brazil (309 as opposed to 238 in England) and in some categories there are considerable differences. The most noticeable difference for the scores is the high number of times that the monkey (golden lion tamarin) is mentioned (90 in Brazil) in relation to human features. The choice of the tamarin was taken in good faith, but the comparable organism in England, the squirrel, probably does not hold a similar place in people's affections. In England, the squirrel was mentioned 24 times and often the comments were not complementary. It is also the case that for the Brazilian pupils there are more human features' comments for animals than for plants, which is not the case with the English pupils.

Table 3. Human features analysis for pre-visits in interviews

| | School Year 5 Meadvale (photographs/UK) | | | | | | | | School Year 5 Gaya (photographs/ Rio) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Object | l | k | f | h | e | c | a | | l | k | f | h | e | c | a | |
| Daisy | 9 | 4 | 3 | 12 | 8 | 2 | 1 | 39 | 6 | 8 | 1 | 5 | 3 | 0 | 1 | 24 |
| Grass | 8 | 5 | 1 | 12 | 10 | 2 | 0 | 38 | 10 | 6 | 0 | 4 | 3 | 0 | 1 | 24 |
| Oak tree/ Amendoeira | 5 | 8 | 3 | 7 | 6 | 3 | 0 | 32 | 8 | 10 | 2 | 5 | 8 | 2 | 1 | 36 |
| Pigeon | 9 | 5 | 3 | 8 | 4 | 2 | 1 | 32 | 17 | 6 | 5 | 4 | 2 | 5 | 7 | 46 |
| Squirrel/ monkey | 3 | 4 | 0 | 5 | 8 | 3 | 1 | 24 | 14 | 15 | 13 | 15 | 11 | 4 | 18 | 90 |
| Ant | 5 | 7 | 0 | 8 | 9 | 3 | 3 | 35 | 14 | 5 | 2 | 7 | 6 | 0 | 2 | 36 |
| Pond | 4 | 3 | 2 | 9 | 7 | 1 | 0 | 26 | 8 | 4 | 0 | 13 | 4 | 2 | 0 | 31 |
| Cloud | 0 | 5 | 0 | 0 | 6 | 1 | 0 | 12 | 4 | 4 | 6 | 2 | 5 | 0 | 1 | 22 |
| *Location (l)* | 43 | | | | | | | | 81 | | | | | | | |
| Knowledge source (k) | | 41 | | | | | | | | 58 | | | | | | |
| Feelings (f ) | | | 12 | | | | | | | | 29 | | | | | |
| Human influences (h) | | | | 61 | | | | | | | | 55 | | | | |
| Direct experience ( e) | | | | | 58 | | | | | | | | 42 | | | |
| Culture (c) | | | | | | 17 | | | | | | | | 13 | | |
| Anthro-pocentric (a) | | | | | | | 6 | | | | | | | | 31 | |
| | Total: 238 | | | | | | | | Total: 309 | | | | | | | |

In general, the human features analysis shows that Brazilian students expressed more emotional views such as the ones that show disagreement about the way an animal is treated. E.g. "*I hate to see birds in cages! My dad used to keep them in cages. I think it's appalling because they were not made to live in a cage"* (girl)*; "I don't like it that golden-lion monkey are under risk. I also don't understand why people hunt animals"* (girl).

They also used more anthropocentric views although all students saw human beings as at the centre of the environment and as the purpose of the environment to some extent. E.g. "*When I look at it (pigeon), I immediately imagine the disease they (pigeons) transmit* (boy); *"They can cause health problems" (*boy).

English children see human influence as being primarily through domesticated places such as gardens, parks and towns and activities like fishing. E.g. "*I see pigeons round my house and they just fly about and they pick up any sort of thing lying dead like worms, sting insects and bread. Any sort of food. They like to live in towns because that is where all the food is from"* (boy).

Brazilian children see human influences primarily through captured, hunted and killed animals and how they are fed and looked after. E.g. "*Monkeys have families and have children to look after; they have to feed them. I imagine them like us. I don't like to see a jailed animal"* (girl).

Although both groups relied on experience from home situations for most of their knowledge, school-based knowledge is also especially important for pupils in the English school. Explanations notably about clouds (where they mention the water cycle) and the oak tree (where they mention photosynthesis) show the significance of school knowledge especially for English pupils.

Using the three analytical approaches has given us a deepened description of the responses and enabled us to compare both aspects of knowledge and experience of the natural objects in pupils from Rio and Bracknell.

## 6. Discussion and implications for research and science teaching and learning

### 6.1-The methodology

The data presented in this paper were collected from a sample of six 10-11 year-old pupils in Rio and six in Bracknell. While this is a small sample, we would not wish our results to give the impression of generalization other than that it summarizes the data which we collected. The results are pointers for future work and show interesting issues, previously unreported, and avenues for research. The sample was selected by the teachers and as such their informed but pragmatic judgment needs to be recognized. They would have some impressions of what the project required and may have differed in how they interpreted our requests for a representative sample of their classes. The schools have many features in common but they are not matched in many respects. They are the closest that we could find given the constraints of the project.

Turning to the interview process with the pupils, although we attempted to be as non-directive as possible, it is not appropriate to control the process and still maintain the sort of contact that is needed to forge a trusting relationship so that children express their understandings as freely as possible. Lastly, the selection of the photographs is an important, though taxing, part of the process and it has become clear through the research that the composition of the photographs, in particular their background context, is a significant part of their effectiveness in eliciting the breadth of knowledge.

The three modes of analysis used in this research interrelate with each other, so that they provide a richer analysis of children's understanding of the natural world than has been investigated before. We suggest that the three analysis modes taken together enable us to grasp elements of the complexity of this kind of investigation when the research object is children's understanding of the natural world. The research approach to grasp such complexity has to avoid reducing it and to be open to seeing new aspects in the data. We argue for a multiple analytic perspective because:

(a) It reinforces the notion that researching into children's understanding of the natural world requires more than thinking about it as merely biological. An analysis that focuses only on the biological aspects is insufficient.

(b) It shows that natural objects cannot be internalized by children only by means of intellectualized and abstract information, like that of the biological organization level framework.

(c) It carries with it the assumption that in order to research the understanding of the natural world, the deeper aspects of socio-cultural representations tacitly embedded in children's experiences of the world (e.g. in different countries), have to be grasped. It makes it clear to us that what we call "natural" world is in fact the result of a long term human cultural relationship and dependent on particular cultures.

### 6.2- The use of photographic probes

In school, we often introduce children to a topic using photographs on work cards or in books and children have access to downloaded photographic images from the web. Photographs are used in assessment materials and in field guides for identification. Our research showed that photographic probes allowed the children to speak openly about what they saw in the photographs both the fore-grounded object and the background and to go on and talk about what else they understand about the natural world. We would suggest that the background of the photograph should be carefully considered when selecting a photograph to elicit children's understandings. It is often the background that helps the children to talk about the interrelationships of the object to other things in the natural environment. This is a field where further research would prove very useful. For instance, it occurs to us that more use could be made of pupils using cameras to take their own photographs of natural objects and that they could be encouraged to think closely about the contexts that they captured along with their chosen objects.

### 6.3-Children value local places

Most pupils described where the objects whose representations we presented could be found. These places were generally places of social interaction. Parks, gardens, botanic gardens, and football pitches were amongst the places mentioned. This suggests that visits to out-of-school venues do not need to be 'pristine' (i.e. 'natural') habitats to be memorable to children. Linking school science with pupils' memories of local places may be an important way of focusing on biological learning, ether inside the classroom or when planning visits.

### 6.4- Children want to name living things

Whenever possible, pupils named the objects we presented and often struggled to give us species names. Naming is also related to local culture selections of the aspects of the individuals and their parts. Being able to name the living things around them was clearly important and this is an area where both teachers and researchers might focus.

### 6.5- Cultures have different relationships to the natural world

The main differences between Rio and Bracknell lay in the realm of human experience with the Brazilian children expressing more emotional and anthropocentric views. They also saw humans as primarily relating to the natural world through capturing and hunting animals (which clearly show a concern about environment harm in this particular culture), whereas in England the emphasis was on domestication.

### 6.6- Children's understanding is rich and deeply embedded

The children with whom we worked were in touch with their environment. They constantly referred to their experience of what they saw everyday in their surroundings. Their knowledge had been enhanced by children's books, TV and video, but they expressed the fundamental way humans have always built their relationship with the environment. As Thomas (1983:52) points out:

*"The observation of the natural world involves the use of mental categories with which we, the observers classify and order the otherwise incomprehensible mass of phenomena around us; and it is notorious that, once these categories have been learned, it is very difficult for us to see the world in other way".*

The children we listened to expressed deep feelings, differing only in which animals and plants they were concerned about in the two contexts. They showed a strong sense that human beings are at the center of the environment and control it. These deeply held convictions are likely to have been developed early in life. This can serve as a significant input for teachers, since it is important to consider ways in which new and old environmental science topics can be taught and learnt. So, a cognitive approach, e.g. teaching levels of biological organization is not enough; teaching about the natural world also needs to take their experience and feelings into account. What is clear is that - as teachers - we need to listen more carefully to our pupils and build our teaching from their experience - what interests them, what they have learnt outside school and how they have chosen to interact with their own natural environments.

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## Appendix 1: Definitions for coding for expressed models

| Feature | Code | Feature | |
|---|---|---|---|
| Naming | n | Name mentioned | The common name for the species e.g. red ant. |
| | | General type | The grouping name e.g. animal, bird, insect , mushroom |
| Physical features | p | Parts | The identifiable parts of the organism e.g. feet, branches |
| | | Properties | The characteristics of the object and those parts e.g. shape, color, number |
| | | Relationships of parts | The relationship of the parts e.g. the leaves are round the stem, antennae on the head |
| Behaviour (doing and changing) | b | | The processes of living, descriptions of movement |
| Mechanism | m | | Causal reason for behaviour, e.g. rain from clouds because they clash |
| Interrelationships | i | | The relationships with other organisms or materials or energy e.g. grass is flattened by dogs |
| Habitat | hb | | Place where the organism lives, or the place where the object is found e.g. mushrooms in a wood, clouds in the sky |

## Appendix 2: Definitions for coding of human features analysis

| Feature | Code | Definition |
|---|---|---|
| Location | L | Place where the object lives, grows or is found. Locations often linked to human influence thus coded for both. |
| Source of knowledge | K | Where information had been obtained from. *"My Dad told me", " I watched this video"* |
| Feelings | F | An emotion or emotive opinion expressed. *" It isn't very nice" "really cute and cuddly"* |
| Human influence/ human action | H | Any action or activity of humans that affects the natural world. *"Pick the flowers", "cut the grass"* |
| Personal experience | E | Any statement that indicates that the child knows about this from their own first hand experiences. *"Saw one in my garden",* |
| Cultural/ multicultural | Mc | Words and phrases that indicate a particular culture. *"In India" "In former Yugoslavia" "In England"* |
| Anthropocentric | A | Animal or plant influence/ effect on humans *"Poisonous". "It bit me" "can kill you"* |

# ELEMENTARY SCHOOL STUDENTS' UNDERSTANDING OF LIFE CYCLES

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## Abstract

As part of a research programme addressing the design and evaluation of teaching sequences in science, we are developing a teaching sequence concerning life cycles for students at school forms 1-5. In this paper we describe a teaching experiment involving students age 9 and 11. The teaching intervention of 15-20 hours, included observations and discussions of life cycles of peas, beans, blowflies and artemia. The students' understanding of life cycles was assessed using a pre-test before teaching, a post-test after teaching and a delayed post-test 6 months later. Eight paper and pencil tasks were used. Data presented in this study are drawn from the 70 students who completed all three tests, 25 students age 9 and 45 students age 11. Analyses of students' answers indicate that learning of a specific lifecycle might not be problematic provided that the child has been given the opportunity to observe and discuss about it. However, analyses also indicate that the link between one generation and the next is complicated, i.e. the notions of reproduction and fertilisation when it is a question of sexual reproduction. This aspect of life cycles needs to be developed further within our research program.

## 1. Introduction

Some minor studies indicate that Swedish students' understanding of science concepts is limited during the years of elementary schooling, which means that curriculum goals are not achieved. (West, 2001; Skolverket, 1997; Nyberg, 2002). Therefore, as part of a research programme addressing the design and evaluation of teaching sequences in science, which is being developed by our science education group at the University of Gothenburg, Department of Education (Andersson & Bach, 2005), we have developed a project for school forms 1-5 (age 7-11) with the intention of improving elementary school science. The aim of this project is to enhance the teachers' competence to develop and evaluate their teaching in order to promote learning and to make science more interesting and stimulating. We try to achieve this aim through collaboration with teachers in the design and evaluation of teaching sequences supported by written teacher's guides.

## 2. Research interest and questions

One of the guides being developed concerns the area of life cycles. In this guide we present research results on students' preconceptions and difficulties in understanding. The nature of the content chosen is also analysed, and we suggest teaching goals as well as lessons that might help achieving these. We emphasize the importance of formative evaluation and give practical advice on how to do this. From pilot teaching based on this guide, several research questions have emerged. Two of these are addressed in this paper:

- *'What are children's conceptions of life cycles, before and after teaching?'*
- *'How can answers to question one inform practice and be used to revise the teacher's guide?'*

## 3. Literature context

During the last two decades, a large amount of studies have investigated students' understanding of science phenomena. A well-known database lists about 6000 publications (Duit, 2002). However, a search in Duit's database results in only one hit for 'life cycle' (Shepardson, 1997). Shepardson made a study on insect life cycles in a class of first graders during a teaching unit. The children's understanding of insect life cycles was explored through pre- and post-instructional interviews, as well as through the analysis of journal entries and talk that occurred throughout an instructional unit on beetle and butterfly metamorphosis. Although the children's ways of seeing and talking about beetle and butterfly life cycles were changed by the instructional experience, the children didn't adopt a more general model of life cycles. In a more recent study Shepardson (2002) explores children's ideas about insects from kindergarten through fifth-grade for a total of 120 children. Concerning insect life cycles he concluded that by observing the growth and development of different insects over time, children can compare the different forms of metamorphosis, learn about the ecological importance of metamorphosis among insects, and can relate the stages of metamorphosis to insect growth and development. Children can then consider why caterpillars and other larval forms are insects as well as why earthworms are not.

There is also some literature on plants and flowers. Tytler, Peterson and Radford (2003a) present a study by Symington and White (1983) where one group of seven year old children (n=83) and one group of twelve year old children (n=115) were asked the question: 'Why do plants have flowers?' According to this investigation young children see the purpose of flowers mainly in terms of the needs or desires of humans, or of other animals such as bees, rather than in terms of the adaptive needs of the plant itself. Only a few of the children answer 'to grow fruit'. This was also observed by Leach, Driver, Scott and Wood-Robinson (1995), who investigated students' ideas of decay, using an apple as example. Some of the students' responses suggested that the students saw the apples as a source of food for people rather than as a seed container for apple trees. Decay was therefore related to the apple not being eaten on time.

Helldén (1992, 2000) has shown that children confuse pollination and seed dispersal, as well as nectar and pollen when they try to explain how a flower is being fertilized.

Driver, Squires, Rushworth and Wood-Robinson (1994b) point out that it is a 'tremendous challenge for pupils to appreciate the spiral of life cycles enabling the continuity of life through time and that it involves far more than memorising life-cycle diagrams or even observing the changes in organisms through an annual or seasonal cycle, although such a practical study may be a useful starting point.

Concerning the concept of living things, Driver et al. (1994b) report that many children do not regard plants as living. Even children that consider growth to be a criterion for life and know that plants grow, might deny plants are alive. The authors also report that although children often don't believe that seeds, eggs and pupae are alive, they may believe that live seedlings, chicks and butterflies can arise from them. They conclude that this might be due to the meaning they attach to the word alive. Carey (1985) argues, in accordance with this, that children, no less than adults, have no simple definitions of life, and that the growing insight about this is due to the child's developing biological knowledge. She holds that 'one cannot simply assume that the word 'alive' is a direct pipeline to children's concept of life' and argues further that even if children have a concept of life, alive may have some other meaning for them.

## 4. Development of the teaching sequence

### 4.1- Definition of the term life cycle

Life is sustained from generation to generation. A pea is planted, it germinates, grows and blooms. Then, after fertilization, pea pods are developed with new peas that can be planted and grow. The pea plant has by then gone through a life cycle. A cycle means in biological context a process, which time after time returns to an initial state. Another example is the fertilized egg of a butterfly, from which a caterpillar is developed and eventually turned into a pupa. Out of the pupa comes the adult butterfly. After mating and fertilization new eggs are laid, and a new life cycle can start. The life cycle of man could begin with the newborn baby and be completed when the baby has become an adult who gives birth to a new child.

### 4.2- Curriculum goals concerning life cycles

The Swedish curriculum (Skolverket, 2002) states that the pupils at the end of the fifth form should have attained the following goals concerning 'Nature and man'. They shall:
- Recognise and be able to name common plants, animals and other organisms in the local environment, as well as be familiar with their environmental requirements.
- Be able to give examples of the life cycle of some plants and animals and their different growth processes.

### 4.3- Teacher's guide on life cycles

The general structure of the teacher's guide has been described in section 2 above. In the guide we suggest a number of specified and complementary goals e.g. that the pupils shall know that both plants and animals are living and that all stages in their respective life cycles are considered to be living stages. We also want the pupils to attain respect for life and its continuity.

Activities suggested are close studies of different organisms and we present examples of organisms suitable for studying life cycles and also methods to handle and observe them mainly indoors, but outdoors as well. We suggest that only one or two pupils plant or make studies together, a prerequisite for taking responsibility for their own organisms. The basic idea is that the students become acquainted with life cycles of a number of different organisms, in order to help them transfer their understanding to different contexts. Studies of peas or beans that the students plant and nurse by themselves in the classroom, is combined with observations of flowers and seeds outdoors. One activity recommended is for example to go 'seed hunting' in the forest nearby, to plant the seeds indoors and follow the growth of an oak or maple or the flower rose bay. Among animals recommended are blowfly and artemia.

To help students understand the continuity of life through time we recommend that the teaching sequence is planned in order to make it possible to follow an organism from one generation to another. The life cycle of a pea is followed during a period of 6-8 weeks. The children can then observe the growth, blooming and seeding and hopefully plant the new seed from the peapod, and see this pea germinate and grow. The life cycle of artemia - a small saltwater living crustacean - can be studied during a period of 5-6 weeks, during which the children can observe the hatching of the eggs, the growth into adults, the mating and the eggs develop by the female. If the aquariums are successful, it is possible to get to study a second or third generation of artemia as well.

As one way to get an interesting discussion of what is living and what is not, we recommend an activity using the fridge and the larder as a starting point. Is potato alive? Is garlic alive? Is lin seed alive? Why? Why not? Let's plant them! Do they grow? Are they alive now? Why? Why not?

## 5. Methodology

### 5.1- Design of the study

Childrens' understanding and knowledge of life cycles has been investigated within a case study design. The process may be characterized as developmental research or action based research (Lijnse, 1995; McNiff, 2002). Pilot studies were carried out during a period of about a year within the teacher-training project mentioned in the introduction. During this period we made progress concerning our knowledge about the difficulties and possibilities pupils have within the area of life cycles and revised the life cycle teacher's guide on the basis of these findings.

Two teachers participated in the main study. They used the revised teacher's guide about life cycles in four different classes. One of the teachers taught children age 9 and the other taught children age 11 and 12.

Around 90 pupils were involved. The teachers were visited in order to find out about their experiences and problems and to give advice. Six visits per teacher were made. The teaching time devoted to life cycles has been 15-20 hours, during a period of on average 10 weeks. The organisms chosen by the teachers for the students' group wise observations and handling were artemia (a small saltwater living crustacea) and peas. One teacher also let the children plant beans and sunflower seeds. Both teachers let the children study the development of blowfly (Calliphora vomitoria) and one tried the metamorphosis of the butterfly 'painted lady' (Vanessa cardui). Both teachers decided to study the development of tree branches leafing and blooming, in the forest nearby, by regular visits there, throughout the spring.

The pupils' understanding of life cycles was assessed using a pre-test immediately before the teaching, a post-test immediately after the teaching and a delayed post-test 6 months later. Data presented in this study are drawn from the 70 students who completed all three tests, 25 students age 9 and 45 students age 11.

### 5.2- The development of the tests

The pre, post and delayed post-tests were based on 13 pencil and paper tasks, 9 of which were used in all three tests. These tasks were tested and evaluated, after initial piloting and revision of the teaching sequence and before the main study, using one teacher working with 40 pupils age 10-12, serving as a pilot teacher. Schedules for interviews and lesson observations were tested at the same time.

The paper and pencil tasks were of three types. In type I, a collection of pictures of stages in the life cycle of a certain organism is presented randomly. The task is to order them in a correct time-sequence. The student may also be asked to explain the reason for the order he/she has suggested. The size of the organism in the pictures is varied so that it is does not function as simple clue to the right sequence (reasoning that 'the older the bigger' will not work). Type II is a multiple-choice problem. The student may also be asked to explain his/her choice of alternative. Type III is a problem to which the student has to write an answer of his/her own. The tasks dealt with in this paper are:

#### 5.2.1- What is alive?

Among twelve pictures of different objects, (Table 1) the task is to cross the pictures that do not show something alive.

#### 5.2.2- Which is the right order?

The task is to order pictures of different stages of the growth of a bean plant in a correct time-sequence. (Type I)

#### 5.2.3- How do flies come into existence?

The task is to choose the correct explanations of the origin of a fly. The alternatives given are:

- Flies give birth to fly babies that grow and become big flies
- Flies lay eggs which hatch, grows and develops into big flies

- Flies develop from eggs to adult flies through larva and pupa stages
- Flies come into existence from rotten fish and meat. (Type II)

### 5.2.4- The old oak

The task is to answer the following question:
'In a forest there is only one oak. Late one autumn, a heavy storm uproots the oak (there is a picture of a fallen oak with almost all its roots in the air). Is there a chance that a new oak will begin to grow in the forest? Explain your reasoning!' (Type III)

### 5.2.5- The peapod

The task is to cross the right alternative concerning whether peapods develop only where there first has been a flower or whether peapods develop from other parts of the plant.
(This question was not used at the pre-test) (Type II)

### 5.2.6- The bee hive

In this question two neighbours, Lilian and Kerstin, are talking. Lilian tells Kerstin that she has installed a beehive in her garden. Kerstin remarks that now she'll get more apples on her apple trees. The pupils are asked to explain what the beehive has to do with more apples on Kerstin's trees. (Type III)

### 5.2.7- How will there be a baby?

The task is to choose the correct alternative concerning the origin of a baby. Three alternatives are given:
- The baby exists in the sperm, but requires the egg for food
- The baby exists in the egg but requires the sperm to trigger its growth
- The baby comes into existence when the sperm and the egg come together. (Type II)

### 5.2.8- The fish that mate

The task is to choose the correct alternative concerning the origin of salmon 'babies'. Four alternatives are given:
- The fish baby exists in the sperm, but requires the egg for food
- The fish baby exists in the egg but requires the sperm to trigger its growth
- The fish baby comes into existence when the sperm and the egg come together
- The sperm becomes a male fish; the egg becomes a female fish. (Type II)

## 5.3 Data Analysis

The students' answers to open-ended questions were analyzed qualitatively. Categories and other details in the analysis were not decided in advance but formed through interaction with the actual replies. The categories emerge by a process of hypothesizing them and checking them against actual answers. This results in a manual, in which the categories are defined by headlines and examples of answers. The manual is applied to all the answers by two researchers. Differences in categorizations are discussed, which may lead to refinement of the manual. This process goes on until there is at least 80% agreement. Four researchers were engaged in the task of constructing a reliable system of categories for the questions used in this study.

## 6. Results

### 6.1- What is alive?

There were pictures of a fly, a moving van, a dandelion, a swede, a lit candle, a pine, agaric, the sun, garlic, a seed, a snail and a TV switched on. In effect, 100% of the pupils in both age groups and on all tests considered the two animals to be living, whereas corresponding numbers for plants varied between 60% and 90%. The 9 year olds considered the plants to be living less often than the 11 year olds. As an example, pre test results for swede and pine are 60% and 72% for the younger, 91% and 96% for the older pupils. For both age groups and on all tests, the garlic tended to be considered alive less often than the other plants (Table 1).

For the organisms in general, no considerable change was shown from pre test to delayed post test except for the garlic and pine, which were more often marked as being alive among the 9 year olds at the delayed post test (70% and 91%, respectively) compared to the pre test (56% and 72%). Among the 11 year olds the seed and the garlic were less often considered to be alive on the delayed post test (80% and 71%, respectively) than on the pre test (90% and 80%).

Within both age groups the sun was marked as being alive less often after than before teaching. For the 9-year-olds there was a drop from 68% on the pre test to 50% on the post-test and 48% on the delayed post-test. The corresponding numbers for 11 year olds are 72%, 41% and 51%.

Table 1. 'Alive or not alive?'
Percentage answering 'YES' at different test occasions

| Object | age 9 | | | | age 11 | | |
|---|---|---|---|---|---|---|---|
| | Pre-test n=25 | Post-test 1 n=24 | Post-test 2 n=23 | | Pre-test n=46 | Post-test 1 n=41 | Post-test 2 n=45 |
| Fly | 100 | 100 | 100 | | 98 | 100 | 98 |
| Snail | 100 | 100 | 96 | | 100 | 100 | 98 |
| Pine tree | 72 | 71 | 91 | | 96 | 98 | 96 |
| Fly agaric | 68 | 75 | 86 | | 91 | 90 | 96 |
| Seed | 68 | 71 | 74 | | 90 | 73 | 80 |
| Dandelion | 68 | 75 | 78 | | 91 | 95 | 89 |
| Swede | 60 | 58 | 65 | | 91 | 85 | 87 |
| Garlic | 56 | 58 | 70 | | 80 | 66 | 71 |
| The Sun | 68 | 50 | 48 | | 72 | 41 | 51 |
| Candle-flame | 60 | 67 | 70 | | 48 | 46 | 49 |
| Driving truck | 24 | 21 | 0 | | 4 | 5 | 2 |
| TV, which is on | 20 | 21 | 4 | | 2 | 2 | 4 |

### 6.2- Which is the right order?

This task probed whether the students could distinguish the difference between four pictures of different stages of a bean plant and place the pictures in a correct time sequence, showing the development of sprouting seed, seedling and plant. The students' ability to do this increased to some extent after teaching among the 9 year olds, from 56% at the pre test to just above 70% at the post test and delayed post test. The 11 year olds' responses were almost the same before and after teaching, just above 75% placing the pictures in the correct order, but increased a little at the delayed post test (87%). The main problem with this task was to distinguish between one small scale drawing of a grown up bean plant with hanging bean pods and a drawing of a not yet blooming bean plant in a larger scale drawing.

### 6.3- How do flies come into existence?

The result was almost identical between the 9 year olds and the 11 year olds. About 25% choose the correct alternative at the pre test, i.e. the fly develops from an egg to an adult fly through the larva and pupa stages. This alternative attracted around 90 % at the post-test and delayed post test.

### 6.4- The old oak

The students tend to respond that there is a chance that a new oak will begin to grow in the forest either 'if there are some roots left' or 'if the trees had some seeds/acorns'. About 50% of both age groups mention seeds/acorn in their pre test answers, e.g. if there are acorns, they could grow into new oaks. There is not much change after teaching, apart from the fact that the 11 year olds specify a little more the notion that an acorn is a seed.

### 6.5- The peapod

It was observed during the teaching that the link between flower and fruit is not obvious among the children in the study. This was therefore tested by a question in the post-test and the delayed post test for both age groups. The result is that about 80% of the students after teaching chose the correct alternative, namely that peapods develop only where there first has been a flower.

### 6.6- The beehive

The result is shown in Table 2

### 6.7- How will there be a baby?

There was an increase in the proportion of the 11 year olds choosing the correct alternative from pre- to post test and delayed post test: 63 %, 88%, 84%.

For the 9 year olds, the corresponding numbers are 56%, 29% and 43%. The pre-post decrease is accompanied by an increase in the amount of pupils choosing the alternative saying that the baby from the beginning is in the egg.

## 6.8- The fish that mate

The result of the task about fish reproduction did not differ very much from the result for humans. There was an increase in the proportion of the 11 year olds choosing the correct alternative from pre- to post test and delayed post test: 50 %, 82%, 73%. For the 9 year olds, the corresponding numbers are 40%, 46% and 43%. We note that contrary to the answers for humans there is no post-test decrease among the 9 year olds.

Table 2. Percentage responses per category on the question about the beehive
Form 3 (age 9) and 5 (age 11) taken together

| CATEGORY | EXAMPLES OF RESPONSES | PRE-TEST n=71 | POST-TEST 1 n=65 | POST-TEST 2 n=68 |
|---|---|---|---|---|
| A. THE BEES EAT/ DAMAGE THE APPLES | - I think that the bees will eat the apples so I don't understand why it would grow better with bees. | 22 | 2 | 7 |
| B. THE ACTIVITY OF THE BEE HAS SOMETHING TO DO WITH THE PRODUCING OF APPLES (NOT SPECIFIED) | - Because the bees fly between the flowers and therefore more apples will appear. | 10 | 0 | 4 |
| C. SOMETHING IS TRANSFERRED FROM FLOWER TO BEE (mostly nectar, also pollen, other) | - Because the bees eat apple nectar. | 13 | 8 | 19 |
| D. SOMETHING IS TRANSFERRED FROM BEE TO FLOWER | | | | |
| 1. Nectar/nutrients/honey. | - The bees give nutrients to the flower, which gives more apples. | 0 | 3 | 1 |
| 2. Pollen (sperms)/pollination | - The bees distribute pollen to the flowers in the tree and where there are flowers more apples can grow. | 0 | 3 | 1 |
| 3. Other | No answers in this category | 0 | 0 | 0 |
| E. BEES FERTILIZE THE FLOWER | - The bees fertilize the flowers so that there will be more apples. | 3 | 3 | 10 |

| | | | | |
|---|---|---|---|---|
| **F.** BEES TRANSFER SOMETHING FROM FLOWER TO FLOWER. | | | | |
| 1. Nectar/Nutrients | - The bee fly from flower to flower and takes nectar. When it has taken nectar from one flower and flies to the next then the nectar will fall off the bee in the flower then there will be apples. | 0 | 6 | 4 |
| 2. Pollen (sperms) | - The bees fly and sucks nectar from apple flowers then pollen get stuck on the hind legs of the bee and when the bee flies to the next flower it drops the pollen seeds on the other flower, which drops it petals and then apples will start growing. | 0 | 25 | 7 |
| 3. Other | -The bees fly to one of the flowers on the tree and then seeds are stuck on the bee and when the bee fly to another flower the seeds fall on the flower and there will be apples. | 0 | 0 | 3 |
| **G.** ATTEMPT TO APPLY A MODEL WITH BOTH MALE AND FEMALE PARTS | - The bee makes the pistols and the stamen to mix then there will be apples. | 4 | 17 | 9 |
| **H.** OTHER | - The bees move the pollen to the tree so the apples will grow. | 23 | 16 | 11 |
| **I.** NOT MOTIVATED | - I don't know. | 20 | 12 | 16 |
| **J.** NOT RESPONDED | | 1 | 0 | 1 |

## 7. Discussion

### 7.1- What are children's conceptions of life cycles, before and after teaching?

#### 7.1.1- Alive or not?

We observe small gains for all plants from pre test to delayed post test for the 9-year-olds. We believe this reflects both general intellectual growth and the specific teaching about life cycles. The decline after teaching, concerning the students' notion that a seed is alive, among the older children, in spite of everyone having planted various seeds, is to some extent confusing. Maybe some children got seeds that didn't germinate? According to Driver et al. (1994b), many children don't consider plants to be living, nor seeds, in spite of knowing that plants grow. They also point at the problem that not all living things show all the characteristics of life all the time and that children find it difficult to think of something as being alive if they cannot observe it moving, eating or growing.

### 7.1.2- Life cycles of insects

The students in the study observed the development of blowfly from the larva stage to the adult fly, including discussions. The pre test, post test and delayed post test demonstrate that the life cycle and development of the blowfly was mostly unknown to begin with, and that teaching in this respect had a positive effect on the students' learning. This is a sign as good as any that concrete experiences combined with discussions can enrich children's knowledge of biological details. However, like Shepardson (2002), we do not believe that the children have adopted a general view of insect growth and development, but the teaching has probably increased their possibilities to do so.

### 7.1.3- Life cycles of plants

The results of the task about placing four pictures showing the growth of a bean plant in a correct time sequence demonstrate moderate gains from pre test to delayed post test. The children's concrete experiences in this case were not as clear as for the blowfly. The 9 year old children had all planted a pea and raised a pea plant from that. Just a few of them, though, did get peapods in time before the post-test and the summer vacation. The 11 year olds planted either bean, pea or sunflower seeds. Not all of them got pea or beanpods before the post-test and summer vacation. Some might have brought them home however and nursed them afterwards.

The results of 'The old oak task' indicate that a general idea of 'from seed to seed' cycles has not been generalized among the children in our study. There is not much improvement after teaching, apart from the fact that the 11 year olds specify a little more the notion that an acorn is a seed.

As was mentioned above, it was observed during teaching that the link between flower and fruit was not obvious among the children in the study. The results from the post-test show that around 80% the pupils after teaching have some knowledge of this concerning the pea plant. To what extent this makes them generalize their knowledge to other plants, we do not yet know. It would be interesting to give this question to children that have not yet gone through teaching about life cycles, to find out if the 'problem' to see this connection is common.

According to Tytler et al. (2003a), there are reports that children rarely see the function of the flower to grow fruit, i.e. the flower's way to reproduce. Only 13% of the 11-12 year old children answered this to the question 'Why do plants have flowers?' Tunnicliffe and Reiss (2000) found that children from 5 to 14 years, exposed to some different kinds of plants, tend to focus on striking anatomical features. The authors believe that pupils can be helped to observe more carefully and with greater precision. Maybe the lack of close studies of flowering plants is one reason for the children not having been aware of the connection between flower and fruit. In Tytler et al. (2003a) is further described a study by Biddulph (1984) of 7-11 year old children, in which was found that not one child out of 80 seemed to know that the structure of fruits facilitates seed dispersal.

### 7.1.4- Mechanisms of reproduction among plants

The results of the beehive task demonstrate that the children are largely unaware of the mechanisms behind fertilization among plants. This is not surprising in view of the fact that there has been very little specific teaching about insects and pollination. There was, however, at one occasion group interviews and discussions with all the students at age 9 concerning the reproduction of their plants. The fruit setting of a blueberry plant was included in this discussion as well. With half of the students at age 11, there were group interviews and discussions in the forest concerning the fruit setting and reproduction of blueberry plants.

However, we are impressed by the creative ways that children use their limited knowledge to invent an explanation to the beehive task. One category of explanation is that bees harm the apples, flowers or trees in different ways. In some of the answers the students write just that. In others they add that the bees will now stay around the hive with its nice honey and therefore cause less harm to Kerstin's apples. 22% respond according to this category on the pre test. On the post test and delayed post test, the corresponding numbers are 2% and 7% respectively (Table 2). This drop indicates to us some development of the children's biological understanding.

Both at the bee hive task and during lessons we have observed that children confuse pollination and seed dispersal, as well as nectar and pollen, which has also been reported by Helldén (1992, 2000). If one does not have an idea of sexual reproduction as the fusion of a male and a female part, and some knowledge of the male and female structures of the flower, it is difficult to get the role of bees in fertilization right, we believe, and also to differentiate between nectar and pollen. One is left to remember rather unconnected details, which might be how answers according to the categories C to F (Table 2) are constructed by the children.

### 7.1.5- Mechanisms of fertilization among animals, including humans

The life cycle of humans was not taught specifically. However, watching the artemia eggs hatch and develop from larva stage into grown up artemia, mating of them and seeing the eggs develop in the female's egg sac made it natural for the teachers and students to compare with humans.

We tested the children's knowledge of fertilization by two similar tasks, 'How will there be a baby?' and 'The fish that mate'. There was a pre-post increase among the 11 year olds choosing the correct alternative concerning the origin of a baby. Contrary to that there was a pre-post decrease among the 9 year olds choosing the correct alternative. This is accompanied by an increase in the amount of students choosing the alternative saying that the baby from the beginning is in the egg. Discussing this pattern of answers with the teacher in question, she immediately exclaimed: 'It is due to the artemias!' Her conclusion was that there had been no distinction made in the teaching between the non-fertilized and fertilized eggs. The children had seen eggs in the artemia without having seen the mating. They had also seen mating take place in spite of lots of eggs in the female artemia. It was not obvious to them, she said, that the origin of the artemia larvae was from both a sperm and an egg.

### 7.2- Implications for teaching and for revising of the teachers' guide

We conclude from our study that the notion of a specific life cycle is not very problematic provided that the child has been given the opportunity to observe and discuss about it. An example is the substantial gain from pre test to post test concerning the task about the origin of a blow-fly. However, it seems as if the link between one generation and the next might be complicated, i.e. the notions of reproduction and also fertilisation when there is a question of sexual reproduction. The sexual reproduction of plants is little known to the children in our study, whereas the vegetative way to reproduce seems more obvious, according to the question about the oak, reported above. The vegetative reproduction of strawberry plants, pot-plants or willow is easily observed and the development of a pea or an apple might just be seen as part of a continuous growing process within the plant, just as the leafing, or growing of branches. This demonstrates that understanding of sexual reproduction shall not be taken for granted and therefore needs to be explicitly introduced and exemplified in a varied way during teaching, and contrasted with vegetative reproduction. A child obviously needs more careful and detailed instruction concerning the sexual reproduction behind the growth of an apple or a peapod than we have provided so far. It seems clear that planting of a sunflower seed and following the growth of it would not automatically lead to an understanding of the mechanism behind sexual reproduction, even if the seeds produced eventually are picked out and planted in turn. The production of seeds would then be just one part of the growing process of the sunflower.

Are these limitations of observations by inspection a problem, one could wonder? Isn't it good enough if the pupils come to understand that the production of seeds is the prerequisite for getting a new generation of the plant? Yes, we would say, to some extent. It is a good start. But as the child grows older it must be desirable knowledge firstly that the child becomes aware that the flower is the prerequisite for the fruit to develop and secondly that this development is due to the fusion of two different cells from a female part and a male part respectively. Having come to an understanding of this, the notion of variation and inheritance among a population would be possible to achieve. As is argued by Driver et al. (1994b), the challenge is to recognize that the distinction between the two modes of reproduction (asexual and sexual) lies in the concept of fertilisation and that this has significance in producing variation. They claim that 'the key distinction between the two modes of reproduction lies in the concept of fertilisation. The key distinction is between 'joining of cells' and 'no joining'. By referring to a wide range of examples of reproduction pupils could be encouraged to recognise that these are all strategies for continuity, but with the potential for stability (asexual) or variation (sexual)' (p. 85).

To which extent this can be achieved with younger students remains to be studied, but as is argued by Tytler and Peterson (2003b), young children has greater ability for scientific reasoning, than has so far been claimed. In our study we saw evidence of children's capability to grasp biological relations in their responses to the question about whether the bees would influence the amount of apples on the apple-tree or not. On the pre test they invented all sorts of explanations, among which the harmful impact of bees were frequent answers. On the pre test and delayed post test respectively, these explanations were substituted by answers where the bee in some way or another was advantageous for the apple production. Although very little 'teacher intervention' had taken place on this subject, the pupils had abandoned their previous idea and begun to use words like pollination, fertilisation, reproduction and nectar, let alone in often a totally 'mixed up' way.

### 7.3- Conclusions

We conclude that teaching needs to be very specific concerning the mechanisms behind reproduction. We need to investigate further what conceptions there are among children concerning for example pollination and fertilization before and after a structured teaching unit on this.

It has been confirmed that improved teaching is needed concerning children's concept of 'alive'. What is their notion about what is living/not living? Students evidently need many varied examples to discuss and reflect upon concerning what characterizes a living organism.

It is also evident that teaching involving studies of living systems both indoors and outdoors demand a well planned and structured instruction with many opportunities for reflections. If this is increased even more, results might improve.

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# PRIMARY SCHOOL TEACHERS' CATEGORIES FOR "ANIMAL": BIOLOGY OR FOLKBIOLOGY?

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## Abstract

The study described in this paper focuses on Greek Primary School teachers' concepts and classifications regarding animals. In the concept study, ten teachers were interviewed individually by means of stimulus materials for the meaning of the concept "animal" and the constant comparative method was employed to analyze data. Findings indicate that the meaning of the concept of "animal" that teachers construe is restricted and anthropocentric. In the classification study, oral oddity tasks as well as paper and pencil tasks were adopted in order to investigate the personal taxonomies of 108 teachers. The findings indicate that teachers use biological taxonomic groups in their classifications, but the meaning and the content of these categories is more similar to folk-biological categories than to scientific concepts. Teachers seem to base their classifications mainly on morphology, behaviour and ecological considerations. The use of such features is typical in the formation of folk-biological taxonomies. The influence of anthropocentric thinking is also evident in teachers' classifications. The findings of this study could form the basis for developing appropriate curricula, for initial and in-service teacher education, taking into account the teachers' own perceptions about animals and anthropocentric thinking.

## 1. Introduction

In every human society, people think about plants and animals in special ways. These special ways of thinking are fundamentally different from the ways humans usually think about other things in the world, such as stones, stars, tools (Medin & Atran, 1999). These special ways of thinking are also present in all cultures and their importance is central for our understanding of thought and behavior. According to Atran et al. (2004) the term "*Folkbiology"* refers to the ways in which humans classify and reason about the organic world. "*Ethnobiology"* is the anthropological study of *"Folkbiology*". One of the key concerns of ethnobiologists is folk taxonomy - the hierarchical structure, organic content and cultural function of folk classifications. "*Naïve Biology"* or *"Intuitive Biology"* denotes the psychological study of folk-biology in industrialized societies, with focus on the ways in which children and adults learn about, think and use biological categories. According to Medin & Atran (1999:11) the preference of the designations "*Naïve or Intuitive Biology*" to *"Folkbiology*" and *"Ethnobiology"* implies somewhat different understandings and uses of scientific Biology as a standard of comparison.

A good deal of research has been conducted in the last 15 years on the emergence of Folkbiology (Johnson et al., 1992; Coley, 1995; Lòpez et al., 1997; Wolff et al., 1999; Coley, 1999; Coley, 2000) not only because of its intrinsic importance as well as a test case for more general ideas about conceptual development (Ross et al., 2002). The findings of recent research with adults (see for example López et al., 1997; Medin et al., 1997) indicate the role of culture and experience on folk knowledge. Folkbiological categories seem to be largely based on morphological and behavioural grounds, as well as on ecological knowledge (Lòpez et al., 1997).

According to Atran et al. (2004), it is important to understand (a) how ordinary people think about the organic world and (b) how scientific concepts emerged in industrial societies for several reasons. First, where and how scientific understanding both converges with and diverges from folk understanding is highlighted. Science education programmes are often based on the intuitive and anecdotal appreciation of these relationships, rather than on careful scrutiny of the historical and the folk record. Secondly, the historical and the folk record can provide us with information regarding the difficulties as well as the capacities of children and ordinary people in comprehending scientific concepts. This has obvious implications not only for science education but, more generally, for public policy with regard to science. Thirdly, tracking developments in understanding within industrialized societies can help peoples from other cultural backgrounds overcome the difficulties or gain profit from these lessons.

A lot of research has been conducted on the concepts and classifications children use about animals (Bell, 1981; Trowbridge & Mintzes, 1985; Tema, 1989; Braund, 1991, 1998; Villabi & Lucas, 1991; Barman et al., 2000; Papadopoulou & Athanasiou, 1998; Tunnicliffe & Reiss, 1999; Kattmann, 2000, 2001). On the other hand, teachers' concepts and classifications remain relatively unexplored, with the exception of Mak's (1998) research on the concept of "amphibians", despite the claim of Bybee (1993) that teachers are the "change agents" of educational reform and that teachers' conceptions and beliefs must not be ignored.

In the same way that learners have fundamental ideas - that is conceptions and beliefs - that should be built on, replaced, removed, or ignored, teachers also have fundamental ideas about both their subject matter and teaching itself. De Jong et al. (1995) have indicated that teachers' knowledge about their subject matter may function as a source of difficulties in teaching curriculum topics. Furthermore, many prospective elementary teachers need to learn the content of science at the same time as they are learning to teach science. However, strong subject matter knowledge is necessary but not sufficient for effective teaching, while teachers need knowledge that blends subject matter and pedagogy (Shulman, 1986).

Based on this background, this study focuses on the following research questions:

- What is the meaning that primary school teachers attribute to the concept "animal"?
- What are the classifications that primary school teachers use about animals?
- Are their classifications more similar to scientific taxa or folk-biological categories?

## 2. Participants and methods

The study was carried out in two parts: the first part was the concept study and the second was the classification study.

a) The concept study*:* At this stage of research, 10 in service primary school teachers, namely 3 men and 7 women, with 8 to 21 years of teaching experience participated. The selection of the participants was made in order to achieve informational redundancy (Lincoln & Cuba 1985:202) or theoretical saturation (Glaser & Strauss, 1970:61) and thus the final number (10) of interviews appeared.

The participants were individually interviewed by means of an adapted version of the interview about instances approach (Osborne & Gilbert, 1979; Osborne & Gilbert, 1980; Gilbert et al., 1985). Stimulus materials were used and the discussion with the interviewee started after he/she had made his/her first classification of the stimulus cards.

The interviews were analyzed using the constant comparison method (Glaser & Strauss, 1967). The framework for coding the transcripts derived from the data. The sampling and the method of data analysis aimed at the emergence of a grounded theory, a theory "that is inductively derived from the study of the phenomenon it represents" (Strauss and Corbin, 1990:23).

b) The classification study: The classification study was conducted in two phases.
The participants of the first phase were the same as in the concept study. The research was conducted with oral oddity tasks. Each oddity task consisted of three cards of stimulus materials and the teachers were asked to remove the odd card in order to form a group of related entities. After this, they were asked to provide a reason for their decision. Using the three cards, which were in a way consistent with scientific Biology, teachers were expected to form groups like: living creature, animal and mammal. Data were again analyzed using the constant comparison method.

The participants of the second phase were 108 in service and student teachers, namely 43 men and 85 women. The teachers' taxonomies were investigated through a paper and pencil test, a technique that was developed by Ulrich Kattmann (2000, 2001) and contains three tasks.

- Task 1: Forming groups of animals and giving names to the groups formed.
- Task 2: Sorting an animal out of a given group (6 items). Each item consisted of a multiple-choice part and a free answer part.
- Task 3: Sorting an animal into a given group (5 items). Each item consisted of a two choice part and a free answer part.

In these tasks, teachers have the choice to sort an animal out of a group of 3 or 4 animals (task 2) and to sort animals into a group of 3 or 4 animals (task 3). In the free answer part, participants were required to state the reasons for their choice.

## 3. Findings

### 3.1- The concept study

In the concept study, analysis suggested that primary school teachers have formulated a restricted and anthropocentric concept "animal", since many teachers exclude human beings from animals. They did not classify human beings as animals, although they seemed to be aware of the argumentation of the Evolution Theory concerning the descent of humans.

*"… I know that they are not included in animal category … they are human beings … although according to a theory, human beings evolved from an ape species…* (T1, 2, 5-7)*".* *(*T1 stands for interview number, 2 for page number, 5-7 for line number).

Table 1. Categorization of the entities depicted by stimulus material

| | Instances | | | | | | | | | | | | | | Non-Instances | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Participants | Cow | Boy/girl | Spider | Frog | Cat | Seagull | Elephant | Lion | Butterfly | Earthworm | Wale | Snake | Herring | Snail | Wild Chicory | Olive tree | Mushroom | Car | Fire |
| T1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T2 | 1 | ;;1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| T3 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T6 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T7 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T8 | 1 | ;;0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T9 | 1 | ;;1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| T10 | 1 | ;;0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

*Note: (a) the symbol (0) and the shading correspond to an entity not included in animals, (b) the symbol (1) corresponds to an entity included in the "animal" category, and (c) the symbol (;;) corresponds to decisions taken with hesitation.*

The criteria teachers used in order to categorize a stimulus as an "animal", were:

(1) **Morphology:** It refers to the external form and characteristics of the entities used in order to make a decision about categorization. All the participants did not adopt morphology as a categorization criterion.

(2) Taxonomy: It refers to the hierarchical relations of the concept "animal" and more specifically to the subordinate categories – bird, amphibian, reptile, insect, mammal, and quadruped - that were recognized as subgroups of the super-ordinate concept of "animal".

(3) Behavior: This criterion is used as defined by Maturana & Varela (1992: 152): "*behavior are all the changes of the stance or the position of a living being that an observer could describe as movements or activities in a given setting*"; "*additionally the word behavior is connected with activities like walking, getting food, searching and so on*" (Maturana & Varela, 1992: 156). The majority of the references in this category are related to movement, and in particular to conscious motion. … "*Animals can move; plants cannot…*" (T1, 2, 14-17).

(4) Presence and properties of life: This criterion is based on claims whether an entity is alive or not - *… "Yes it is an animal because it has life…"* (T7, 77, 1) - or statements, which connect the properties and processes of reproduction, development and metabolism with animals.

(5) The nature of the entity: This category refers to essential and intrinsic characteristics of the entity such as whether it is man-made or naturally occurring. "*[…no] car [is not an animal] is made by human … that has no relation to animals"* (T1, 2, 24-26).

(6) Heterotrophy: This category includes a few references about the manner of nutrition, the occurrence of photosynthetic ability. "*… it makes its food itself, in contrast to animals that take their food ready …"* (T3, 24, 28-29).

(7) Mental ability: This is the main criterion that teachers used to separate human beings from the animal kingdom. The statements of this category contain references to special human abilities like language, reasoning, learning, critical thinking, culture and so on. All these abilities seemed to signal the human superiority over other species. "*… Animals have [a kind of mental ability] but it is of inferior kind, they are inferior…*" (E9, 106, 24).

(8) Values and ideology: The criterion /category related to values is the most anthropocentric one. In this category there are implicit references to religious influences like: "*… My perception is that human beings constitute the highest rank of creation…*" (E3, 23, 39-41), also references to animals like the *"inferior other"*.

Table 2. Comparative presentation of pupils' and teachers' criteria regarding the concept of "animal"

| Pupils' Criteria | Teacher's Criteria |
|---|---|
| *Morphology* | *Morphology* |
| *Taxonomy* | *Taxonomy* |
| *Behavior* | *Behavior* |
| *Properties of life* | *Existence and properties of life* |
| *Anatomic Elements* | |
| *Senses* | |
| *Habitat* | *(Habitat)* |
| *The nature of the entity* | *The nature of the entity* |
| *Reason* | *Mental ability (including reason)* |
| *Dangerous for humans* | |
| *Utility for humans* | |
| | *Heterotrophy* |
| | *Values – Ideology* |

The categories/criteria teachers employed in order to group entities into the animal category are compared with the categories/criteria used by pupils on a similar task (Papadopoulou & Athanasiou, 1998). As shown in Table 2, teachers' categories are, of course, more complicated; yet anthropocentric thinking is apparent in both groups. The anthropocentrism of pupils is mainly expressed through the comparison with human beings - the human being as the normative entity - and also by naïve categories such as "Dangerous for humans" or "Utility for humans". On the other hand, anthropocentric criteria of teachers such as "Values -Ideology" and partly "Mental ability" are well-elaborated categories, connected with ideas having a long history in the Western Thought.

### 3.2- The classification study

#### 3.2.1 Part I

In the first part of the classification study, data suggested an extensive use of scientific taxa labels. In naming and reasoning about (a) each entity that is excluded and (b) the groups they formed, teachers used scientific taxa labels and 39 out of the 92 groups were denominated with a scientific name. Teachers also created groups that are connected with: 1) the relations of entities with human beings, 2) ecological relationships between entities, 3) the distinction between artificial and natural and 4) human distinctiveness.

Table 3. Oddity tasks: the excluded entities

| Interviewees | 2nd triad Wild Chicory – Cow – Snake | | | 4th triad Human - Snake - Wild Chicory | | | 7th triad Cow – snake – Human | | |
|---|---|---|---|---|---|---|---|---|---|
| | Wild Chicory | Cow | Snake | Human | Wild Chicory | All different | Human | Snake | All different |
| E1 | ● | | | ● | | | ● | | |
| E2 | ● | | | | ● | | ● | | |
| E3 | ● | | | | | ● | | ● | |
| E4 | ● | | | | ● | | | ● | |
| E5 | ● | | | | ● | | | ● | |
| E6 | ● | | | | | ● | | | ● |
| E7 | ● | | | ● | | | | ● | |
| E8 | | | ● | | ● | | | ● | |
| E9 | | ● | | ● | | | ● | | |
| E10 | ● | ● | | ● | | | ● | | |

*Note: Shading represents the formation of a biological category.*

It was found that the use of non-scientific categories was most common in tasks where one of the 3 entities was a human being. In addition, teachers used the term "animal" with a restricted and anthropocentric meaning. *… Plant, animal, human being … man is again different … because of his mental ability …* (E9, 114, 5). The meaning attributed to the terms like "mammal" and "insect" is not clear in this phase.

In this phase of the study, data analysis of oral oddity tasks suggested the anthropocentrism in the thinking of teachers, as they tend to exclude human beings from the animal kingdom. They form groups in order to exclude human beings and to confirm their superiority. However, more research is needed on the use of scientific taxonomic names by teachers and this follows in the next stage of the classification study.

### 3.2.1 Part II

In the second part of the classification study, the content and the formation of the teachers' biological taxonomic groups, which are related to the concept of "animal" were further investigated.

Task 1 – The personal taxonomies of teachers
According to Kattmann (2000, 2001), this kind of tasks provide the ability to record the kind of teachers' taxonomies in relation to other animals, i.e. classifications of biological categories or classifications based on other criteria. Furthermore, they provide the ability to record the denotation of biological categories, according to the animals included in them.

Thirty-eight (38) kinds of classifications, which were finally included into seven wider categories, were recorded:
"Biological Classification": It includes groupings with the names: insects, reptiles, birds, mammals, amphibians, invertebrates, rodents, fishes, mollusks, arthropods, vertebrates.
"Habitat": It includes groupings of animals according to their habitat and more specifically marine animals, aquatic animals, tropical animals, etc.
"Relationship with humans": It includes groupings concerning the determination of animals according to their relationship with humans or their use by humans; more specifically, domestic animals, wild animals, field animals.
"Morphology": It includes groupings regarding the morphological characteristics of animals; more specifically, quadrupeds, animals with shells, animals with two legs.
"Nutrition": It includes the classifications in reference to the kind of the animal's alimentation as well as the alimentary relationships between the animals; more specifically, carnivores, herbivores, etc.
"Reproduction": It includes classifications like "oviparous", "they give birth to little ones", and finally the category
"Movement": It includes the justifications regarding the type of movement; more specifically, "they crawl", "they fly".

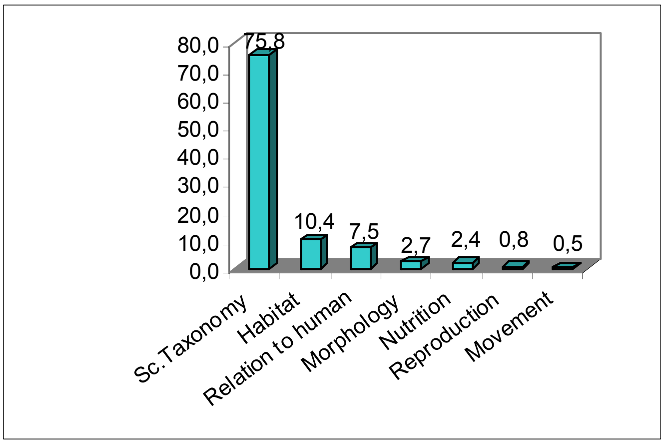
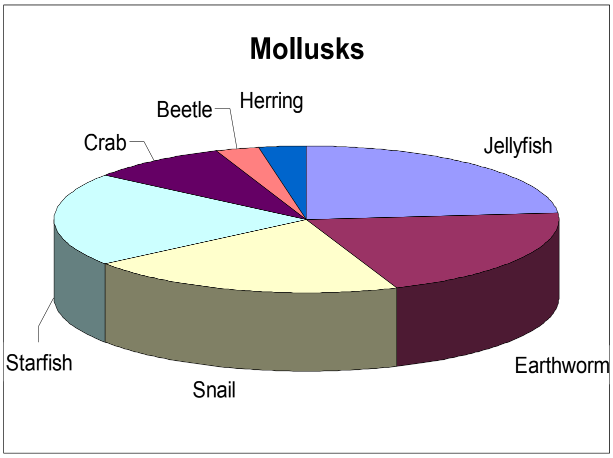



Figure 1. Teachers' personal classifications (2nd classification study, task 1)

As shown in Figure 1, teachers' classifications are mainly made (to a percentage of 75,8%) by means of the terms of the scientific biological taxonomy. The study for the formation of these categories, however, reveals the significant divergence of the content of some of them from those of the scientific biological taxonomy (Figure 2).

It appears from the analysis of these data that the animals, which are less commonly classified into biological categories are the crab, the jellyfish, the starfish and the herring. Moreover, the animals, in which the widest divergence in the use of the biological category and the correspondence to the biological taxon are the spider, the earthworm, the snail, the jellyfish, the starfish and the crab. The invertebrates are used the least and they are classified inconsistently.



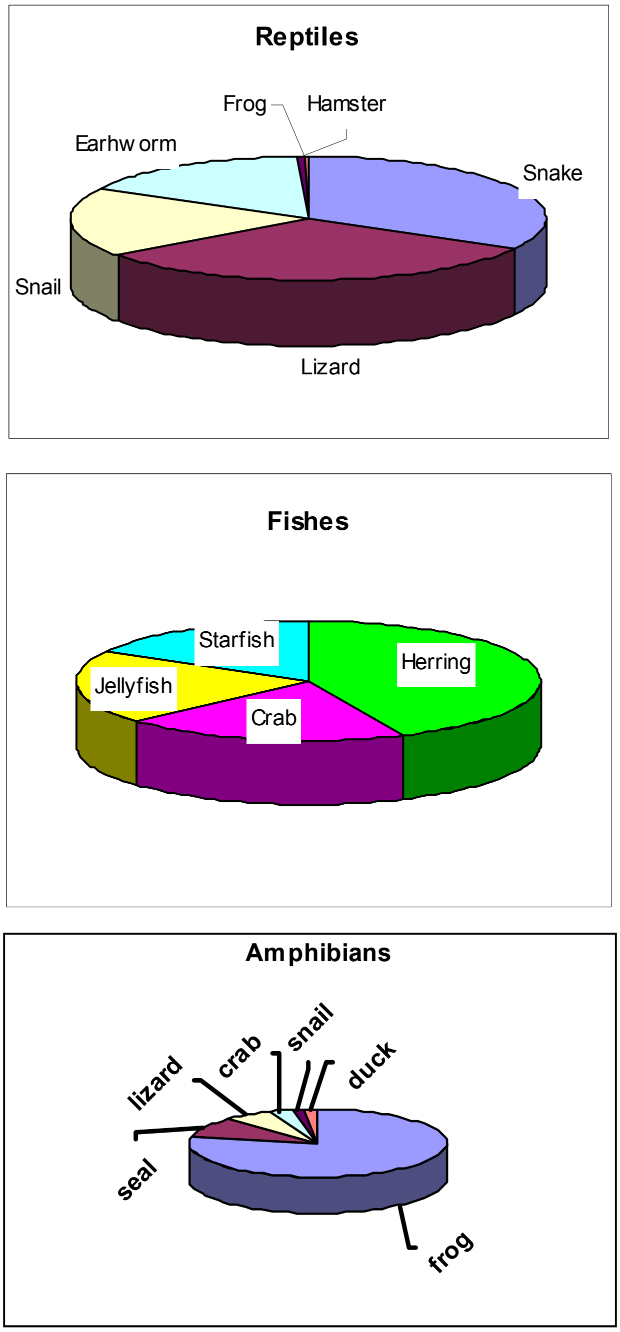



Figure 2. The content of biological categories used by teachers: The categories Mollusks, Reptiles and Fishes and the animals of which they are consisted

Regarding the personal classifications of teachers, as they arose from task 1, it is possible to make the following observations in total:

a) There is a wide use of biological taxonomic categories by teachers, as also shown in Figure 1.
b) It is obvious that, while biological designations are attributed, the content corresponds to classifications of a different kind. More specifically, the taxonomic categories of **invertebrates,** with the exception of **insects,** do not seem to constitute main categories for the organization of the biological world for teachers, since, reference to them and the knowledge about them seems to be limited.
c) Teachers constitute the group of **amphibians** according to the **habitat** of the animals that fall into it, namely living in the water and the land consisted of animals like frog but also seal, duck crab (Figure 2, 4th pie-diagram). This is a category that does not correspond to the biological taxon *Amphibia*.
d) What is more, the group of **fishes** is formed again on the basis of **habitat,** consisted of animals living in a sea-aquatic environment - like crab, starfish & jellyfish-, and it does not correspond to the taxa *Agnatha*, *Chondrichthyes*, *Osteichthyes* (Figure 2, 3rd pie-diagram).
e) The group of **mollusks** is formed with great inhomogeneity. To a degree, it seems to be formed according to the quality, which is implied by the designation, namely a soft body, and it does not correspond to the biological taxon *Mollusca*.
f) The group of **reptiles** is formed according to the manner of **movement** implied by the designation and it does not correspond to the biological taxon *Reptilia*.

In tasks 2 & 3, the categories that teachers used for the justification of the selections of exception from the group and integration to the group are:

a) **"Biological Classification"** includes 22 kinds of groupings that were justified by the teachers by means of the designation of a biological group.
b) **"Habitat"** includes 45 kinds of references in total to habitat as a justification of the taxonomic selections of teachers.
c) **"Morphology"** includes 22 kinds of references in total to the **external characteristics** of animals.
d) **"Type of Movement"** includes 15 references to the manner in which animals move.
e) **"Alimentation"** includes 12 kinds of references in total to the type of alimentation of animals.
f) **"Relationship with humans"** included references to the threat of animals for humans, as well as their possible utility to people.

For the classifications of teachers, as arising from tasks 2 & 3, it is possible to observe:

- The use of biological categories for the justification of selections is wide (63.9-46.3%) in the case of the tasks for the recognition of difference, though limited (12.9-44.5%) in the tasks for the recognition of similarity. On similarity tasks the decision is taken with movement (47.2-52.8%) and habitat (58.3-47.2%) as main categories (Figure 2 and 4).
- Regarding the denotation of biological categories, which are being used by teachers for the justification of their selections on similarity and difference tasks:

There is no differentiation between the meaning that teachers attribute to the category and the meaning of the concept at biological classification in the case of **mammals**.

a) In the case of the category of **reptiles**, it is once again confirmed that it is formed on the basis of the manner of movement implied by the designation and therefore teachers seem to include animals such as the worm, the snail and the caterpillar in this category.
b) The category of **birds** also seems to be formed on the basis of the manner of movement (flight), as implied by the designation of the category. The selections of teachers lead us towards this conclusion.

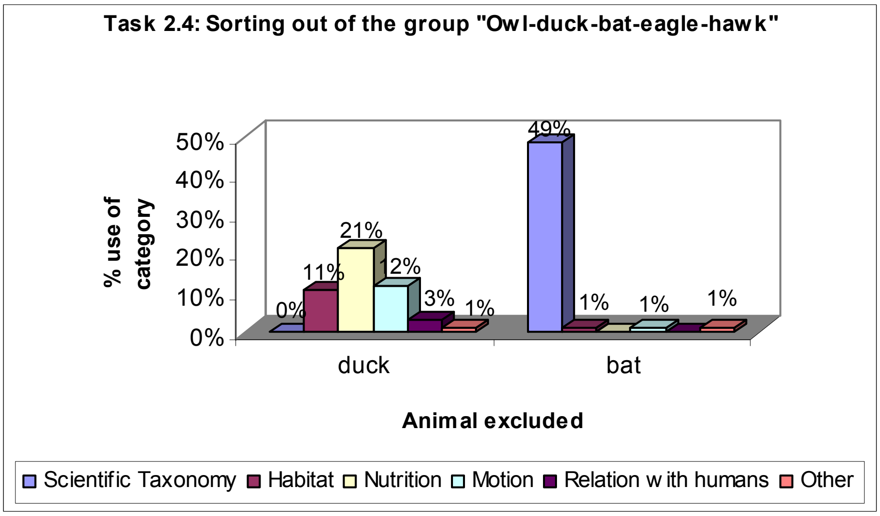



Figure 3. A similarity task - The animal sorted out of the group "Owl - duck - bat - eagle - hawk" and the reason of teachers' choice

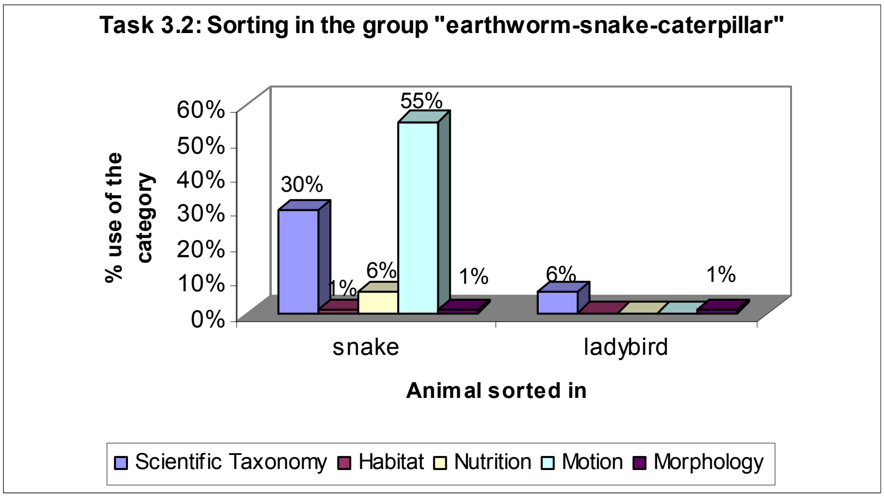



Figure 4: A Difference task - The animal that fits in the group "earthworm - snail - caterpillar" and the reason of teachers' choice

## 4. Discussion – Pedagogical consequences

Medin & Atran (1999) support the special significance of Folk Biology in the understanding of human thought and behavior, since a great part of human history went by (and still goes by) in close contact with the plants and the animals and it is hard to imagine that the cognitive function of humans was not influenced by this coexistence. It has been supported that there is no culture, globally, except from those maybe that have been influenced by Aristotle and subsequent scientists, essentially the western ones, which regard that men and the rest of the living organisms belong to the same ontological category (Atran, 1990, 1996: 677). This claim by Atran has been doubted by more recent findings (Coley et al., 1999; Ross et al., 2003). The findings of the present research converge with the results of research that record the ontological distinction between humans and other animals. In addition, the findings support Atran's claim (Atran, 1990, 1996: 677) that the teaching of Sciences has a limited effect on the folk taxonomic forms and the effect of the teaching of Biology on them is marginal. For most peoples, human being is the rule for the comparative identification of other animals, but man himself is not an object of comparison (Atran, 1990: 32). Teachers make a limited use of the morphological criteria for taking their classification decisions and consequently it is not possible to identify a similar morphological comparison of humans with other animals, as this happens with children (Papadopoulou & Athanasiou, 1998).

The meaning teachers attribute to the concept of "animal" is limited and anthropocentric since humans are not usually included in the range of the concept. The study of the ethnobiological framework as well as the history of the scientific Biological Taxonomy, shows the long road that this perception has traveled through time, as well as its widespread, yet not overall, dissemination to various societies of the planet. This is about the self-placement of human being on the world, whose position is determined out of the animal kingdom and consequently out of nature. Naturally, the conquest of the human condition is regarded, not only by teachers and children, as transcendence from the animal condition and the whole historical course of the human society conduces to that. However, this separation of humans from nature and mostly the sense of superiority and omnipotence it breathes, has been regarded by environmental thought as a cause for the dominating behavior of humans over nature and in our case over animals.

Regarding the groupings of animals and the denominations of categories, a wide use of scientific biological designations is recorded with respect to the categories formed by teachers. It can be said that this finding is in a way the continuation of Kattmann's (2000, 2001) findings, who ascertains a greater use of taxonomic categories as the age of pupils increases.

Teachers' taxonomies, despite their apparent approach to the scientific biological taxonomy, are essentially closer to the folk biological classification framework. This stance is supported by the following observations:

- Teachers' taxonomies are usually placed on the level of life form of the folk biological classification, for which, in the case of animals, life forms more or less correspond to the modern scientific divisions (mostly classes). The use of the general term "fish" by teachers and its denomination on the basis of habitat, namely its living in the sea, directs to the folk biological use of the term and not to the corresponding scientific taxa. Relevant uses by teachers of the terms of "reptiles" and "amphibians" are also detected and denominations, according to the kind of movement and the habitat respectively, which are also obviously closer to Folk Biology, instead of the relevant scientific taxa.

- As it has already been ascertained in the results, the taxonomic categories of invertebrates, with the exception of insects, do not seem to comprise main categories for the organization of the biological world for the teachers, since their reference and the knowledge about them seems limited enough. On the folk taxonomic systems accordingly, the interaction of the perceptive easiness (e.g. size) and the cultural meaning have determined on which animals names have been given, which have been accumulated on residual categories and which were ignored (Bentley & Rodriguez, 2001), and all these findings mostly regard invertebrates. The marginal place of invertebrates on the folk biological systems and the limited knowledge of people for them render the evaluation of their contribution to ecological processes difficult. Consequently, the participation of invertebrates in the important processes, on the basis of food chains, is logical to avoid the attention of the average man.

According to Atran (1996: 671), the evolution and the development of the western whole scientific systematic overlooked the ecological relationships, colors, odors, tastes and textures, which comprise the most obvious identification and access tracks in the world of beings that surrounds us. Only by means of confining organisms from their local habitats and describing them with the tones of written speech, irrelevant with the senses, is it possible for a universal system of biological comparisons and contrasts to appear. This presupposes the sacrifice of the local virtues of the folk biological knowledge, which includes the cultural, ecological and the sensory information.

Cobern (1993, 1998) supports that it is important for the teaching of science to understand the central, culturally grounded beliefs for the world, which the students and the teachers, we could add, transfer in the classroom. As an instance of these central, mostly culturally grounded beliefs, we could mention the answers to the questions: "What is the essence of nature?", " What does it mean to be a human being?", "Under what sense and to what extent are human beings different from other living organisms?", "What is culture?" (Cobern, 1994). Education in Biology is successful to the extent that Biology can find a place in the cognitive and socio-cultural environment of children and adults.

Regarding the education and the training of teachers on the classification of animals, the observation that the basic concepts of Biology, like the concept of "animal", are combined by everyday people with an axial framework, which is popular enough and also comes from a long way through time, should not be ignored. Obviously, it is not possible for the total of these beliefs to yield with the appeal of scientific authority only, as far as the content of the concept of "animal", since it is connected with a mesh of values and beliefs. With the above remarks for the deep socio-cultural grounding of some ideas, it is not implied that these beliefs should remain intact from the educational and training procedure. This remark has the sense of understanding the size and the type of the undertaking, which, according to our opinion, does not only consist of the conceptual change that is usually intended by Science Education. This undertaking does not simply concern the doubt of the pre-existing concept of "animal", but it also concerns values and beliefs, which are connected with the manner in which people perceive themselves. In addition, education on biological scientific taxonomy is essentially a limitation of the possible primary concern for the anthropocentric-ecological, morphological and behavioral relationships and their abandonment for the benefit of deeper qualities on which scientific taxonomy is grounded.

The training of teachers on the Scientific Biological Taxonomy, the design of relevant analytic curricula with an evolutional and ecological orientation, the extensive teaching of the Theory of Evolution itself and the exploitation of examples and cases from the history of Biology and Systematics, could open new paths in the thought of teachers, their knowledge and their pedagogy. The evolutionary-oriented teaching of Systematics could include, apart from the phylogenetic relativity, the presentation of major groups of living organisms, with their evolutionary history and the appearance of their characteristic adaptations as a central axis. Last but not least, the biological evolution of humans can be a part of the training of teachers, since it seems to form possibly the most central friction point for the recognition of the biological unity of all living organisms, including humans.

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# WHERE DO BABIES COME FROM? THE IDEAS OF 5-YEAR-OLD CHILDREN ABOUT HUMAN REPRODUCTION AND BIRTH

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## Abstract

Understanding human reproduction is possibly influenced by psychological, cultural and social factors. When developing learning environments in this context, a series of elements such as children's conceptions, emotions and psychological stage, or parents' and community's attitudes towards the issue need to be taken into account. This paper is particularly concerned with the intuitive conceptions and thinking models that preschoolers hold about gender, human reproduction and birth, as well as with the development of a learning environment on the basis of the former within a socio-cognitive theoretical framework. Our findings show that children's models are actually more compatible with scientific ideas than earlier studies have shown. Myths about babies' origin seem to be replaced by technologically oriented models, probably in the light of the medical authority within modern society. Unlike earlier research findings, a significant part of the children participating in this study make gender distinctions drawing upon genital and not socially shaped differentiating characteristics. Taking into account the children's ideas as well as the vygotskian notion of *ZPD*, we developed a learning environment combining story narration, drawing, puzzle and card assembly group-tasks. The characteristics of the learning environment and the development of children's ideas within the former are finally discussed.

## 1. Introduction

Understanding human reproduction is possibly influenced by psychological, social, cultural or religious factors, despite of being framed in biological terms. Children at the age of 4-5 years are frequently confronted with the mystery of the emergence of a new life in their own families or their friendly environment and they seek all the essential answers. Media can actually play a key role in such queries, a fact that seems to be easily neglected by many parents who often let their children watch TV programs unattended and probably come across inappropriate information about sexual relationships.

Thus, kindergarten needs to offer young students a well-organized, clear introduction to the subject of human reproduction and the underlying gender differences, taking into account a series of elements such as children's psychological stage and emotions as well as parents' and community's attitudes towards the subject. Furthermore, in a socio-cognitive theoretical framework, the development of such an introductory learning environment cannot but seriously take into consideration children's own ideas about the subject. Since the reported research work is quite limited in Greece as well as around the world, we come up with exploring kindergarten children's ideas about human reproduction and then proceed to the development of a learning environment on the basis of the former. In particular, we are concerned with children's intuitive conceptions and thinking models about gender, human reproduction and birth, as well as with the consequent development and pilot implementation of a learning environment on the subject.

## 2. Theoretical background

### 2.1- The emergence of biological thought

There are two main views concerning the emergence of biological knowledge in early years. According to the '*primal view theory*' (Carey, 1985, 1991; Carey & Spelke, 1994), conceptual change in early years involves the transition of young children's view from a *'psychological'* theory to a *'biological'* one. Carey claims that around the age of 10, a significant rearrangement takes place in children's mental structures, resulting in the emergence of intuitive biological knowledge from the psychological one. According to the *'plural theories' view'* (Keil, 1992, 1994; Wellman & Gelman, 1992), biological knowledge emerges as a separate domain quite early and it is defined as the ability for causal explanatory reasoning for biological issues. Many researchers agree that children by the age of 5 do acquire and express this ability (Springer & Keil, 1991; Rosengren et al., 1991; Hickling & Gelman, 1995; Coley, 1995, 2000; Hatano & Inagaki, 1994, 1997) depending on the topic and the mode of probing their ideas.

In fact, children at the age of 4-5 come up with some biological explanations, while they still express anthropomorphic and intentional reasoning (Springer & Keil, 1991). Thus, it seems that whether there is a late transition from psychological to biological knowledge or a separate biological domain from the early childhood, the acquisition of biological knowledge should be defined in a such a way to also include a transition from the anthropomorphic reasoning -which is expressed by intentional causality (Carey, 1985) and artificialism (Piaget, 1929)- to the biological one.

This transition requires some causal understanding for biological processes and it is probably achieved through analogical reasoning and personification (Inagaki & Hatano, 1987). Furthermore, it is considered as restricted by social factors like social conventions associated with the practice of teaching and the environments within which it is performed (Coley, 1995; Zogza & Papamichael, 2000). Young children can employ such reasoning mechanisms to further develop explanations of biological character within naïve theories (i.e. *'essentialism', 'teleology', 'vitalism'*) characterizing their age.

Most early years educators accept - although not always explicitly - the view of separate domains of knowledge in early childhood and develop accordingly learning environments for young children. The key question is which subjects are the most appropriate for young children to deal with, on what grounds we can specify them and how far we can go. Research in children conceptions and beliefs are of great importance in this respect.

## 2.2- The development of knowledge about human reproduction

Understanding human reproduction may be influenced by psychological, social cultural and religious factors. Many researchers have studied the development of children's conceptions on the subject. According to Piaget (1929), children's ideas about babies' origin are expected to follow the same sequence of cognitive developmental stages as their ideas about physical causality; in other words, to go through two stages.

In the first stage of '*artificialism*', the baby is assumed to have existed before its birth and children merely wonder where it has really been. Because of this belief, they spontaneously accept parent-told fables according to which God, storks or angels bring babies to families. Piaget also claims that children believe that babies are made limb by limb, but in spite of this artificial mode of creation they are alive. They also believe that parents play some role in the origin of babies but they don't believe that babies are actually created by parents. On the contrary, children of the second stage, accept that babies are created into their parents' bodies and out of their own body material.

Similarly, according to Carey (1985), early ideas about babies' origin may claim that babies are found in a shop or a factory, or they are made piece by piece in the mother's stomach when she intents and wishes to have a baby. Such ideas expressed by children around the age of 5 reflect the '*intentional reasoning*' that precedes the development of more biologically oriented conceptions. Later, a transition *from* understanding the parents' relationship in purely social terms *to* recognizing its sexual aspect takes place with the emergence of ideas about sperm and egg. During this transitional stage young children express *'animism'* in regard with the sperm, which they think of as having a specific aim. The overall model is the so-called '*agricultural model'* according to which a bean-like seed is planted into the mother's body and / or an egg similar to that of a hen is hatched inside her. Finally, the third stage according to Carey takes place around the age of 11 and has to do with the construction of a biological model on human reproduction that recognizes the contribution of both parents through their sexual relationship.

Bernstein and Cowan (1975) suggest that the cognitive development of children in regard with babies' origin is mostly influenced by their ability to reason about *'causality'* and *'identity'*. They claim that *"only when the child begins to perceive that events and phenomena have causes that he can attempt to investigate what they are; when the child recognizes that he himself and other persons are continuous beings, conserving identity despite the transformations in appearance due to maturation, that he can think about his own origins or those of his siblings"*.

A series of studies carried out in Israel, Middle East, Australia, Sweden, England and North America (Kreitler & Kreitler, 1966; Goldman & Goldman, 1982), show that most children at the age of five recognize that babies are located in the mother's body before birth. Furthermore, they believe that babies are made due to the large quantity of food consumed by the mother. Concerning the babies' origin, very few children refer to the father's role mentioning the *"seeds that he gives to the mother"*, whereas most of them attribute a mainly supportive role to him. Finally, the mother's role is not conceived in terms of her participation in a sexual relationship, but rather in terms of a body that must rest, eat well and stop smoking to protect the health of the carried baby.

## 3. Objectives of the study, research design and methodology

### 3.1- Objectives of the study

According to the socio-constructivist view of learning, children construct personal theories about natural phenomena while interacting with their natural and social environment (Brown et al. 1989; Vygotsky 1978). Successful learning may occur when new concepts are introduced on the basis of children's original conceptions, which need to be destabilized through a teacher-driven process of cognitive conflict (Zogza & Papamichael, 2000). Consequently, children's conceptions about a subject should be elicited and taken seriously into account when developing a learning environment for the subject in question (Ravanis & Bagakis, 1998).

Thus, this study is concerned with exploring how young children think about human reproduction and birth nowadays in Greece and also with developing a relative learning environment. More specifically, the objectives of the study are:

1. To identify young children's conceptions about human reproduction by addressing the questions of
   - How do preschoolers distinguish male and female individuals?
   - Which are their models about babies' origin?
   - What do they think about a fetus's life during pregnancy?
   - Which are their conceptions about the birth of a child?
2. To develop a learning environment about the aforementioned aspects of human reproduction in the context of the socio-constructivist view of learning.

### 3.2- Research design

Our research took place during 2001 and 2002 at four public kindergartens in the area of Patras. The participants were 88 children, 44 of which were boys and 44 girls. The mean average of children's age was 4.8 years old. The study took place in three phases:

- **Phase I:** Elicitation of children's conceptions - pre-test
- **Phase II:** Planning of the learning environment and pilot implementation with 17 children of phase I
- **Phase III**: Evaluation of the learning environment with a post-test conducted one week after Phase II.

### 3.3- Elicitation of children's conceptions

The elicitation of children's intuitive conceptions and thinking models about gender differences, human reproduction and birth was carried out through two different techniques:

- **Individual clinical interview:** Each child had to go through a 15-minute interview in order to answer a structured questionnaire designed on the basis of previous relevant studies. The child was motivated to answer the questionnaire in the context of a unifying story.

The interviews were tape-recorded. The Osborne and Gilbert (1979) method was employed to find out children's perception of sex differences. We expected children of this age to focus on the external characteristics for recognizing the sex of an individual and thus we chose to present them with photos of naked babies and avoid references either to dressing style or secondary sex features.

- The 'Draw & Write' technique (Williams et al., 1987): Each child was provided with a sheet of paper on which we had sketched the outline of a woman's body and was then required to draw a baby into the mother's belly. It is noted that the body's outline was not well structured at the area of the belly in order for the child to decide if the belly should look distended or not.

Finally, it should be noted that children's ideas as traced in this phase of the research are also used as a pre-test for the evaluation of the learning environment developed upon them.

### 3.4- Data analysis and definition of educational goals

Considering previous research findings, we categorized children's ideas in models. The analysis of children's ideas provided the necessary means for subsequently defining the *'Zone of Proximal Development' ('ZPD')* (Hedegaard, 1990), setting teaching and learning goals and developing an educational environment for pursuing them. It is worth noticing that the parents had been previously informed about the whole process and agreed upon the participation of their children in this experimental setting that concerns a rather delicate issue.

## 4. Results

### 4.1- Children's conceptions

Concerning the gender distinction, most of the children (70.6%) expectedly produce correct answers, while almost half of the children's correct responses (47%) are constructed by appealing to the reproductive organs. Table 1 shows the percentages of the correct responses to all the items of the questionnaire addressed to each child during Phase I.

In Piagetian terms, it could be claimed that children give *'egocentric'* responses, functioning more within the first stage of *'artificialism'* and less within the second stage where babies are thought as being made by mother's and father's body material. Some children seem to be in a transitional stage expressing the idea that the father puts the baby in mom's belly artificially. Although children of the first stage do not come up with myths about stork or Santa Claus bringing babies, very often they do express the view that babies are brought by God or refer to the key role of a doctor or medical technology in general.

The model of babies' creation in mom's belly when she eats a lot is less common here (23.5%) than in other studies. Furthermore, regarding the father's role in reproduction, 10 of the participating children recognize the sexual aspect. 11% accept the contribution of both parents in the creation of the baby when talking about seeds or making descriptions and explanations of sperm-like or egg-like entities. Most of the children seem to believe that the father does not help at all or he helps somehow by supporting the mother in various ways (i.e. driving her to the hospital, paying the doctor or even mediating between God and mom's belly for the 5% of the children).

Table 1. Children's 'scientific' ideas in Phase I

| Questionnaire Items | Correct responses | % |
|---|---|---|
| 1 | Gender distinction<br>↳*Correct* | 70.6% |
| 2 | Justification of distinction<br>↳*Sex reproductive organs* | 47% |
| 3 | Where are babies before their birth<br>↳*Mom's belly* | 58.8% |
| 4 | Position of baby in mom's body<br>↳*Puffed belly* | 47.1% |
| 5 | Creation of baby<br>↳*Contribution of both parents* | 11.8% |
| 6 | How baby gets out of belly<br>↳*Either from the belly or, from mom's genital* | 11.8% |
| 7 | While inside mom's belly, the baby<br>↳*Moves* | 76.5% |
| 8 | While inside mom's belly, the baby<br>↳*Breathes* | 70.6% |
| 9 | While inside mom's belly, the baby<br>↳*Grows* | 41.2% |
| 10 | While inside mom's belly, the baby<br>↳*Grows by mother's food* | 23.5% |
| 11 | While inside mom's belly, the baby<br>↳*Feeds through a cord* | 5.9% |

In the *'Draw & Write'* task, most of the children (80) draw the baby inside mom's belly that is sketched as either puffed or flat. Most of the children understand that the baby inside mom's belly breaths (70.6%), feeds (almost 30%), grows (41.2 %) and moves (76.5%). Concerning the baby's birth, we notice that most of our children believe that the baby comes out of mom's belly facilitated by the doctor, while very few think the baby as being born through mom's genital. In other words, very few children seem to have in mind natural birth.

### 4.2- Models about babies' origin

Children's ideas about babies' origin are categorized in 5 models:

- The '*social model*' (expressed by 3 children out of 88), which actually does not provide an explanation of babies' origin except claiming that the only necessary condition for a baby to be created is that mom and dad will get married and sometime later *'they will decide to have a baby'*.

- The *'external factor model'* (expressed by 46 children out of 88), according which the baby originates in mom's belly due to the *action of external factors* such as supernatural powers or at least medical authority. The baby is thought as being put in mom's belly by God, (*'Christ', 'Holy Mother', 'Saints', 'Angels'*) or a doctor. Alternatively, God or a doctor puts in mom's belly not a ready-made baby but a seed that will grow and become a baby. The *'external factor model'* seems to exist in parallel with the *'social model'* previously presented
- The *'only mom model'* (expressed by 12 children out of 88) according which the baby arises in mom's belly due to a little bean-like seed that she owns and grows by eating a lot of food.
- The *'both mom & dad model'* (expressed by 5 out of 88) underlining the father's contribution as follows: "*Dad pushes the baby inside mom's belly when they kiss each other"* or *"Mom's seed grows in her belly when dad kisses her many times"*. It is obvious that even the children that employ the rather advanced *'both mom & dad model'* are not able of identifying the body functions involved in the process.
- The *'biological model'* (expressed by 10 out of 88) according which "*Mom and dad love each other, make a tight hug and a little seed ("a line and a round") of the father unites with a little egg of the mother and the baby grows in mom's belly"*.

In the *'external factor model'* as well as in the *'only mom model'*, the mother is totally responsible for the development of the baby inside her body. She herself is the 'recipient' and the feeder of the baby, while the father has a supportive or / and a mediating role. Children conceive both parents only in social terms. However, in the *'only mom model'* there seems to be a first conception of *a material continuity* between the mother and the baby.

The frequent reference of 'seeds' within this model possibly shows that children mainly develop it on the basis of their experience with plants. Furthermore, this model may be correlated with Carey's '*agricultural model*', while more importantly the emergence of parents' biological role can be clearly traced in the last two models.

It is worth mentioning that our findings differ from those of previous studies (a) in the appearance of a 'biological' view about the sexual intercourse and the equal contribution of both parents in baby's creation and (b) in the frequent reference to medical technology in the form of *"special machines, scissors and knives that the doctor uses"*. In fact, children seem to be very well informed about hospitals and medical procedures.

### 4.3- Developing a learning environment

#### 4.3.1- Setting educational goals regarding babies' creation

Being the most advanced of the 5 models that we identified in Phase I, the *'biological model'* actually constitutes our main educational goal. More specifically and in accordance with both our findings and our theoretical background on the development of biological knowledge, we aim at

- Facilitating young children in shifting their reasoning on human reproduction from *'artificialism'* and *'intention'* to *'biological explanations'*, i.e. to think of the baby as a product of both parents' bodies.

To accomplish this aim, we consider that the following prerequisites should be fulfilled:

- Prerequisite 1: Children need to be able to define gender differences.
- Prerequisite 2: Children need to develop the idea of continuity from parents to a new human being as this is conceived by the resemblance of children with their parents. The existence of a preliminary concept of heredity in the framework of a naïve essentialist / vitalistic theory has actually been identified in previous research (Springer & Keil, 1989; Fasouli & Zogza, 2004), while children try to explain the cause of the resemblance (i.e. "*Children receive 'something' from their mother and their father*").

Using Vygotskian terms, we could claim that the *'biological model'* is clearly located within the *'Zone of Proximal Development'* for those children expressing the *'only mom'* as well as the *'both mom & dad' models.* Thus, children expressing these models are expected to be able to conceive the role of both parents in biological terms if properly supported within a learning environment, while children already expressing the 'biological model' are expected to make their models "biologically" coherent and consistent in terms of identity, continuity and causality. Finally, children expressing the less advanced *'social'* and *'external factor'* models are expected to conceive the contribution of at least one parent in biological terms.

#### 4.3.2- Setting educational goals regarding fetus' development and birth

On the basis of children's ideas about the foetus during pregnancy and the baby's birth that were mostly close to a 'scientific' view, we set the following educational goals:

- All children must be able to correlate baby's growth inside mom's belly with the increase in the size of the latter.
- All children must be able to link the concepts of 'food' and 'growth' and extent this idea to the baby's growth considering mother's body as the food-provider for the baby.
- All children must develop the idea of natural birth.

### 4.4- An overview of the learning environment

The learning environment presented hereafter was implemented at one of the four public kindergartens of Patras that took part in the elicitation of children's ideas in Phase I. More specifically, 17 children whose ideas were previously identified worked within our learning environment for the two-hour session corresponding to one day's educational program. The whole session was videotaped.

The learning environment is consisted of 5 distinct stages

- Stage A - *'creating a puzzle'*: Children are presented with two photographs of naked babies cut in puzzle pieces. One of them depicts a baby girl, while the other one a baby boy. Children are required to put the pieces together in order to re-synthesize the two photographs and then identify their differences. What follows is a discussion about how the depicted babies came to the world.

- Stage B - *'listening to a story'*: Children are told a story -which was created on the basis of their own responses to the questionnaire used for the interviews in Phase I- serving as a context for cognitive conflicts and discussion. They are also presented with drawings showing the events of the story.
- Stage C - *'reproducing the story':* Children are provided with a series of cards depicting randomly the events of the story and are required to put them in the right order so that the story can be reproduced. In fact, children are asked to narrate the story following the card-sequence they came up with themselves.
- Stage D - *'describing the events':* Children are provided with captions with characteristic phrases of the story and are asked to put each of them below the corresponding card.
- Stage E - *'drawing favorite parts of the story'*: Children are required to draw what they liked most in the story they worked with.

In regard with the story and the associated drawings and cards, it should be noted that the focus is set on five main events:

- A man and a woman meet and flirt with each other.
- Then they get married.
- The couple makes an intimate hug and little seeds from the dad's body move into the mom's body, where the little egg is waiting to get united with the dad's seed.
- Mom's belly grows as the fetus, which is located inside her belly, grows.
- Finally, mom gives birth to the grown baby.

### 4.5- Evaluation of the learning environment

Comparing the children's models resulting from the pre-test (namely from children's responses in the phase I interview) with those resulting from the post-test (namely from children's responses in the phase III interview), we attempt to identify any possible changes. Our findings are summarized in Table 2 that shows which children express each model (see numbers in parentheses) as well as their total number (see numbers in bold).

The progress in the 17 children's thinking on the subject after working in our learning environment can be described as follows: The only child that initially expressed the '*social model,* shifts to the *'external factor model'* in the post-test by attributing baby's creation to the intervention of God. Concerning the 10 children that expressed the *'external factor model'* in the pre-test, 3 shifted to the *'only mom model'* and 4 to the *'biological model',* while 3 did not shift at all. 2 of the 3 children that initially expressed the *'only mom model'* shifted to the *'biological model',* while the third one did not shift at all. Finally, the only child initially expressing the *'both mom & dad model'* also shifted to the *'biological model'.*

Table 2. Comparing children's models in pre- and post-test

| Models | Pre-test | | Post-test | |
|---|---|---|---|---|
| | Children | Number | Children | Number |
| *'Social model'* | *(9)* | 1 | - | - |
| *'External factor model'* | *(1), (2), (4), (7), (10), (11), (12), (13),(14), (15)* | 10 | *(2), (9), (10), (15)* | 4 |
| *'Only mom model'* | *(3), (5), (6)* | 3 | *(4), (5), (13),(14)* | 4 |
| *'Both mom & dad model'* | *(8)* | 1 | - | - |
| *'Biological model'* | *(16), (17)* | 2 | *(1), (3), (6), (7), (8), (11), (12), (16), (17)* | 9 |

According to the aforementioned, it could be claimed that our learning environment has actually provided a quite effective context for pursuing the educational goals upon which it has been developed. Being the central part of the environment, the story seems to underlie the drawings and the card-based narration produced by the children.


Figure 1. Children's drawings during Stage E

## 5. Discussion

Children's conceptions on human reproduction seem to be characterized by the co-occurrence of both social and biological explanations. Marriage is a strong prerequisite for having a baby, while the father is mainly thought of as having a social role in the process by assisting and supporting the mother. Children's serious difficulties in understanding the idea of a 'material continuity' between the parents and the baby seem to result in a frequent construction of explanatory models on the basis of external factors in regard with the appearance of the baby inside the mother's body.

However, the employment of the *'biological model'* -although rather limited- by preschoolers of our study, does justify our intention to come up with a learning environment addressing the subject of human reproduction and birth. It is worth-noticing that children expressing the *'biological model'* do recognize a *'from-parents-to-baby'* 'material continuity' and locate the cause of the baby's creation within the very couple and not within the couple's external environment. So, it seems that it would be purposeful to provide preschool teachers with appropriate learning environments that -making use of children's own models- actually allow for their development to the *'closest'*, more advanced ones.

Thus, the Vygotskian notion of the *'Zone of Proximal Development'* may very well be applied on the level of defining the educational goals of such learning environments, like in the case of the one presented here. Apart from using children's ideas in such a way, the socio-cognitive character of our environment has also to do with both the teaching strategies and the educational materials that are employed. More specifically, the notion of *'cognitive conflict'* is applied during the narration of the story, when some of the children's ideas are integrated -in their own 'words'- in order to be cross-examined in the light of well-known, observable facts, which are not really compatible with the former. Aiming at supporting children in elaborating their own ideas, the teacher challenges the latter while the children act upon the chosen educational material (i.e. puzzle, drawings, cards and captions).

In regard with the content of the learning environment, it is worth noticing that widely accepted socio-cultural conventions like starting a family *after* getting married remain intact. This actually has to do with respecting the common attitudes of Greek adults towards the issue, as well as the young children's emotions as expressed in their own sayings.

Moreover, a detailed description of the sexual intercourse is considered to be premature for such an early age and is thus avoided. However, the children are presented with drawings depicting the testes and the ovaries, as this is considered to be essential for introducing the idea of 'material continuity' between the parents and the baby. It is noted that although we used drawings that magnify invisible parts of the human reproductive systems, we do recognize that this might be rather strange for the young children who do not have any experience with magnifying lens or other similar devices.

Finally, we note that the choice of not correlating human reproduction with that of other living organisms - such as plants or other animals - actually serves avoiding possible misunderstandings involving analogies between seeds and sperm or bird eggs and human eggs. Seeds need water and sunlight to grow, while baby birds are hatched from bird eggs, ideas that could probably be transferred to the human reproduction, resulting in a completely misleading view on it. This risk is actually maximized by the close meaning of the words 'seed' and 'sperm' in the Greek language.

The implementation of the learning environment that we developed showed that the young participants are very interested in the subject and thus actively engaged in all five stages. Children interact significantly with each other during making the puzzle, sorting the cards to reproduce the story and drawing those story parts that they like the most, while some of them act as 'loud speakers' putting aside the more timid ones. More interestingly, our results provide clear indications of children's progress on reasoning about human reproduction. Applying the learning environment with a significantly larger sample is one of our future plans since it could further validate the effectiveness of the former, especially if combined with following up the children that took part in this study for late post-tests.

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# STUDENTS' CONCEPTIONS OF GROWTH AND CELL DIVISION BEFORE AND AFTER INSTRUCTION

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## Abstract

The study presents the frequencies of students´ conceptions of growth and cell division before and after one-hour-instruction. The investigation supplements qualitative results by directing the attention to those conceptions which might occur most frequently to students. Thus teachers can concentrate their preparation on practical requirements. 120 students (9th grade) participated in the investigation using a questionnaire. 29 students out of this group were instructed and the lesson's effectiveness was examined. The most frequent conception of growth and cell-division in open tasks was "division of cells" followed by the scientific concept "division and enlargement". In closed tasks "division and enlargement" became the most prominent concept. If students were encouraged to think about this concept it might represent a plausible explanation to them although it often did not yet belong to their repertoire of concepts. When conceptions of division were examined "becoming more" and "separation" appear far more frequently than "becoming small". In the lesson students broke a bar of chocolate into pieces. They clearly recognized that division leads to more pieces but the whole does not increase in size or mass. The scientific concept "division and enlargement" was almost completely transferred into the students' consciousness.

## 1. Introduction

In previous qualitative research many students' conceptions of growth and cell division were discovered (Brinschwitz, 2002; Riemeier, 2003). Because of the quantity of these conceptions it is not possible to focus on all these conceptions in a cell biology lesson. Therefore, the aim of our investigation is to determine the probability of the occurrence of certain conceptions. By distinguishing frequent conceptions from less frequent ones this investigation could enable assistance in the preparation of a teaching method that considers students´ conceptions.

In addition we examine the effectiveness of a lesson that considers prominent students' conceptions. In order to gain some first experience materials - designed accordingly to educational research - were employed in one lesson with the 9th grade and the effect of this was examined. These teaching materials have already been tested in teaching experiments. By documenting students' statements during the experiment it was already possible to discover students' "pathways of thinking" and to gather a change of conceptions towards the scientific concepts (Riemeier, 2003; Riemeier & Gropengießer, 2005). This research investigates some of these teaching materials under classroom conditions and analyzes their influence on students´ conceptions.

## 2. Research Questions

The main questions of this investigation are:

- *'Which conceptions of growth and (cell) division are developed by students most frequently?'*
- *'How will a one-hour lesson taking students' conceptions into consideration influence these conceptions?'*

## 3. Theoretical Background

This research is based on moderate constructivist epistemology (Duit & Treagust, 1998) and the revisionist theory of conceptual change (Posner et al., 1982; Strike & Posner, 1992). Furthermore, the theory of experiential realism (Lakoff & Johnson, 1980, Gropengießer, 2003b) is used to interpret students' conceptions to gain a deeper understanding of students' ways of thinking.

Moderate constructivism understands the broadening of knowledge as an active construction on the basis of already existing conceptions. The active, self-guided and self-reflective learner is important here (Duit, 1995 citing Tobin, 1993). According to constructivism, when structuring learning environments the following aspects should be taken into account (Gerstenmaier & Mandl, 1995): Authenticity and real situations, multiple perspectives, and social contexts as cooperative learning in groups should be provided. Additionally, the learning environment should enable learners to construct knowledge and interpretations themselves and should also offer opportunities for gaining experience.

From the constructivists' point of view the aim of a lesson is to influence concepts depending on certain contexts in the direction of the scientific concept (Duit, 1995). Such a conceptual change theory was provided in Posner et al. (1982) and in Strike & Posner (1992). According to this theory a conceptual change only occurs when four essential conditions are fulfilled: There must be dissatisfaction with existing conceptions, a new conception must be intelligible and must appear initially plausible and should also suggest the plausibility of a fruitful research program (Posner et al., 1982; Strike & Posner, 1992). It should be added here that the term conceptual change is not totally appropriate because during the lesson an individual's already existing conceptions should not be exchanged and replaced by scientific ones. Conceptions that existed before the lesson and scientific conceptions should be both kept in mind and should be applied correctly according to the specific context (Duit & Treagust, 1998).

Furthermore, the theory of experiential realism is used to interpret students´ conceptions. Following this theory we distinguish understanding between embodied and imaginative conceptions (Lakoff & Johnson, 1980). Thought is embodied in the sense that our basic conceptions grow out of bodily experience. Moreover the core of our conceptual system is directly grounded in perception, body movement and experience of a physical and social character. In addition imaginative conceptions are not directly grounded in experience, they are developed by transferring conceptions from one directly experienced area to a non-directly experienced area. For this we use metaphors or analogies. In that sense metaphors do not lie within the single word and do not serve as some poetic decoration but rather in the conceptual structure.

This metaphorical concept is inextricably linked with our normal talking and thinking (Gropengießer, 2003a). In that way, we structure our life according to conceptions which are built by metaphors. These metaphors arise from units of experience that are perceptible by the senses and are transferred to some abstract “target areas”. Non-metaphorical schemes come from daily life experiences and create the “origin area” of the metaphors. During the process of understanding and when talking we create a systematic similarity between these two areas.

The framework of "Educational Reconstruction" serves as a theoretical background to prepare, to carry out and to evaluate research in science education (Kattmann et al., 1997). The three components of the framework – clarification of scientific conceptions, investigations of students´ perspectives and design of learning environments – are put into relation with each other to create more effective lessons. When working on these three components an iterative approach is striven for which means that interim results and repeated changes in perspectives are considered and therefore influence further research on the components (Kattmann et al., 1997).

## 4. Research method and test design

Based on the results of qualitative research (Brinschwitz, 2002; Riemeier & Gropengießer, 2005) popular conceptions of cells and cell division were integrated into the different tasks of a questionnaire. We inquired about everyday-life conceptions of growth and division without an explicit relationship to cells and cell division as well as scientifically-oriented conceptions thematically related to the cell theory. This research was carried out by using this questionnaire. Altogether the questionnaire comprised four open and six closed tasks. In the questionnaire the open tasks were always presented before the closed ones because the students were supposed to first describe their conceptions without any prior influence.

120 $9^{th}$ grade students of four different classes of a Berlin high school were tested. Until the $9^{th}$ grade, students have not yet received any instruction on cells or cell division according to the curriculum (Senatsverwaltung für Schule, Jugend und Sport, 1986). The survey took place between the end of September and the beginning of October 2003. On the basis of the results of this survey, a lesson was prepared and taught to 29 students in two separate groups. Four days after that lesson took place the students were tested again to find out any changes after one hour of instruction. In addition to these students who were taught, two

other groups of altogether 24 students, who did not receive any instruction, were also tested a second time as a control group. For the pre- and the post-test the same questionnaire was used. The students were able to determine the time to work on the questionnaire themselves; 45 minutes was enough in all cases.

For the evaluation of the open tasks, the category scheme of the qualitative research by Riemeier (Brinschwitz, 2002; Riemeier & Gropengießer, 2005) was used. The data was quantitatively analyzed with the computer program SPSS 11.5. According to the "Law of Comparative Judgement", the evaluation of each complete paired comparison task resulted in a scale after z-transformation (Bortz & Döring, 2002). The computer program PCSCAL was supplementarily used to create the paired comparison scale and for additional analysis of reliability (Niketta, 1989). To compare the results of the paired comparison tasks before and after the lesson the computer program PCGROUP (Niketta, 1996) was used. This program uses the Chi$^2$-Test to examine if different groups evaluate the objects of a paired comparison task differently.

## 5. Results

### 5.1- Conceptions before the lesson

#### 5.1.1- Students' conceptions of growth

In all tasks four prominent concepts of growth were found (Brinschwitz, 2002; Riemeier, in prep.; Table 1).

Table 1. Frequent concepts of growth

| Scheme | Indication of the concepts | Explanation of the concepts |
|---|---|---|
| Division means becoming more, growth means becoming more. | Growth happens because of **division of cells.** | Living beings grow because their already existing cells divide. |
| Division means becoming more, growth means becoming bigger. | Growth happens because of **division** of cell mass **and enlargement** of existing cells (cell division). | Because of the change between the phases division and duplication of genetic material and of cell mass, living beings grow. |
| Growth means becoming more. | Growth happens because of **cell multiplication**. | Living beings grow by increasing their number of cells. A specification of how this increase happens is not given in this concept. |
| Growth means becoming bigger. | Growth happens because of **cell enlargement**. | Living beings grow because of an enlargement of existing cells. |

*Note: **Bold**: Labels for the concept in the figures below.*

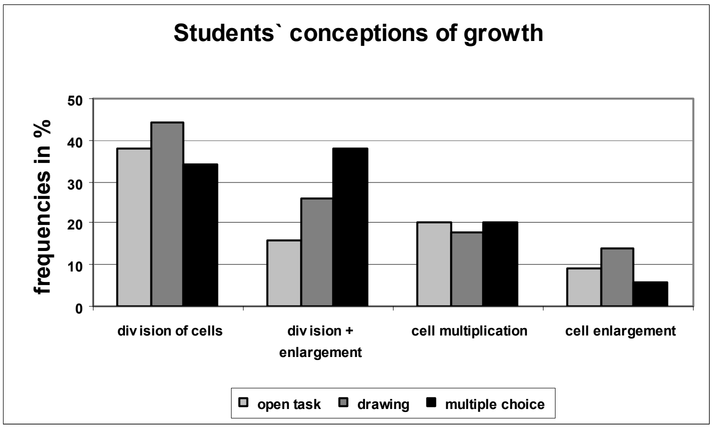


Figure 1. Relative frequencies of the four prominent growth conceptions in an open task (n=112), in the drawings (n=116) and in the multiple-choice task (n=120)

In an open task, in which the students were supposed to describe their conceptions of growth of multi-celled organisms the concept "division of cells" occurred more frequently than the other three conceptions (Figure 1). It was possible to identify conceptions of growth and division from the drawings and accompanying comments (Figure 2). In the drawings the concept "division of cells" was also the most prominent concept (Figure 1).

## Example of a student's drawing

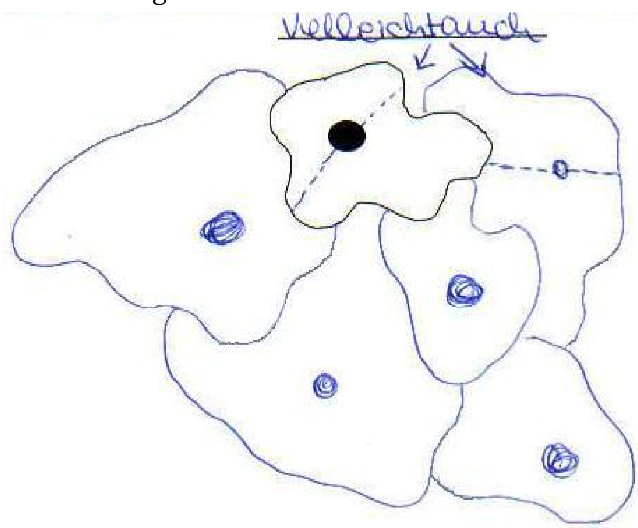


Figure 2. A student's drawing about the growing process of multi-celled organisms (The student's comment about this drawing: "The number of cells increases, so that the organism grows. Or maybe the cells divide again and again.") Identified conceptions of growth: "Division of cells", "cell multiplication" (Table 1); scheme of division: "Division means becoming more" (Table 2).

In a multiple-choice task, students were asked to choose a growth concept that comes closest to their own concept. A few students were not able to determine only one concept. The concept "division + enlargement" was chosen most frequently by the students (Figure 1). Furthermore, the concepts "division of cells" and "cell multiplication" were prominent (Figure 1).

In a closed task students had to evaluate given conceptions of growth on a scale with five levels. Here the concept "division + enlargement" was more likely to be equal to the students' concept than the concept "division of cells". The latter was even less important in this task than the concept "cell multiplication" (Figure 3).

Accordance with conceptions of growth

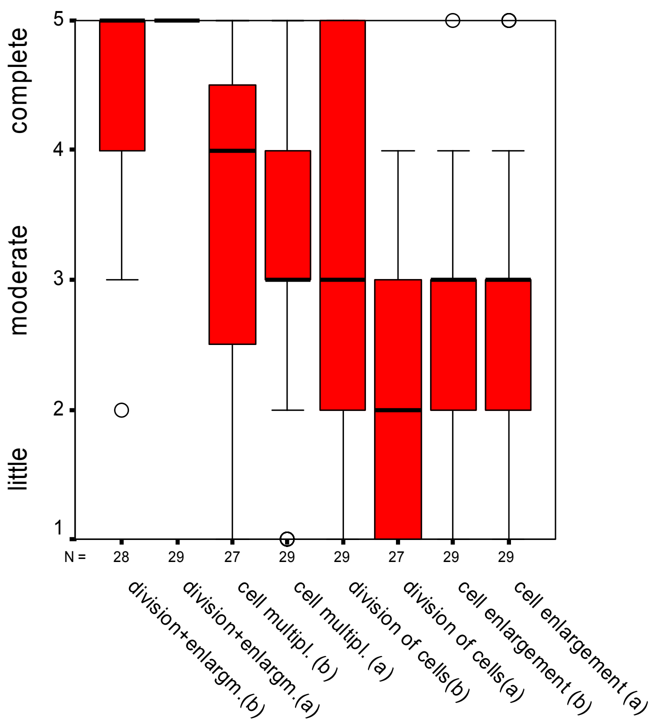


Figure 3. Decision to which degree the growing conceptions correspond with the students' own conceptions, before (b) and after (a) the lesson. The five sections of the ordinate correspond to the five levels of the rating-scale. The higher the number, the higher the accordance with the certain conception (n = 29). Only data of the students who attended the lesson are presented. This reflects the results of the whole population properly. A boxplot characterises the distribution and dispersion of a variable, displaying its median (thick line) and quartiles (box, 25th to 75th percentile). Whiskers atthe ends of the box show the distance from the end of the box to the largest and smallest observed values that are less than 1.5 box lengths from either end of the box. A circle identifies the position of an outlier. Outliers are between 1.5 box lengths and 3 box lengths from the end of the box.

In a paired comparison task of the four conceptions of growth the students had to decide each time between two conceptions. After z-transformation the evaluation of the data resulted in a scale (Figure 4). Testing for linearity as well as for variability of conceptions ($p<0.01$) revealed significant results.

Scale of growth conceptions

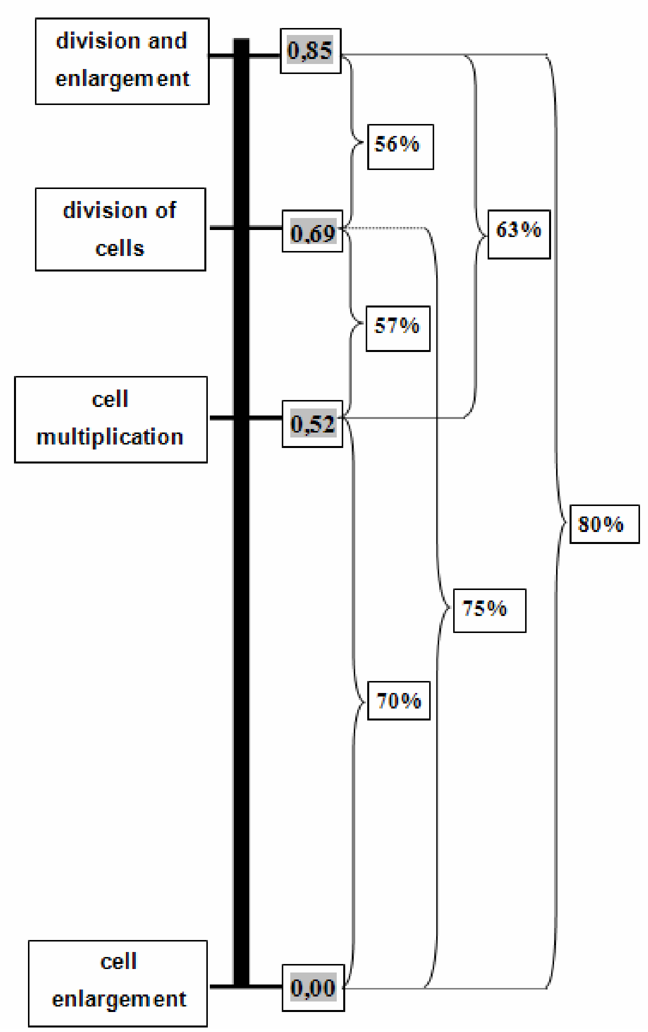


Figure 4. Scale of growth concepts after z-transformation. Percentages indicate how many students (e.g. 70%) prefer the upper concept (e.g. cell multiplication) in direct comparison to the lower one (e.g. cell enlargement) (n= 96).

The concept "division + enlargement" is here of premier importance, it was e.g. preferred over the concept "division" in 56% of all comparisons (Figure 4).

In summary it can be said that in all open tasks the concept "division" is the most frequent concept. In contrast, the concept "division + enlargement" is the most prominent one in closed tasks and in the paired comparison task. The concept "cell enlargement" has little significance for students when explaining the growing process of organisms.

### 5.1.2- Students' conceptions of division

In all tasks five schemes of division were found (Riemeier & Gropengießer, 2005; Riemeier, in prep.; Table 2).

Table 2. Schemes of division

| Indication of the scheme | Explanation of the scheme |
|---|---|
| 1. Division means **becoming more** | When dividing, the number of separate parts increases |
| 2. Division means **separation** | When dividing, two separate parts emerge that are no longer connected |
| 3. Division means **becoming smaller** | When dividing, the pieces that emerge are smaller than the original object |
| 4. Division means **breaking apart** | To divide in this sense can be understood as "to split up" |
| 5. Division means **becoming less** | To divide in this sense can be understood as "to distribute" |

*Note:* ***Bold****: Labels for the schemes in the figures below*

In an open task students' conceptions of the term "division" in daily-life contexts should be examined. Nevertheless, most of the students referred to cells in their answers. The scheme "becoming more" is the most prominent one. In this context the scheme "becoming smaller" is more important than the scheme "separation" (Figure 5).

Altogether it was possible to identify three schemes for division in the drawings. In some drawings more than one scheme was found. About two thirds of the students thought about "becoming more". Nearly as many students imagined the division process as a separation of cells. Less than half of the students drew the cells after the division smaller than the original cell (Figure 5).

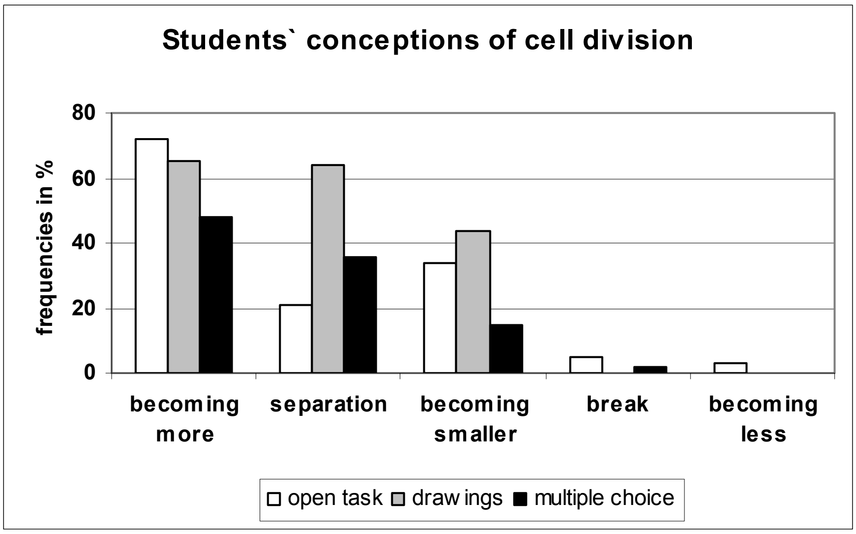


Figure 5. Relative frequencies of the students' conceptions of division in an open task (n=110), in the drawings (n=116) and in a multiple choice task (black, n=157)

In a multiple-choice task, students were supposed to choose a conception that corresponded most likely to their own conception. Not all students were able to determine only one conception. Altogether 157 decisions were made (Figure 5), in which "becoming more" and "separation" were preferred.

In the complete paired comparison task the students had to decide in each case between two of the five schemes of division. After z-transformation a scale was made (Figure 6). Testing for linearity and for variability of schemes ($p<0.01$) revealed again significant results. The order of importance of the five examined schemes of division is shown in the scale (Figure 6). The scheme "becoming more" is preferred over all other schemes. The two schemes "breaking apart" and "becoming less" are of no importance in the context of cell division (Figure 5, Figure 6).

Scale of division conceptions

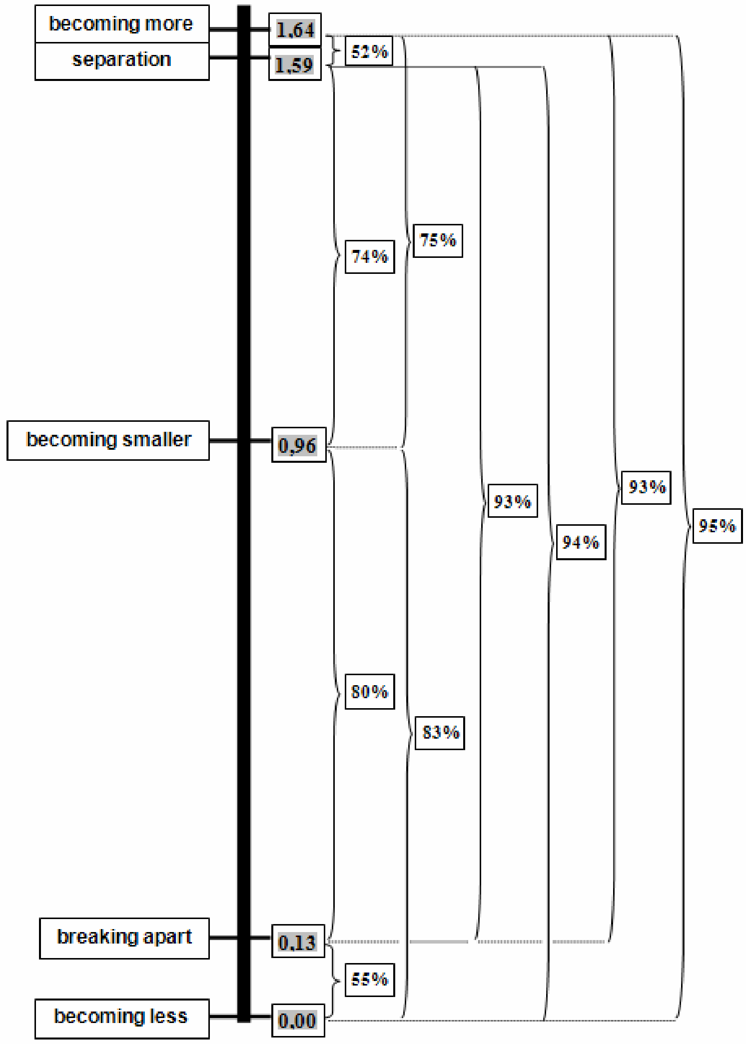


Figure 6. Scale (z-transformation) of the students' schemes of division. Percentages indicate how many students (e.g. 55%) prefer the upper concept (e.g. breaking apart) in direct comparison to the lower one (e.g. becoming less) (n=81).

### 5.2- The lesson "The growing process of multi-celled organisms"

This lesson was prepared based on recent research results (Brinschwitz, 2002; Riemeier & Gropengießer, 2005). The main goal of the lesson was:

- The students should understand the growing process of multi-celled organisms as a combination of division and enlargement of cells.

Because of the distribution of frequencies the lesson had to emphasize the range of the concept "division of cells" and was also to show the plausibility and fruitfulness of the concept "division + enlargement" (Posner et al., 1992).

The students' drawings from the pre-test-questionnaire were used during the lesson as an introduction after a time-lapse film about a growing onion root. The fact that drawings are a successful method to evaluate conceptions is a justification for the importance of drawings during the lesson (Holthusen, 2002). Furthermore, it is possible to show and to document the change and development of conceptions with drawings (Gropengießer, 2003b).

According to the latest research developments by Riemeier (in prep.) the instruction method "breaking apart a bar of chocolate" (Figure 7) as well as others were used. By "breaking apart a bar of chocolate" students could notice that pieces decrease in size and increase in quantity. The transfer to the growing process should cause a cognitive conflict and should finally result in a conceptual development. At the end of the lesson a worksheet was used to record the results. On that worksheet the students drew the growing process again. They also had to transfer their conceptions to the growing process of a bean plant presented with pictures.

Figure 7. Student breaking apart a bar of chocolate

### 5.3- Conceptual development after the lesson

The success of the lesson was e.g. shown in the following student's comment that was noted during "breaking apart a bar of chocolate" (Figure 7): "The chocolate divides like the cell. That doesn't make any sense! When cells are becoming more and more and becoming smaller then they also have to become bigger afterwards! They also grow!" Also, in the students' drawings, sketched on the worksheet right after the lesson, 29 of the 31 students drew the scientific concept "division + enlargement". The students had more difficulties transferring this concept to the example of the bean plant. Here only 21 of the 31 students described the scientific concept in their explanations. As expected, in a control group that had not received any instruction on that topic, no significant changes appeared at any time.

#### 5.3.1- Students' conceptions of growth

Four days after the lesson, a period of time after which normally the next lesson could follow, the students were tested again to see how much they had retained. More than two thirds of the students who attended the lesson, and therefore significantly more students than before the lesson, remembered the scientific concept "division + enlargement" while the concept “division of cells” was described and drawn by less students. There was no significant change measurable for the other conceptions (Figure 8).

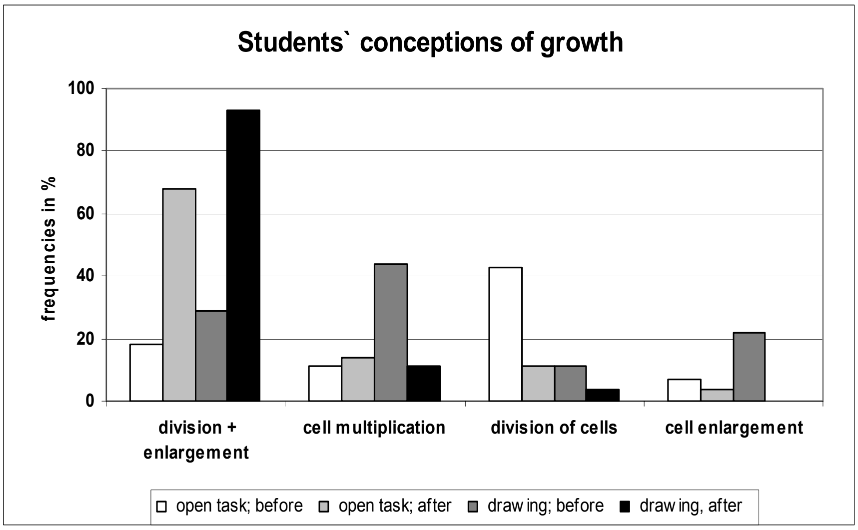


Figure 8. Students’ conceptions of the growing process of multi-celled organisms in the open task (n=28) and in the drawings (n=27) before and after the lesson

In the drawings, a conceptual change towards the scientific concept was even more obvious. Nearly all students drew the scientific concept “division + enlargement” after the lesson. At the same time, significantly fewer students supported the growth concepts “division of cells” and “cell multiplication”. The concept “cell enlargement” was not drawn anymore (Figure 8).

The same is confirmed in the closed task: After the lesson all students completely agreed with the concept “division + enlargement” which describes a highly significant change compared to the answers before the lesson (Figure 3). On a scale of accordance the concept “division of cells” is evaluated as “none” to “moderate” after the lesson which is significantly less than before.

In the multiple-choice task 28 out of 29 students chose the concept “division + enlargement”. Also in the paired comparison task in nearly all decisions the scientific concept “division + enlargement” was preferred over all the other conceptions after the lesson. Testing for the difference in the order before and after the lesson resulted in a significant change ($Chi^2=4.4706$, df=1, p=0.0326). In the control group no significant changes in the order of the scale from the pre- to the post-test were recorded nor in the evaluation of single conceptions.

### 5.3.2- Students’ schemes of division of cells

Altogether the one-hour of instruction did not cause any changes in the schemes of cell division. Only in the drawing task significantly more students supported the schemes "becoming more" and "becoming smaller". The scheme "separation" was still drawn as often as before.

## 6. Discussion

### 6.1- Distribution of frequencies of growth conceptions

*"Division of cells"* is the most frequent concept in open tasks of the pre-test. Zamora and Guerra (1993) also found in a survey of 150 students of the 7th, 8th, and 9th grade that many students describe cell multiplication as "division of cells". In this research the concept "division of cells" was also mentioned in the context of growth. Furthermore, students also imagine the multiplication of bacteria as a division process of cells (Hilge, 1999). Research by Hackling and Treagust (1984) examined as well the process of cell multiplication as a result of cell division and also in the context of growth: Less than half of the 48 10th grade students understood that growth happens because of a division process of cells, although they had just received instruction on genetics. None of these studies examined if students think of an increase in cell mass after this division process. The concept "division of cells" is assigned to the schemes "growth means becoming more" and "division means becoming more" that are based on everyday-life experiences. Learners transfer experiences from the macroscopic everyday-life area to the microscopic area to create conceptions in an area without any direct experiences (Brinschwitz, 2002). Students only see that the number of cells increases as a result of division and this must cause growth. But they do not recognize that growth is not possible because cells are becoming smaller at the same time.

In order to understand cell division, students have to reflect upon the different meanings of division, so that they can focus on "becoming smaller" by division. For that purpose, the instruction method "breaking apart a bar of chocolate" is recommended: While implementing it students realize that pieces are becoming more but the whole does not become bigger. The scientific concept *"division + enlargement"* is the second most frequent concept in open tasks. In contrast, in all closed tasks it is the most frequent concept. Presumably, this high evaluation of the scientific concept can be explained because the questionnaire has described the concept in the closed tasks. The description of conceptions is one possible way to cause a conceptual change in a certain context for learners (Gropengießer, 2003b). Perhaps the questionnaire presented a conception to the students that until then had not yet belonged to their prior repertoire of conceptions. So the students chose a conception that seemed to be plausible although it did not have to be part of their conceptual ecology thus far.

In general, the concept *"cell multiplication"* is of moderate importance. Students who support this concept transfer the everyday-life experience "becoming more" to cells. Additionally, they have realized that growth is possible only because of cells.

The concept *"cell enlargement"* is without exception of little importance. This concept can be explained through the embodied conception that growth is perceptible as an increase in mass over time (Brinschwitz, 2002). Obviously, the experience that cells are normally not visible (but they would be if cells grew continuously) makes this concept seem to be unrealistic. This result is contrary to the one by Zamora and Guerra (1993). This research showed that among 7th, 8th and 9th graders the most frequent answer to the question of what happens to cells during the process of growing was that they grow as well. They stress that "to grow" in this case only refers to size not to number. According to these results, there are students who have not had the experience that cells show a limited enlargement in size. It should be possible to give students the opportunity to gain this experience, e.g. when comparing the cells of onion roots from a long and a short root (Riemeier, in prep.).

### 6.2- Distribution of frequencies of division schemes

The scheme *"becoming more"* as a result of division turned out to be the most frequent one. The everyday-life experience that the number of pieces increases when dividing is the origin of this embodied conception (Riemeier, 2003). This conception is very important for students. In that way, most of the synonyms that were used by students in the open tasks instead of the term "division" included the scheme "becoming more". The transfer of this to cell division results in the scientifically inappropriate conception that an increase of pieces causes growth. The instruction method "breaking apart a bar of chocolate" takes this aspect into consideration and offers the opportunity to realize the contradiction that has remained undiscovered so far.

The scheme *"separation"* emerges frequently in all students' answers. A possible explanation can be found in the synonyms used by the students instead of the term "division". After all, two thirds describe "separation" in addition. It seems as if students make sense of the term "division" by using everyday-life experiences that imply separation. When transferring these to cell division of multi-celled organisms the meaning "separation" does not find any scientific correspondence.

Although former studies did not examine the scheme "separation", conceptions of separation during the process of division could nevertheless be found. In that way Zamora and Guerra (1993) determined the concept "when cells start to grow they start to distribute themselves all over the body".

Because of the strong presence of the scheme "separation" that was shown in this study, lessons should focus on it. Students have not had the experience that cell division does not mean separation at the same time. Additionally in a lesson the difference between the multiplication of single-celled organisms, where the scheme "separation" is scientifically correct, and the growing process of multi-celled organisms can be discussed (Brinschwitz et al., 2003).

Altogether the scheme *"becoming smaller"* is of moderate importance in the context of cell division. Although "becoming smaller" is highly important for students in everyday-life situations when dividing it loses significance when transferred to cell division. However, according to the scientific concept, division implies also that cells are becoming smaller. This fact which should actually be familiar to the students from the above-mentioned everyday-life situations should be used for a lesson to demonstrate that division alone, which is becoming more and at the same time becoming smaller, does not contribute to growth. The conception "becoming smaller" is prere-quisite so that students will deem an enlargement necessary for a mass increase after the cell divides. The instruction method "breaking apart a bar of chocolate" makes students aware of this aspect (Riemeier, in prep.).

### 6.3- Students' conceptions of cell division after the lesson

Often conceptions are resistant to extinction by conventional teaching strategies (Zamora & Guerra, 1993; Hackling & Treagust, 1984; Wandersee et al., 1994; Brinschwitz, 2002). Therefore an instruction method on the basis of the framework of "Educational Reconstruction" (Kattmann et al., 1997) was chosen in which students' conceptions are taken into account when preparing lessons. The used instruction materials caused a conceptual development towards the scientific concept (Riemeier, 2003; Riemeier & Gropengießer, 2005). In this investigation the success of this method was tested under classroom conditions. The one-hour of instruction with the above-mentioned materials clearly resulted in a significant change towards the scientific concept "division + enlargement".

After the lesson the concept "cell enlargement" was chosen more often than "cell multiplication" in the paired comparison task. By then the students clearly evaluated the aspect of cell enlargement during the process of growing as having more importance.

Among the schemes of division it was not possible to obtain conceptual changes in the same way as among the conceptions of growth although during the lesson the difference between a student's drawing that included the scheme "separation" and another one in which the cells did not separate after division was demonstrated. The scheme "separation" has proven its worth in everyday-life situations and cannot be simply changed by such verbal instruction methods. In a following lesson it should be pointed out that the everyday-life meaning of separation cannot be transferred to cell division. Time-lapse films could be a possible instruction method to demonstrate the difference between the growth of multi-celled organisms and the multiplication of single-celled organisms.

In conclusion, with the research results our instruction method cannot be asserted as more successful than others. But it was possible to show that it is successful. Therefore good reasons exist to teach lessons that consider students' conceptions. As long as there is no comparable research that is able to show similar success with conventional teaching strategies this teaching method is to be preferred over others.

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# GREEK STUDENTS' ALTERNATIVE CONCEPTIONS ABOUT EVOLUTION

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## Abstract

This article reports the results of an investigation addressed to 195 secondary school students attending the final year of their compulsory education, in five different school units in Greece. This investigation was designed to document their understanding of the concept of evolution as well as to contribute to the development of a proposal of revising biology curriculum in secondary education. This revision should target to the promotion of scientific literacy taking into account students' alternative conceptions. Data source was a written questionnaire filled by each individual student of the sample. After the data analysis, students' alternative conceptions were classified to four categories: teleological-creationistic, teleological-naturalistic, tranformistic-Lamarckian and Evolutionary- Darwinian. The vast majority of students expressed non-evolutionary views, which are mainly related to teleological and creationistic beliefs. These findings suggest the necessity to introduce the teaching of evolutionary theory as o core theme in secondary education.

## 1. Introduction

The Secondary Education curriculum in many countries is currently undergoing change, raising important questions about what should be included. The concept of evolution by Natural Selection constitutes the central principle that biologists use to understand the world. It is almost universally accepted as the best available explanation of biodiversity. Evolutionary theory provides the framework for an understanding of all modern Biology, but the term 'evolution' also relates to socio-cultural, religious, and eugenical questions and ideological mythologies.

It is important to teach evolution in biological education because it enables children to clarify and integrate biological concepts. At the same time it offers educators an opportunity to illuminate the nature of science, to explain the limits between scientific and non-scientific argumentation and to distinguish opinion from evidence-based statements. The teaching of biological concepts without an explanation of evolution deprives students of a powerful conceptual tool for interpreting the origin, diversity and unity of life. Thus, evolution is a core theme in scientific literacy.

The definition of "scientific literacy" has two central key components: science concepts (knowledge) and the use of those concepts. *In contrast, the existing curriculum, classroom instruction and textbooks focus mainly on science content. Scientific literacy emphasizes "what is important for students as reflective citizens to know, value and be able to* *do" (Bybee, 1987). Biological alphabetization is a core aspect of scientific literacy (Simonneaux, 1994). Evolution, as a key component of alphabetization, offers the framework to answer questions about the diversity, the origin and the changes of life through time. Additionally, teaching evolution within the context of alphabetization raises deeper questions related to the role of chance and uncertainty. Therefore, understanding evolution prepares children to accept change and chance and perceive them as opportunities for the future. Biology teachers face the challenge of educating their students to deepen their understanding of evolution in order to become scientific literate citizens.*

### 1.1- Questions about scholarly diffusion of Evolution in Greece

Although Francois Jacob claims that the secondary school science curriculum should approach the study of the living world through the study of evolution (Jacob, 1999) the place of evolution within the school curricula of the 21st century is still marginal - not only in Greece but in many other countries.

The initial training of a scientist plays a large part in shaping the methodological and conceptual matrix of the next generation and when a certain kind of knowledge is not properly transmitted to the following generation, it is evident that it will remain marginal. In Greece the theory of evolution did not enter the university curriculum until after the overthrow of the colonels in 1974. How was it then taught? Results from a previous inquiry into Greek textbooks and curricula from 1970-1990 (Lakka, 1999) showed that the biological community was not well informed about evolutionary theories. Additionally, evolution is not included in the program of national exams being set for teachers as a prerequisite for their appointment at state schools. Even now there exists a widespread belief that the theory of evolutionary theory is guesswork. This is a common sense belief, widespread in the population as well as among science teachers, as it was reported in our previous research (Lakka, 1999). We are currently working with teachers on pre-service and in-service training courses raising the issues about evolution discussed in this paper.

The curriculum of Greek Lyceum includes some reference to the concept of evolution, but the actual teaching of evolutionary theories in the classroom is absent, for various reasons. The most important reason is that evolution is not included in the syllabus of the university entrance national exams. In lower secondary education the subject of evolution is included in the current syllabus and in the textbook of the third year, but being the last chapter is almost never taught. In the new biology syllabus of lower secondary education the time allocated to teaching of the unit of evolution is less than 2% of the total time allocated to biology (Pedagogical Institute, 2003) Although there is no doubt of the importance of Evolution in scientific context, there is some sort of problem in its inclusion in Secondary Education.

Evolution by Natural Selection can be easily defined. However, it is a complex concept underpinned by many other basic concepts that also need some understanding, such as 'genetic information', 'individual', 'population', 'mutation', 'adaptation', 'hazard', 'selection', 'migration', 'species' etc. It is also underpinned by the ideological dimension of its concepts and the idea that evolution always means progress and improvement. Our previous epistemological and historical studies on the construction of biological concepts and teachers' representations (Lakka, 1999) as well as students' conceptions about biodiversity (Vassilopoulou, 1998) revealed many epistemological and cognitive obstacles related to evolution, which must be considered in the light of the new biology born on the post-genomic era and the new directions in didactic. Questions about pedagogy and didactic are strongly connected with epistemological aspects. For this reason, recent research emphasizes the similarity between children's scientific thinking and the historical construction of scientific concepts. The way that children perceive the world is expressed through their alternative conceptions. Research based on alternative conceptions developed rapidly during the last two decades.

### 1.2- Didactic and alternative conceptions

According to constructivist theories of learning, children's alternative conceptions play a considerable role in organizing their knowledge and in building scientific concepts through conceptual change. We use the term *alternative conceptions* to mean the fundamental beliefs which students have about how the world works, which they apply to a variety of different situations (Dykstra, 1992). Children's alternative conceptions may include common sense beliefs about the biological world, the origin of species and of human being. According to Ausubel (1978) "many common sense "truths" are plausible in the sense that they could be true, but they do not happen to be so. The incorrect alternative especially is backed by the weight of authority, tradition or persuasive language, often masquerade as common sense truisms. Some truisms in educational practice, because of their seeming "naturalness" and familiarity may tend to impress us as the eternal verities" (Ausubel, 1978).

Identifying alternative conceptions has been the focus of a number of studies, which have provided qualitative analysis of the conceptual difficulties that students experience when learning Biology. A number of these studies have shown that the concept of evolution is poorly understood (Cambell & Mitchell, 1998; Demastes et al., 1995; Fortin, 1994). Other studies, focusing on biological concepts related to an understanding of evolution have produced similar results – for example, studies of students' conceptions of biological inheritance and genetics (Lewis & Wood- Robinson, 2000) and biological adaptation (Clough & Wood- Robinson, 1985).

## 2. Research design and methodology

### 2.1 Research design

Our aim was to uncover Greek students' beliefs about evolution in order to construct a first cartography of students' alternative conceptions using written responses to a questionnaire (see Section 2.2). Our research questions deal with identifying students' alternative conceptions of evolution:

- 'Do students accept the Darwinian theory of evolution?'
- 'Do they use teleological explanations?'
- 'Do they accept the role of chance and mutation in the evolutionary process?'
- 'Do they connect evolution to the proper time scale?'

195 students aged seventeen, drawn from five Lyceums, took part in the study. The five schools are situated in different areas: urban (one school), suburban (two schools) and rural (two schools). In each school, students follow one of the three different courses offered in Greek Lyceum: theoretical, scientific or technological We questioned students of all courses, in order to have a representative sample of the student population attending the third class of Greek Lyceum. 51 of the students attend scientific course, 63 of them attend classical studies and the remaining 81 attend technological course. Participation was voluntary and the answer sheet was anonymous. The research took place in the classrooms and the questionnaire was distributed to students by their science teachers, who carried out this work under our instructions.

### 2.2- Design and administration of the questionnaire

We based our research instrument, which used 8 open ended and multiple-choice questions, on a questionnaire designed and used by Fortin (1993). Three of the questions focused on knowledge and five on students' opinions about evolution. The knowledge questions related to basic evolutionary themes such as:

- Origin of species
- Role of chance and role of program in the origin of life and the emergency of human being
- Role of mutations and natural selection
- Awareness of Darwin's' theory
- Spatio - temporal dimension of the origin of life

#### 2.2.1- The questionnaire

1. When do you think Man first appeared on Earth?
2. Do you believe that the existence of Man on Earth has been planned? Explain your answer.
3. Write a short history of the appearance of life on Earth from its beginning until today.
4. In your opinion is the history of life on Earth the result of…
    a. Nature's program
    b. Chance
    c. God's plan
    d. Other
5. The way in which biologists present the history of life is based on….
    (Choose the option that is closest to your opinion)
    a. Observations which draw a conclusion
    b. Scientific evidence, which draws on a scientific theory
    c. Scientific dogma which conflicts with religious beliefs
    d. Other (explain)
6. Choose the option that is closest to your opinion.
    a. Animals which exist today did not always do so, but appeared at different stages in the history of life on Earth. All of them have developed from the same original cell
    b. Animals that exist today have always been in existence but some have become extinct to what we see today.
    c. Animals that exist today have always been on Earth, but originally were in different

form. In the passage of time these developed and progressed
d. Other (explain)

7. The variety of life on Earth is mainly the result of…
   a. Mutations
   b. Natural Selection
   c. Adaptation to the environment
   d. Cross- breeding
   e. All of them
   f. Other (explain)
8. What did Darwin support?

## 2.3- Analysis

We use quantitative analysis and content analysis. The analysis units are certain words or phrases. The emphasis was given to the meaning of each phrase (semantic analysis). Conceptions are expressed by combination of concepts, through explicit links, forming propositions. In such a way we found the key -concepts that students have expressed in their answers. These key-concepts are the core of each conception. These concepts are represented in the concept map we construct for each category. Concept maps are intended to represent meaningful relations between concepts in the form of prepositions (Novak & Gowin, 1984). In each concept map we classified the concepts following the rules of Novak about hierarchy and progressive differentiation of concepts. Thus, we placed the most inclusive concept at the head of the concept map that we constructed out of students' responses.

- Teleological - Creationistic: In this conception key-concepts are: God's plan, creation, Adam- Eva, Bible, fixity of species. Characteristic expressions are: "God created the human species". "Nothing happens by chance". "All living organisms are a result of God's desire". Major criteria to classify a student in this category were: using Bible to describe the emergency of life and the existence of Man on Earth, denying the role of chance (question 4 option c, question 5 option c and question 6 option b). They also use short time-scale. The above conception is illustrated in concept map 1 (Figure 1).

- Teleological- Naturalistic: In the question on how organisms changed, students explicitly move around the idea that there is a program in Nature that motivates changes. Following are some examples of teleological arguments: "I' m sure that nothing is accidental and everything has an explanation and an aim in Nature". Key- concepts in this category are: program, Nature's plan, extinction, inner need /intention of organisms, nothing at random. It seems that students prefer simple and firm explanations, which do not include the probabilistic view and the role of chance. The difference from next category is that students accept the extinction of species and internal need of organisms (see concept map 2 in Figure 2).

- Transformistic- Lamarckian: The major criteria used to label a student as belonging to this category were: they do not accept the role of chance in their explanations, they think that evolution happens in response to environmental change and the driving force of changes is adaptation (question 6, option c and question 7 option c). Describing the history of life they use the concept of adaptation as the central one and also they use short time-scale. In their descriptions they do not use the notion of creation and they use the following key-concepts: adaptation to environment change, improvement of organisms, gradual complexity, not fixity of species, Nature's program (see concept map 3 in Figure 3).

- Evolutionary- Darwinian: The major criteria used to label a student as belonging to this category were: to accept the role of chance (question 4, option b), to recognize Natural Selection as the driving force of Evolution (question 7, option b), to realize that all organisms evolved from a common ancestral cell (question 6, option a). Additionally, when answering open –ended questions, students of this category describe the emergency of life using key-concepts of the evolutionary scenario giving scientific acceptable explanations. They also understand time scale and realize that evolution may take millions of years.Here are some characteristic answers: “The presence of man has not been programmed. It is the result of accidental mutations”. “Life emerged in water environment from a single cell.”

The above students use the notion of mutation and chance as factors of Evolution. They believe that all living organisms are coming from an ancestral cell. They recognize the importance of Natural Selection as the main process in Darwin’s theory of Evolution. In their descriptions of the history of life they used the following key- concepts: lack of program, lack of intention, chance, probabilism, Natural Selection, mutation, knowledge of time-scale. The results of analysis of students’ answers are illustrated in the concept map 4 (Figure 4).

## 3. Results

We grouped students’ alternative conceptions in 4 categories according to previous analysis:

1. Teleological - creationistic: The core concept in this category is the “simultaneous creation of species”. Students pointed out that creation of species is the result of God’s Program. Even though they did not mention the term teleology, they used teleological explanations in their scenarios of the origin of life. The analysis of students’ answers is illustrated in the concept map 1, which summarizes the concepts and the lines of thinking within category 1 (Figure 1).

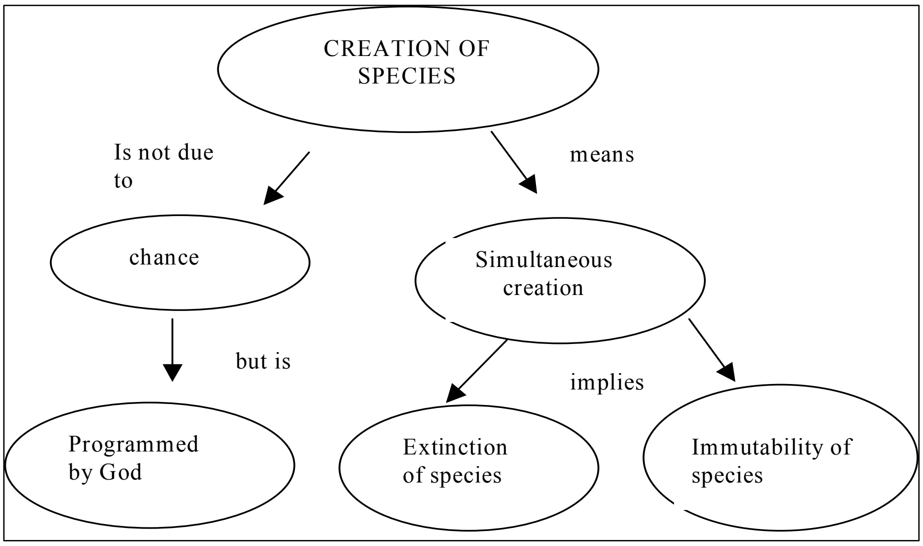


Figure 1. Concept map 1 - Teleological-Creationistic-fixism

**2. Teleological- Naturalistic:** In this category the core concept is the "creation as an inner need of organisms". Students' responses show ignorance of the role of Natural Selection, mutation and chance. The analysis of the responses is illustrated in concept map 2 (Figure 2).

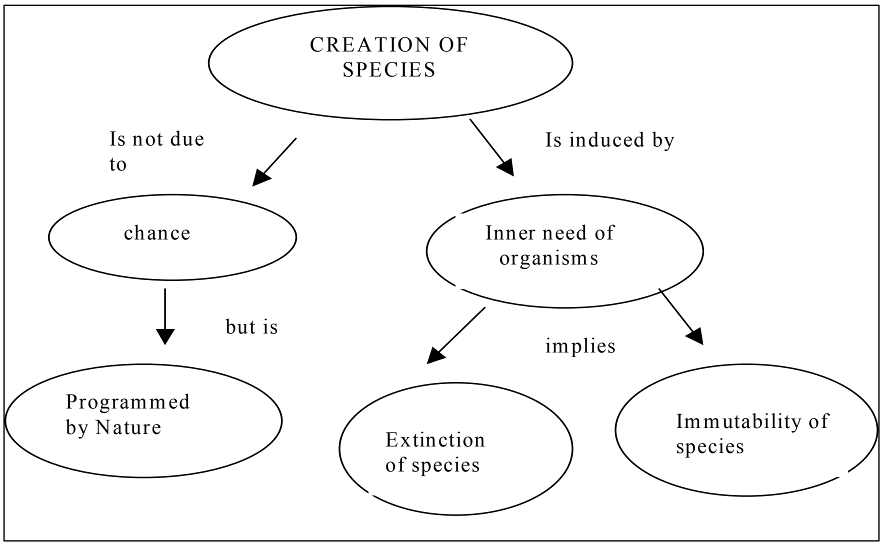


Figure 2. Concept map 2 - Teleological-Naturalistic-fixism

**3. Transformistic- Lamarckian:** Students of this category accept the notion of Evolution but they believe that species are being transformed gradually during the geological periods without any extinction (Figure 3).

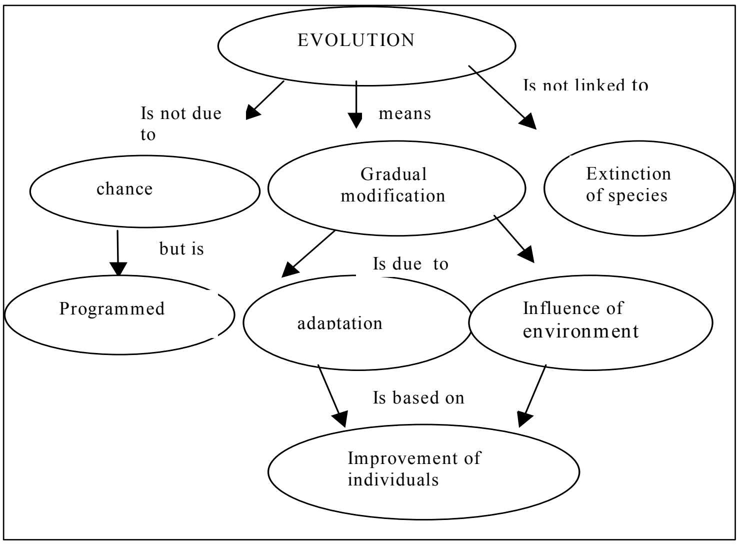


Figure 3. Concept map 3 - Lamarckian-transformistic

**4. Evolutionary- Darwinian:** This category comprises of students who use evolutionary terms in their descriptions of the origin of life. We constructed concept map 4 using the key concepts of their answers: Evolution of species, Natural Selection, chance, probability, common ancestral cell and mutation (Figure 4).

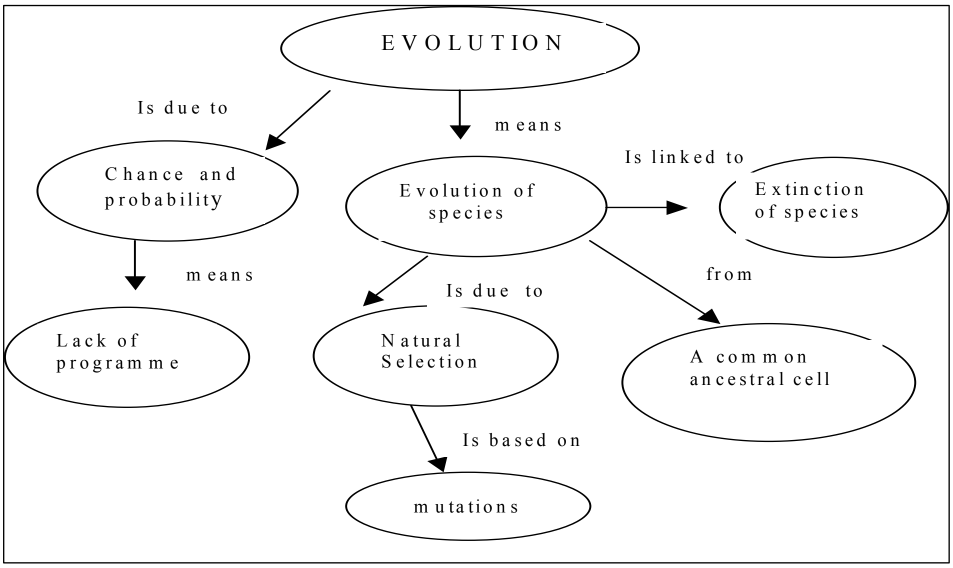


Figure 4. Concept map 4 - Evolutionary-Darwinian

Table 1 presents students' most representative answers. These answers show that the majority of students accept the existence of program either by God or by Nature. The creationistic position is the most dominant among Greek students in rural areas. Students who express the evolutionary scenario accept the role of chance and base their answers on scientific causality.

Table 1. Results by area

| Results by area | | | |
|---|---|---|---|
| Answers | Rural | suburban | urban |
| Question 2 | % | % | % |
| Program (Nature or God) | 63,7 | 54,7 | 41,3 |
| No program | 22,5 | 30,2 | 52,2 |
| Don't know | 13,8 | 15,1 | 6,5 |
| Question 4 | | | |
| Nature | 31,2 | 22 | 17,2 |
| Chance | 18,8 | 24,4 | 48,3 |
| God | 46,2 | 51,2 | 34,5 |
| other | 3,8 | 2,4 | - |
| Question 6 | | | |
| evolutionary | 20 | 22 | 26,2 |
| Teleological (naturalistic or creationistic) | 40 | 27,7 | 9 |
| tranformistic | 35 | 45,3 | 64,8 |
| other | 5 | 5 | - |

## 4. Discussion and conclusion

The four alternative conceptions described above, are primitive and intuitive. So, when we speak about "evolutionary - Darwinian" or "transfomistic - Lamarckian" conceptions of students, we do not expect a coherent - explicit conceptual framework as those described by Jimenez-Aleixandre (1999). The Lamarckian conceptual framework reflects the transformistic philosophical view of how changes happen in Nature and neglects the role of chance. Additionally, we mentioned that some students are so confused that their responses are mixed. In some questions students' answers reflect school knowledge (about the beginning of life) and in other questions (especially the ones concerning the origin of man) students appear fully creationists.

Teleological beliefs seemed to be widely spread. In this conceptual framework we recognize an important psycho-cognitive resistance to Evolution Theory, as it activates mythical archetypes about the origins of life and Universe. Creationistic interpretations were predominant. Students seem to feel more comfortable using explanations in terms of purpose and design than accepting the role of chance. Teleological reasoning in relation to Evolution was found to be held by 71% and 56% of the students in grades 10 and 12

(Tamir & Zohar, 1991). Our findings about Naturalistic and Lamarckian students' conceptions could be compared with similar investigations in England (Deadman & Kelly, 1978).

We have to underline some misconceptions about Darwin's theory. The great majority of students (85%) identify Darwin's theory with the following conceptions: "Man comes from monkeys". "The strongest survives in Nature". "Living creatures with no use have to be exterminated". These misconceptions are related with two common beliefs about the process of Natural Selection. The phrase "survival of the fittest" is commonly associated with Natural Selection ignoring that the key is not the survival itself, but survival and reproduction of the fittest organism. The phrase "struggle for life" does not necessarily refer to open fighting.

Students, when answering about Darwin's theory, limit their responses only to human being and do not refer to Darwin's work about the origin of species. We have to point out that the only chance students in our sample might ever had to hear about Darwin's theory was three years earlier, during the last year of lower secondary education. We can therefore infer that these answers are due to the lack of information and the influence of common sense beliefs. Additionally, some students confuse the origin of life ant the origin of Universe. They believe that life emerged when Big- Bang happened and the first molecules and cells were formed. These misconceptions are related to the time scale.

It has to be said that there was a differentiation of students following the science course from those following theoretical course. Students following the science course seemed to be more influenced by evolutionary theory. We also noticed a difference between the perceptions of students at urban areas and students of rural areas (Table 1).

Students of rural areas have expressed the teleological –creationistic view at a percentage of 60%, answering the question "when do you think that Man first appeared on Earth?". On the contrary, students of urban areas (Athens) turned up with evolutionary beliefs. We have to point out that there was also some difference between the two schools of rural area. This drives us to the conclusion that not only the place of the school, but also the specific conditions (mainly the effectiveness of teaching content and approaches) play a crucial role in the construction of students' conceptions.

Although students' ideas about evolution lack coherence, as shown in their responses, some key-concepts emerged in our research, which allowed us to categorize students' conceptions into the four categories that have already been described. The study of students' responses has alerted us towards the fact that the majority of students hold non-evolutionary views which connotes mainly teleological and creationistic beliefs.

These results suggest the need to include the teaching of Evolution theories in Secondary Education Curriculum as a key factor in students' scientific literacy. Nevertheless, the contribution of teacher's qualities as science teacher and her/his perception on teaching Evolutionary Theories in Secondary Education syllabus make the real difference. This means that there is a need to investigate teachers' conceptual framework about Evolution and develop teacher training on the specific topic. Theories of Evolution are not a dogma, but a model that needs critical consideration and verification (Fortin, 1994). Of course this does not mean that it is a subject to be neglected in Secondary Education. There is a need for biology teachers and researchers in Europe on the one hand to show the importance of the problem and its results in future generation's scientific literature and on the other hand to promote the reform of the Curriculum in life Science in the light of Evolution.

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# SECTION 2

# REASONING: SCIENTIFIC THINKING AND ARGUMENTATION

# TRAINING STUDENTS HOW TO ARGUE THROUGH COMPARATIVE ANALYSIS OF TEXTS GIVING OPPOSING VIEWS OF GMOS

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## Abstract

The aim of the present work is to encourage students to debate the repercussions of biotechnology applications. To improve the pertinence of students' arguments on this socially controversial scientific issue, we tried to train students to analyze the train of thought of different persons with differing views. It is a quasi-experimental case study. 40% of the students in the experimental group, which underwent the training between pre-testing and post-testing, were found to have developed more sophisticated arguments, while the quality of the arguments in the reference group did not vary between pre-testing and post-testing. On the other hand the training did not appear to affect the quality of oral argumentation which seems to be influenced more by personal and social factors. Our objective is to inform people about research methods, their applications and possible consequences so that they are capable of taking well-founded decisions when the facts are not clear and also of taking part in debates. The idea is to educate people *about* and *for* action which calls upon social values and skills such as debating or arguing.

## 1. Socially controversial issues

Agriculturally oriented biotechnology is a controversial techno science. It raises socially “controversial” issues, which lead to debates on the production of reference knowledge;

- The issues are controversial because they are omnipresent in the social and media environment and because participants in the teaching situation (both students and teachers) cannot avoid them;
- They are problematic issues because in the classroom, teachers often feel that they are not capable of dealing with them.

## 2. Different levels of study of players’ ‘conceptions’

Participants’ “preconceptions” correspond to what Beitone & Legardez (1995) called the system of representation-knowledge. This is a sum of opinions, beliefs, attitudes, and information from various sources (including scientific popularization) residues of learning from previous schooling or from social representations. The studies focus on samples of different types. They may be samples of students and teachers in different disciplines. The objects studied correspond to various facets of the system of representation-knowledge; these may be perceptions, knowledge, attitudes or opinions. Let us consider the main results.

## 2.1- Study of knowledge

International research on the didactics of biotechnology claims to be part of the socio-constructivist approach and had tried to identify students' knowledge.

Research reveals that high school students have a lot of gaps in their knowledge of the biological field in question. They are often confused by terminology, even if they use scientific jargon, which only goes to prove that they have a superficial lexical knowledge. The way in which research is implemented, the limits to scientific research and technical prowess, the results obtained and the cost of biotechnologies are largely unknown to them. On the other hand, they refer to the basic principles of some biotechnologies (cloning and transgenesis): the identical reproduction of an individual, the transfer of 'something genetic' from one individual to another. While the students can identify a few applications, they do not grasp the range of possible applications of biotechnology.

## 2.2- Study of attitudes - opinions

Researchers studying the didactics of biotechnology often use this type of study which is rooted in a sociological approach. This type of approach is often combined with investigations into the state of scientific knowledge. Research issues form around the question: are opinions and attitudes based on scientific knowledge?

Following the example of Lewis et al. (1998), we use the word '*opinion*' to refer to values attached to particular issues in specific contexts and the term '*attitude'* to refer to more general values. For example, with respect to animal transgenesis, if we consider that the breeding of transgenic cows capable of producing humanized milk in industrialized countries is not acceptable, this is an opinion; whereas considering that producing transgenic animals is ethically unacceptable no matter what the circumstances, is an attitude.

The students express attitudes or opinions even if they do not have the basic knowledge. Their opinions on biotechnology are not homogeneous, and depend on the applications in question, on the context envisaged, on the organism 'manipulated' and on the objective. Thus, for instance, medical biotechnology is accepted more easily whereas agricultural and agro food biotechnology is more controversial. Moreover, plant biotechnology is accepted more easily than animal biotechnology. The relationship with living beings is different. People identify more with animals, especially mammals than with plants. Concerning mammals, the arguments which are most often used concern the well-being of the animal or maintaining the telos of the animal (in other words, not transforming the essential nature of the animal). With respect to fish for instance, it is the ecosystem which is in danger. Many other questions are raised, for instance the unnatural character of manipulations which is 'blasphemous', sanitary and environmental safety etc. Depending on the applications, opinions are more or less qualified by the same individuals. They may for instance be very emphatic and negative about animal cloning and yet be ambivalent about genetic diagnosis.

Analysis of the different types of formal or informal teaching situations (exhibitions) shows that the appropriation of knowledge either does not affect students opinions at all or at least not much. The participants simply have to know the principle of any given biotechnology (i.e. cloning or transgenesis) in order to have an opinion. They have previous opinions and it is difficult to change these, since they are not based on knowledge.

## 3. Classroom debates on biotechnologies

Can classroom debates improve students' ability to make well-founded decisions and participate in debates? Debating situations can be classified as part of the wider field of 'issue situations'. As emphasized by Aline Robert (1999), problem issues which have been widely used for teaching research correspond to a complete, fairly specific scenario. Two types of factor are involved when developing them (this is known as didactic engineering), in particular when designing the initial problem and the content has to be carefully chosen to allow for precise management, including different distinctly separate moments. They are scenarios which are created by didactic engineering in which the content and management of activities have been carefully thought out. Their specificity depends on the carefully described type of knowledge brought into play and on contextualizing and socializing the subjects of debates.

Dolz & Schneuwly (1998) defined four dimensions to be taken into account when choosing a debating theme:
- *"a psychological dimension including motivation, students' motions and interests;*
- *a cognitive dimension which refers to the complexity of the theme and the students' state of knowledge;*
- *a social dimension related to the social relevance of the theme, its potential for controversy, its challenges, its ethical aspects* (…);
- *a didactic dimension which requires that the theme not be too humdrum and that it have content which can be 'learnt' ".*

The debating situation proposed below satisfies all of these requirements.

Driver et al. 2000; Jiménez-Aleixandre et al., 2000; Osborne, 1999; Solomon, 1992 … pointed out that debates used for teaching science made it possible to improve students' conceptual understanding, help them understand the epistemology of science, help them develop investigative skills (particularly through practical work) and help them improve their decision-making ability with respect to socio-scientific issues. The objective of the work described here is to develop students ability to argue about the consequences of biotechnological applications so that they can participate in social debates on this issue.

Analysis of the debates can draw on argumentation theories which make it possible to describe the basic argumentative pattern (Toulmin, 1958; Adam, 1990, 1992; Plantin, 1990, 1996), to distinguish between various kinds of arguments (Perelman & Olbrechts-Tyteca, 1988), to define various forms of rebuttal (Apothéloz, Brandt et Quiroz, 1992), and to identify the role of argumentative connectors and orientation markers (Anscombre & Ducrot, 1983).

Classroom debate on socially controversial issues has a different significance to that of a debate on a scientific concept. The latter is mostly epistemological in nature and is used to help students grasp what English speakers call 'the Nature Of Science'. Classroom debates on socially controversial issues, due to their very nature, cannot be limited to a single discipline. The knowledge involved constitutes what Fourez (1997) calls "islets of rationality" which are multi-disciplinary in nature and vary in size according to the scale of the social context considered.

Plant biotechnology is a controversial scientific issue, which we intend to introduce in classroom debates. It is characterized by a lack of consensus among researchers, particularly as to its environmental risks and effects. For instance the controversy centers around the consequences of GMOs in developing countries. We believe it is important to get students to debate the issues by examining the positions taken by various researchers, institutions and journalists.

The students' line of reasoning is largely shaped by the media or their social milieu. Our intention is to get them to distance themselves from adopted arguments by encouraging them to think for themselves by analyzing the information available and then to express their own thoughts on the matter. Apart from this, argumentation is an intrinsic part of learning as knowledge is gradually developed through informed debate.

In a quasi-experimental study involving detailed analysis of the dynamics of argumentation, we observed that conventional debating enables more sophisticated argumentation than role playing (Simonneaux, 2001). We then wished to evaluate the effect of training on argumentation. Osborne et al. (2001) tried to improve students argumentation skills when dealing with purely scientific content, by getting them to learn how to use Toulmin's diagram (1958). We do not believe that this approach is relevant for improving argumentation on socially controversial scientific issues. The research question is: Does training students how to develop arguments by analyzing the argumentation of various influential people with conflicting views improve their argumentation?

## 4. A case-study on GMOs: Methods

The quasi-experimental study was undertaken with a class of 24 agricultural students in their final '*baccalaureate*' year. The protocol defined three stages. During the first of these, students were given texts expressing conflicting opinions. The students were called upon to give their own considered opinion and to identify the information they wanted to obtain. The students were then ranked according to their argumentation.

In the second stage, half of the 'good (11) and bad (13) debaters' (with the quality of the argumentation having been measured by the number of valid arguments developed and the number of supporting arguments for a given point) participated in a comparative analysis of two new texts with opposing views. This was the experimental group.

The analysis attempted to study the social and physical characteristics which produced the discourse (Who is speaking? What stakes are involved? What is the context?), the argumentation developed (the type of argument, its validity, its powerfulness, whether it was justified, etc.) and also to identify argumentation markers in the form of specific words. Modalization involves modalizing (an expression), in other words producing a marker or a set of formal markers by which people express their more or less full agreement with the content of the discourse.

Since Artistotle, modalization has been classified in many different ways. Bronkart (1996) chose four categories:
- logical modalizations consisting of judgments as to the degree of truth of the expressed postulates; these are described as certain, possible, probable, undeterminable, etc. ;
- deontic modalizations which evaluate what is expressed in terms of social values ; the facts expressed are presented as (socially) acceptable, forbidden, necessary, desirable, etc.
- appreciative modalizations expressing a more subjective judgment; the facts expressed are presented as fortunate, unfortunate, strange according to the person evaluating;
- pragmatic modalizations which judge an aspect of the responsibility of a person for a process; these particularly concern capacity for action (the power to do something), the intention (wanting to do something) and the reasons (the justification for doing something).

The students then write their own considered opinion and spell out the information they would like to obtain.

During the third stage, all of the students (the experimental group (10 students left) and the control group (11 students left)) gave their considered opinion on two new texts with conflicting views. A debate was then held. The debate was recorded (with both video and sound taping) and transcribed in its entirety. We then evaluated the quality of the written and oral argumentation, before comparing the quality of the argumentation of the control group and the experimental group (Figure 1).

We analyzed the macro structure of the debates. To do this, the corpus was divided into episodes. The episodes grouped together semantic units on the same theme. The macro structure was analyzed to reveal the dynamics of the discussions, the themes debated and recurring themes.

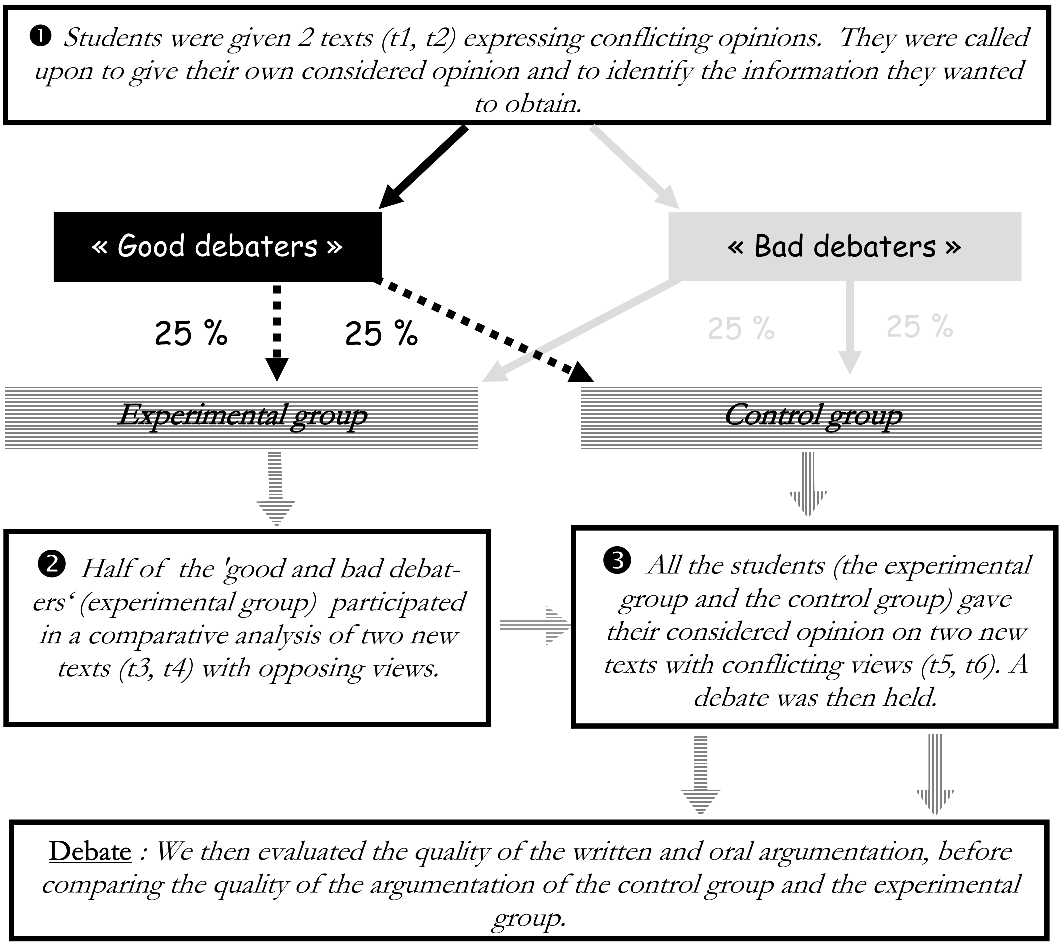


Figure 1. The protocol defined three stages

We analyzed the argumentative strategies in students' responses to pre and post testing and during the debate; we identified declarations with no justification, simple arguments with only one justification, multiple strategies including several encapsulated or linear justifications. We identified the fields of knowledge or social references on which the students' arguments were based and assessed the validity of the arguments used. We identified the explicit reliance on analysis of the texts provided. We also identified the modalizations used.

In argumentation theory, the meaning of an expression contains an allusion to its possible continuation (Ducrot, 1980). The expression is an attempt to orient later discourse. Anscombre et Ducrot (1983) refer to argumentation in language. According to them, '*all expressions of a given language give and draw their meaning from the fact that they intend to impose on the speaker a particular type of conclusion*'. All speech is '*advertising due to the fact that its internal value is part of the follow-up that it is looking for*'. In refined analysis of extracts from episodes, we tried to identify the systems of argument inference conveyed by language. It is possible to identify marks in the structure of an expression such as '*morphemes, expressions or phrases which in addition to their informative content give the argument a particular orientation which leads the recipient in a given direction'* Ducrot, 1980. These are the marks that we tried to find.

Finally, we recorded the characteristics of the arguments developed during the debate. In addition, we recorded students' averages in French, Philosophy, Biology and Agronomy.

## 5. Findings

### 5.1- Pre post-test analysis

For the pre-test, the texts with conflicting viewpoints dealt with the production of transgenic rice enriched with vitamin A, likely to prevent certain forms of blindness in India.

The students' arguments are political, ethical, economic, ecological, biological and related to human health. The information they requested is ethical, agronomical, ecological, economic, political, professional and related to human health. Furthermore some students have considered consumer opinion, the presence of GMOs in our current consumption, the location of transgenic crops, the future of this type of crop and the effect on organic farming.

For the post-test the texts concerned the interaction between GMO production and developing countries. The students' arguments were economic, agronomical, ecological, ethical, related to human health and the global availability of food. The information they requested was agronomical, economic, ecological, related to food and human health.

40% of the students in the experimental group developed more complete written argumentation for the post-test than the pre-test. This was measured by the number of valid arguments put forward as well as the number of supporting arguments for any given point, whether these came from 'good' or 'bad' debaters as determined by the pre-test. The quality of the argumentation of the students in the control group did not vary between the pre-test and the post-test. Half of the students in the experimental group explicitly referred to the argumentation strategy developed in the texts studied by them during the comparative analysis led by the teacher. They used the skills they had acquired during that analysis.

### 5.2- Debate analysis

The students who spoke out most during the debate and who developed the most valid argumentation were those who defined themselves, during our interviews with them, as the most 'actively committed ecologists'. They belong either to the experimental group or the control group. Furthermore they developed much more sophisticated argumentation during oral debate than in their written texts.

The students who did not take part in the debate were those with the worst school results (in French, philosophy, biology, agronomy), with the exception of one student from the experimental group who proved to be a 'poor debater' in the pre-test and who did not participate in the debate, but who developed a very sophisticated argumentation during the post-test. However this student did not have poor school results.

We should no doubt try other forms of debate, in sub-groups for instance, to make it easier for students to speak out.

During the written and oral exercises, students used all kinds of modalizations: logical, deontic, appreciative and pragmatic. They got very involved in their argumentation.

The students intervened 94 times. Three students who claimed during our interviews with them to be committed militants expressed themselves at greater length than the others: Mélodie (104 lines out of the 556 transcribed) had participated in a cooperative action in an African country; Martin (54 lines out of 556) is the son of organic farmers; Mathias (197 out of 556) came first in the class, is considered to be a leader and is also the son of organic farmers. 4 students out of 21 did not speak. These were students who had the lowest marks in French, Philosophy, Biology and Agronomy.

***Macrostructure of the debate***

| Lines | Episodes |
|---|---|
| 1-17 | *Introduction by the facilitator* |
| 18-21 | Intervention on patent rights |
| 22-34 | *Input by the facilitator requesting students' points of view on the texts ; these were on the whole negative. Facilitator requested explanation* |
| 35-46 | Criticism of the type of assistance given to developing countries |
| 47-53 | Criticism of the distribution of food products around the world |
| 54-55 | *Input from the facilitator concerning the potential for the production of transgenic plants which are drought-resistant* |
| 56-70 | Description of various risks ; demonstration showing how developing countries become dependent on aid |
| 71 | *Input from facilitator on how companies operate* |
| 72-80 | Highlighting of companies' financial strategies |
| 81-93 | Presentation of an alternative way of helping developing countries ; agricultural training integrated or adapted to the context of developing countries |
| 94-96 | Input on the limits of technology transfer |
| 97-100 | *The facilitator asks whether there are any people in favor of developing GMOs in developing countries* |
| 101-108 | Demonstration of the contradiction between agronomical usefulness and deterioration in economic terms |

| | |
|---|---|
| 109-122 | Identifying risks and uncertainties |
| 123 | *The facilitator asks students to spell out the issues related to GMOs.* |
| 124-131 | Question-answer session on research into food risks related to GMOs; reference to Putszai's work |
| 132-136 | Question answer session on the promotion of research giving frightening results |
| 137-148 | Declaration on how companies impose GMOs on farmers who do not want them |
| 149 | *Facilitator again asks students for their point of view on the texts* |
| 150-169 | Denouncing of companies patenting living organisms ; description of companies' repressive practices in confiscating living organisms |
| 170-175 | *Facilitator input on another country which produces GMOs, China* |
| 176-189 | Reference to South America ; criticism of food assistance which includes GMOs for African countries |
| 190-193 | *Facilitator input* |
| 194-216 | Discussion on the unfair competition of rich countries due to GMOs, which will henceforth be able to produce oils which until now have been exported by small countries. |
| 217-251 | Discussion on the specialization of agriculture in developing countries and the decrease of food producing agriculture |
| 252-255 | *Facilitator urges those who have not spoken to do so* |
| 256-268 | Demonstration of a paradox: reciprocal aid between industrialized countries and developing countries is based on economic interest |
| 269-274 | Description of an alternative: fair trading |
| 275-349 | Discussion on the sluggish development of fair trade: lack of information or life choice |
| 350-351 | *Input from facilitator on how African researchers work on GMO production* |
| 352-365 | Intervention on the dominant western model |
| 366-372 | *Input from the facilitator on the possible stopping of the European moratorium on transgenic crops* |
| 373-449 | Discussion on the efficiency of resistance to GMOs: from consumer information to revolution (!) |
| 450-451 | *Input from the facilitator on the consumers' role* |
| 452-462 | Health problems to which consumers might react |
| 463 | *Input from the facilitator on whether or not there is a problem* |
| 464-473 | Intervention on the problem of the irreversible nature of GMOs |
| 474-480 | *Input from the facilitator on refusing GMO activities in the hypermarkets* |
| 481-512 | Discussion on the economic interest of products which are guaranteed free of GMOs in the GMS; on the manipulation of consumers by advertising |
| 513-514 | *Input from the facilitator: are the farmers you know willing to produce GMOs?* |

| | |
|---|---|
| 515-528 | Discussion on the usefulness of GMOs for 'major' producers |
| 529-538 | Input on whether GMOs really are economically useful for farmers |
| 539-541 | Intervention on the unilateral interest of companies |
| 542-549 | Discussion on the lack of clear labeling |
| 550-554 | Discussion on the analogy with the use of growth hormones in Spain |
| 555-556 | *The facilitator closes the debate.* |

By 'discussion' we mean interactive exchanges in the form of dialogue or argumentation. We refer to dialogue argument when it is constructed by two (or more) people or when it takes into account the arguments of others as a basis on which to oppose them. It is possible to talk about dialogue argument even it is produced by one person as pointed out by Scott and Mortimer (2002) who use the idea of dialogue voice as taking into account the point of view of the person listening to the dialogue even if that person is not speaking. In episodes 194/216 and 217/251, two dialogue argument events are interwoven. The two protagonists first discussed export competition between rich countries who are able to produce oils by means of GMOs which previously had been exported by small countries. For one of the protagonists, Jacques, this was the major argument against GMOs. For the other, Martin, this specialization of agriculture in developing countries for exportation is dramatic since it is done to the detriment of food production. We can see from the following extract that Martin bases his comment on Jacques's argument in order to convince Jacques ; it is the adverb 'precisely' that demonstrates this.

| | |
|---|---|
| Jacques | But in any case you can't only eat…. I mean those who are making coconuts can't only eat coconuts. |
| Martin | That's **precisely** because coconuts have been specially grown for exportation |

*Content and disciplinary issues raised by students*

The content of the debate can also be analyzed according to the distribution and importance of the issues that we have related to various disciplines. We measured the relative importance of each of the disciplines used according to the number of lines referring to them in the transcription (Figure 2). The classification by discipline is very tricky as the themes dealt with are often cross-cutting (e.g.: the contradiction between agronomic usefulness and economic growth, 101/108). The analysis reveals that the scientific themes are almost of marginal importance in the debate which mainly revolves around economics and 'politics'. These different discipline themes are distributed throughout the debate, for instance there are four sequences for the scientific themes which take up four distinct time periods.

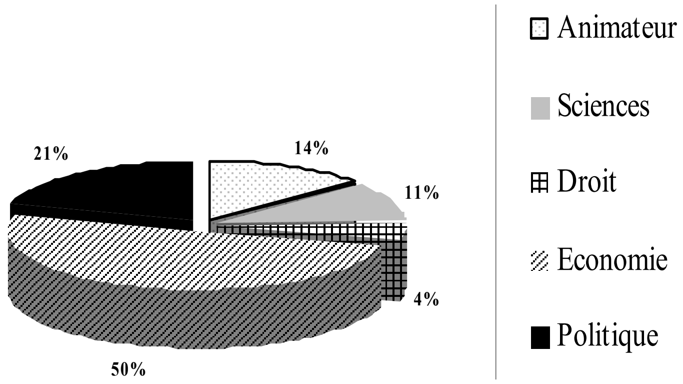


Figure 2. Distribution of different disciplines in the debate

***The concepts dealt with in the different disciplines***

Many themes were dealt with (Table 1) without being expressed in a scientific way. For instance, concepts of 'irreversibility' in science or 'dependency' in economics were discussed without the precise terms being used. Some themes were of course dealt with superficially and would need more investigation or complementary explanations

As far as economics is concerned, many concepts were discussed but essentially company economics and developing countries. Concerning companies, it was possible to see students identifying with two types of players: farmers (the debate took place in an agricultural high school) and consumers as opposed to companies or distributors. The positions defended were often simplistic (one has to choose between food and leisure, fair trade is a short circuit) or based on an antagonistic system (poor countries / rich countries ; farmers / companies ; distributors / consumers) which simplifies interactions between players: *'the big farmers are all into GMOs'* (Guillaume – 517). Concerning exchanges with developing countries, fairly strong stands were taken in favor of a fairer distribution of wealth: *'this will lead to more poor countries which are even poorer'* (Jacques – 108), *'and moreover, they don't benefit from their exports'* (Martin – 211) *'it's quite crazy'* (Mathias 159).

We have used the word 'political' to mean the organization of society and rules which govern the world and not in the sense of exercising power. Politics was referred to critically to improve the functioning of the system. Without naming or explaining them clearly, the students' discourse or the concepts used all referred to principles of justice and fairness and the question of citizens being informed: *'they have hidden GMO problems from us'* (Mathias - 135) *'people must be informed'* (Mélodie - 283) *'if only the information were reliable'* (Mathias – 436).

Table 1. Themes from disciplines dealt with during the debate

| Science | Law | Economics | Politics |
|---|---|---|---|
| Human health<br>Acquisition of resistance<br>Water resources<br>Irreversibility<br>Risks and uncertainty | Possibility of patenting living organisms<br>Labeling | Assistance to developing countries and dependency<br>Development<br>Training and development<br>Transfer and Innovation<br>Specialization / exportation / food production / monoculture<br>Exportation / competition<br>Fair trade<br>Consumption<br>Companies' strategies | Information<br>Citizenship<br>Democracy and profit<br>Roles of the state<br>Ethics<br>Profit and mutual aid<br>Poverty |

***The students' sensitivity to themes differed***

The scientific themes were mostly dealt with by two students: Mathias and Jacques, Jacques did not say much but was generally the one who introduced the theme by an illustration which was then developed by Mathias. Jacques obviously had more difficulty expressing himself. Mélodie and Martin, two students, who spoke a lot, did not say anything about the scientific themes.

Concerning politics, Mélodie had strong opinions and used very vivid vocabulary: revolution, people, strike, capitalism. To all intents and purposes, Guillaume, Christophe and Nicolas only got involved during the political debate and then to express support for various demands but in a disillusioned way or at least in a way that expressed their powerlessness faced with an all-powerful State: '*we won't be remaking the world !*' (Christophe – 397) '*you can demonstrate as much as you like and then they do what they want…*' (Jacques).

**Quotations extracted from the articles provided**

Half of the students who had participated in the experimental group based their arguments on extracts from the articles provided. For instance, Jacques declared: '*here is the part about lauric acid* (he checked in the article) *which has been found in palm oil and coconuts and which may be put into rape and then the small countries who export palm oil and coconuts will no longer be able to export them because the big countries will no longer need them. But the only problem is that even though it may be good for the big countries not to have to import coconuts and so on, for the producing countries it's their only means of existence, I mean the economy of those countries is generally based on the exportation of products like this and coconuts in some countries is almost the main export crop , it's the major source of income for the country. So they can no longer export because of GMOs and this will mean they will be in an even worse position than they are now*'.

Fictitious quotations about 'ideal types', used as arguments
To lend weight to their arguments, they relied on pseudo evidence of fictitious people corresponding to ideal types. For instance, Mathias argued: *'when the GMOs arrive that's great and we are told: 'we'll sell you GMOs' but who is asking for this? I have never heard a farmer who said 'I want GMOs'. They are made available to him, he is told how advantageous they are and how he will earn money by growing GMOs, so he says 'OK, I'm gonna try it'. But in the beginning, the idea for GMOs did not come from farmers, it came from biochemical industries and…'*

Alternatives proposed
Students proposed two alternatives to GMOs for developing countries:
- contextualizing training for farmers from developing countries. For instance, Elodie said: *'the best solution for them to get enough to eat would be to train them to cultivate their land along with their ecosystems so that they learn how to do it in spite of the drought and the rest'.*
- develop fair trade. For instance Mathias suggested: *'there are other things but there are little things which have been done, it's not much but things such as fair trade, things like that, ways that are tried out by a smaller minority striving towards something that is fairer and more just'.*

Questions without answers highlighting risks and uncertainty
*'Will we really be able to use GMOs without any problems? Do we know the problems that they might cause in the long term?…I have the feeling that there are many questions to which there are no clear and precise answers and that they nevertheless have to be answered before getting into something… that we don't really know anything about'.*

*Questions leading to negative answers backing up arguments*
The purpose of these questions is to orient the later discourse of the protagonists. It is a form of argumentation in language which Ducrot is fond of. For instance, *'but won't they make mistakes? will they set up all the necessary procedures so that no risks are taken?'.*

The conflict between agronomic and economic interest
*'If the countries are guided, it might work, for instance in an article they talk about cotton which would resist insects in India… if for instance it was correctly explained to them, that it would be advantageous because they wouldn't have to use so much insecticide, the cotton could develop and so on, but we'd have to see whether afterwards… because with these new genes perhaps other countries would produce them and they would lose the monopoly on the market with fewer profits and so on. That might lead to the poor countries being even poorer'* is what Jacques wondered.

All forms of modalization were used
Linking of cause and effect to identify a vicious circle assumed to be inexorable is known as logical modalizations: '*Well there are several problems, OK if it does resist drought, that's good because in general these countries…, in these countries there is a lack of water for irrigation,* ***but afterwards*** *there are many problems which will follow. Will these plants be*

*able to resist rodents, disease and so on? It's not sure.* ***So*** *we will have to introduce other GMOs which will cost even more but which resist disease, rodents,* ***and obviously*** *that costs something* ***and obviously we'll have to****, even if at the beginning we help them to pay for it, we give them…it's a little bit like a system where at the beginning you introduce this technique to help them* ***but afterwards and when they are no longer able to do without it,*** *they will be caught in the trap and we'll tell them 'yes now you have to pay for the technique' and they won't be able to pay and the debt of the third world will get even bigger and will continue in this vicious circle in which we have been since…*

In the following extract, Jacques used logical, pragmatic and appreciative modalizations:

| | |
|---|---|
| *But the thing is that it's perhaps good that for these big countries,* ***it's good because they*** *won't have to import coconuts and so on,* ***but*** *the producing countries,* ***it's almost their only means of existence****, I mean the economy of those countries is generally based on the exportation of products like that* ***and finally,*** *for some countries coconuts are practically the major export, the major source of wealth for the country.* ***So if they are no longer able*** *to export because of GMOs, this* ***will put them in an even worse position*** *than they are in at the current time.* | Logical modalization<br><br>Pragmatic modalization<br><br>Appreciative modalization |

Deontic modalizations were also used ; for instance Mélodie declared: *'but that dates from colonization when the whites arrived there and told them 'OK, that's great, we need that in our country so you're gonna grow that and we'll give you the money' and* ***in the end they were exploited, we've been exploiting them for 400 years even thought there is no longer slavery ; now they're growing it, they're starving and we're getting rich…there you have it…'***

***We give then we sell***

Five students described in this way the strategy they assumed was being used to get farmers to adopt GMOs and to create profits: at the beginning, you give it to them and then you sell it to them.

***Which reproducibility?***

We might wonder whether such a debate can be reproduced. The outside facilitator is no doubt capable of channeling students' expression, but just as a teacher could possibly be more directive or stimulate debate if needed. Students may then experience incitation as an injunction and then produce what they think is expected of them.

Our question as to the reproducibility deals more with the sequence and the themes which are dealt with. The sequence of the debate seems to be strongly marked by the participants who prefer both themes and opinions. Is there a Mathias and a Mélodie in all classes? Furthermore, there appears to be a relative consensus in this group as to the positions defended, whether concerning farmers' interests (as opposed to that of companies) or those of developing countries. What would have happened if we had focused on contradictory opinions?

*What use can be made of the debate?*

One may imagine that it would be possible to take up some conceptual notions dealt with in a simplistic way if the teacher is able to identify them. In the experimental protocol adopted here, the debate was used to structure knowledge which had been developed with the documents provided. One might thus conceive of the debate as a time for exchanging opinions and that this debate is prepared beforehand by introducing content as in this quasi experimentation and then a post debate programmed ahead of time but whose content would be determined by the concepts raised during the debate but which need to be specified. This complementary work on specifying or reformulating would appear on the one hand to be difficult to do during the debate, requiring the teacher to lead and not to specify content and on the other hand would risk inhibiting students' discussion.

*The role of the teacher leading the debate*

It may be difficult for the teacher to remain neutral and to adopt an attitude of respectfulness towards antagonistic opinions. He has to stimulate the argument by throwing out ideas, reformulating them and asking relevant questions. A teacher who is not familiar with debating situations may end up inhibiting students' arguments ; this can be seen for instance through a few expressions such as the 'OK' which stops the argument and the 'alright' which opens it on the other hand. In the first case, the intonation drops, in the second it rises.

## 6. Conclusion

While it appears that interdiscursive analysis conducted with students on conflicting texts does affect the quality of the students' written argumentation, oral argumentation is influenced more by social factors (students' political commitment, the position of the leader in the class). Students in difficulty appear not to dare participate in oral argumentation.

Training students to argue by means of interdiscursive analysis of texts with conflicting points of view does give promising results. Of course, we should be cautious and not generalize from a case study. Such a case study should be considered to be a first approach to the problem, given the limitation of external validity that a study like this one has. We should improve the way we train students to argue. We might imagine organizing debates in sub-groups to get students to speak more efficiently. We might prepare the oral argumentation by comparing written arguments developed individually by students. After having written down their arguments, each would then read it out to a sub-group of four students for instance.

Not all science teachers feel that they are capable of conducting this type of analysis with their students. Should we consider training them to do this or should we develop interdisciplinary sequences with teachers of literature or philosophy?

Science teachers sometimes hide behind a description of confirmed scientific facts. The trend then is to 'cool down' the controversial issues, to reduce the 'risk of teaching' and in so doing to diminish the meaning for the students. In this respect, Legardez thinks that we should on the contrary be able to manage this risk and be able to use controversial issues as a classroom tool. The complementarity between interdiscursive analysis of conflicting positions and a debating situation is a way of facing the risk

Another problem is training teachers to lead debating situations. As we have seen, this involves managing emotions which always come into play in potentially conflicting argumentation situations and hence being careful not to stop students from arguing. When training teachers, either using heteroscopy or autoscopy, it is possible to analyze recordings of debating situations, in other words, recordings of debates conducted by other teachers or by themselves in order to enable them to identify clues for closing debates, the reformulating they do while betraying students' ideas, etc.

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# REACHING CONSENSUS THROUGH ADVERSARIAL DISCOURSE: PEERS' ARGUMENTATIVE ACTIVITY ON PREDICTING EXPERIMENTAL OUTCOMES IN THE CONTEXT OF GENETIC ENGINEERING

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## Abstract

This study aims at highlighting the argumentative activity of one small group of 2nd- year biology students, collaborating on a task of making predictions about the outcomes of bacterial transformation as a gene-cloning step. Our focus here is set on the use of *argument* in peers' attempt to resolve the adversarial predictions about the luck of the recombinant plasmid vectors when mixed with the bacterial hosts. Thus, this paper is particularly concerned with peers' argumentative strategies towards reaching consensus, as well as with the underlying cognitive processes and epistemic operations in which peers are involved in the context of these strategies. The analysis of peers' discourse identifies the *argument from counterfactual consequences,* a pattern shaped through the process of *categorization* with the contribution of epistemic tools such as *appealing to domain knowledge, analogy, real facts* and *commitment to consistency.* Moreover, it is shown that the critical response to this pattern involves the reverse process of *particularization* through epistemic operations such as *appealing to peculiarities* and *domain knowledge, or defining.* Finally, some educational implications in regard with peers' argumentative reasoning are discussed.

## 1. Introduction

Students' discursive activity in various educational settings has recently become a central theme in science education research (Mason, 1996; Duschl et al., 1999; Lewis and Leach, 2000; Diaz de Bustamente et al., 2000; Jimenez & Pereiro, 2002; Simonneaux 2000; Osborne et al., 2001). In fact, a continuously growing body of studies - grounded on a social constructivist perspective of learning (Vygotsky, 1978) - attempts to shed light on the use of argument as a tool of constructing meaning in science classrooms and to subsequently inform the development of more effective learning environments (Driver et al., 2000). Thus, emphasis is placed on exploring a number of related issues like the structural elements and conceptual content of the argument, the warranting strategies and the underlying cognitive processes, the social distribution of the argument among peers or the discursive resources mobilized in peer-groups (Pontecorvo & Girardet, 1993; Resnick et al., 1993; Roth, 1995; Kelly et al., 1998; Kumpulainen & Mutanen, 1999, Desautels & Larochelle, 1999).

Attempting to build on this line of research work, we first developed a nine-task didactic sequence of genetic engineering (Ergazaki et al., in press) in the theoretical framework of *situated-learning* (Brown et al., 1989). Subsequently we explored several aspects of 2nd-year biology students' discursive activity, while collaborating in small groups to produce joint answers to each task of the developed sequence (Ergazaki & Zogza, 2003a; Ergazaki & Zogza, 2003b). In this paper, we present the adversarial discourse of one peer-group on a task of making predictions about the outcomes of bacterial transformation and we are particularly concerned with the use of *argument* towards reaching consensus.

## 2. Theoretical framework and objectives of the study

### 2.1- Theoretical framework

Our study theoretically draws on the Vygotskian model of *social constructivism,* which stresses the social and situated nature of learning by considering knowledge construction as both an inter-personal and intra-personal process taking place in social settings (Vygotsky, 1978). Social interaction is also the key element of the closely related theory of *situated-learning* (Brown et al., 1989), which emphasizes the notion of learners' 'apprenticeship' in 'authentic', in other words 'meaningful & purposeful', domain activity.

Given the central role of argumentative practices within the scientific enterprise (Driver et al., 2000), as well as the conceptualization of scientific thinking as argument (Kuhn, 1993), apprenticeship in scientific culture includes apprenticeship in scientific discourse. In other words, apprenticeship in constructing, warranting and negotiating scientific claims through arguments.

Argumentation may have three different forms, which specifically are the analytical, dialectical and rhetorical (Van Eemeren et al., 1996). Grounded in the domain of formal logic, the analytical argument consists of a set of premises leading to a conclusion either inductively or deductively. On the contrary, being part of the informal logic, the dialectical argument is constructed during inter-personal critical discussion, as well as during the dialogue of oneself with the *'generalized other'* (Pontecorvo & Girardet, 1993). This form of argument is constructed with premises that are not evidently true; thus, it is based on presumptive reasoning (Walton, 1996). Finally, the rhetorical argument is the one that aims at persuading an audience -for example a science classroom- without putting much emphasis on the adequacy of the so-called 'evidence'.

The argumentative practices within the scientific enterprise may involve argumentation of all the three forms, but they are primarily based on the dialectical argument (Latour & Woolgar, 1979). Thus, although the analytic argument may be a tool towards objectivity and the rhetorical argument a persuasive device towards the public understanding and acceptance of modern scientific applications (Jimenez et al., 2000), the dialectical argument is the one that actually frames the construction and communication of scientific knowledge. Being scientists' 'authentic' tool, the dialectical argument has a significant role to play in the learning process.

### 2.2- Objectives of the study

The work presented here is part of a research project on the development of a student-centered teaching approach aiming at the promotion and study of students' scientific reasoning and discourse in the context of genetic engineering. Focusing on one task of the developed didactic sequence that requires predictions about the luck of the recombinant plasmid vectors when mixed with bacterial hosts, the present work is particularly concerned with the dialectical argument in peers' adversarial discourse.

The research question addressed in this paper is *'How do collaborating students construct their arguments when attempting to resolve the adversarial predictions about the outcomes of bacterial transformation as a gene-cloning step'.* More specifically, *'which argumentative strategies do they employ'*, '*which cognitive processes do they activate when shaping and also rebutting these strategies'* and *'which epistemic tools do they use when carrying out these processes'.*

Thus, the objective of this paper is to highlight the construction of arguments in peers' discourse by identifying the argumentative strategies and exploring their cognitive and epistemic features.

## 3. Methods

### 3.1-The task & the setting

A didactic sequence on the basics of genetic engineering addressed to biology students attending the subject of Molecular Biology in the University of Patras was developed upon aspects of the *situated-learning* theory, aiming at providing students with a context of practicing scientific reasoning and discourse.

More specifically, 2$^{nd}$-year biology students of the University of Patras were supposed to collaboratively participate in a hypothetical drug-designing project with the mission of cloning a plant gene responsible for the synthesis of a protein potentially useful as an anti-cancer drug. The overall cloning-mission to be completed was segmented to nine partial tasks. These tasks require experimental choices about restriction enzymes and cloning vectors, predictions in regard with bacterial transformation, proposals of gene-locating treatments and finally stating and testing hypotheses for the failure of the cloned plant gene in synthesizing its coded protein into the bacterial host cells.

The peer-group discussion presented in this paper concerns the task of making predictions about the luck of possibly recombinant plasmid vectors when mixed with their bacterial hosts. Being embedded in peers' hypothetical mission of cloning a medically useful gene, the study of the effectiveness of bacterial transformation is possible to become *meaningful* and *purposeful* to them, since it functions as a prerequisite for the ultimate accomplishment of their mission.

In regard with the classroom setting, it is noted that it was student-centered. More specifically, students collaborated in small groups to create joint answers without having been assigned pre-defined roles, while the teacher's contribution was restricted in introducing the study-subject, giving hints to facilitate peers if necessary and conducting the whole class discussion that followed the of group work.

### 3.2- An overview of the analytic procedure

The peer group discussion which was produced by a three-girl group was tape-recorded, transcribed and segmented to *message units*, each expressing a single idea in possibly more than one linguistic clauses (Kelly et al., 1998; Mason, 1996). The next step was to locate those sequences of *message units* that function as *premises* towards a specific *conclusion* about the outcomes of bacterial transformation. In other words, to identify peers' *arguments* (Voss & Means, 1991; Resnick et al., 1993) *for* or *against* specific predictions regarding the luck of the recombinant plasmid vectors when mixed with the bacterial hosts.

After identifying the task-answering arguments in peers' discourse, we looked for the possibly underlying argumentative patterns. In other words, we attempted to figure out if peers activated any generic argumentative strategies, which apart from giving rise to the specific arguments could equally be applied as argumentative templates in totally different contexts.

Walton's argumentation schemes for presumptive reasoning (1996), as well as the typology proposed in Perelman & Olbrechts-Tyteca's new rhetoric (Van Eemeren et al., 1996) provided us with an analytic framework to start with. In addition, Billig's approach to the cognitive processes of *categorization* and *particularization* (1996), as well as Pontecorvo & Girardet's (1993), Mason's (1996) and Jimenez et al.'s (2000) approach to the episemic tools employed in the construction of arguments within different domains, were taken into account for the analysis of peers' argumentative activity.

## 4. Results

### 4.1- An overview of peers' discourse

At the outset of the discourse, Elsa (*E*) seems to recognize bacterial transformation as a problematic step in the gene-cloning process. Thus, appealing to the cell wall as a barrier to the entrance of plasmids into the bacterial cells, she claims that the recombinant plasmid vectors will *not* find their way in the bacterial hosts.

Vasso *(V)* on the other hand, instead of being concerned with the adequacy of the 'cell wall-barrier' argument, she stands for an *a priori* rejection of the arguments' claim, based on the very existence of genetic engineering. In other words, she points out the *fact* that genetic engineering is *indeed* performed in biotechnology labs, as sufficient for proving the 'no-entrance'-prediction to be false: 'plasmids cannot fail entering the bacterial cells, since performing genetic engineering is a known fact'.

Despite the plausibility of *V*'s argument, *E* responds rather critically by appealing to the essential nature of genetic engineering, in other words by recognizing it as a human-driven technology. According to *E*, the cell wall may be a considerable barrier to plasmids but cannot really 'resist' the 'inventive mind': 'plasmids' entrance into bacterial cells may be artificially facilitated by researchers, since genetic engineering is indeed a human practice'.

After failing to undermine the 'no-entrance'-prediction due to *E*'s successful response, *V* proceeds with doubting the blocking function of the cell wall. In particular, *V* appeals to the *fact* that food molecules *do* enter the bacterial cells, as sufficient for undermining the 'cell wall-barrier' argument: 'the cell wall cannot be a blocking barrier for entering substances, since the entrance of food molecules in bacterial cells is a known fact'.

*E* responds once more by attempting to differentiate between the entrance of plasmids and that of food molecules: 'food molecules undergo a totally different treatment compared to plasmids once they get into bacterial cells; so, they also have to find their way-in differently; plasmids cannot follow the same 'entrance-path' as food molecules, because they would similarly end up fragmented by enzymes within the bacterial lysosomes; thus, the cell wall may very well be a blocking barrier for plasmids, without necessarily interfering with the entrance of food molecules as well'.

*E*'s critical response seems to be successful in persuading *V* that her counter-arguments are not sufficient for undermining neither the claim for 'no-entrance', nor the argument *for* it. So, the peer-group commonly accepts the 'cell-wall barrier'- argument and consequently recognizes that inserting the recombinant plasmid vectors into the bacterial cells that will provide for their replication is indeed a problem that needs to be solved. Beginning to explore it, peers come up with the 'Troijan Horse'- like idea of using phages as vehicles for plasmids' transport into the bacterial cells. In other words, they suggest a *'vector-in-vector'* system as a solution to the bacterial transformation problem.

#### 4.2- The findings from the analysis of peers' argumentative activity

As already shown, the 'cell wall-barrier'- argument is the central point of reference in peers' argumentative activity, since it is the one that causes all the adversarial exchanges among them. Being single-premise, the argument in question is structured as follows:
- *Claim*: plasmids cannot enter bacterial cells
- *Warranting premise*: because bacterial cells have a cell wall

It is clear that the *claim* (or *conclusion*) is directly supported by explicitly invoked domain-knowledge. Put forward in support of the 'no-entrance'- prediction, this 'argument from knowledge' becomes commonly accepted in the peer-group only after going through two successfully rebutted attacks (Figure 1).

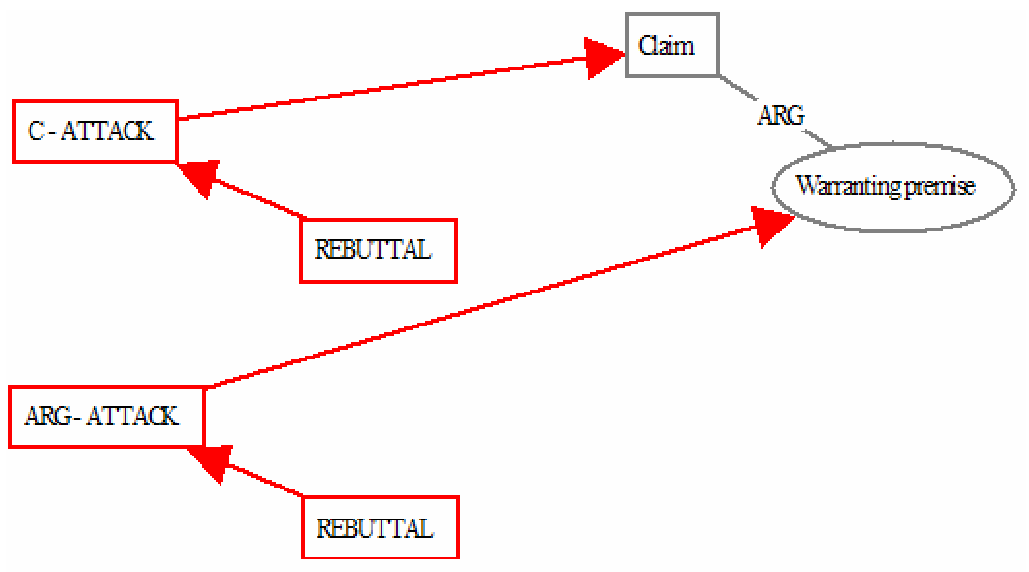


Figure 1. A schematical representation of peers' argumentative activity

But how exactly do peers organize the two attacks against the central argument, as well as the subsequent rebuttals? In other words, *which* arguments do they activate to oppose the central argument and *which* to critically respond to the raised oppositions? And furthermore, do they follow any patterns when constructing these specific arguments?

The first attack is particularly concerned with the *claim* of the central argument and consists of two *premises* in support of the opposing *conclusion*:

- *Premise I*: If the *claim* is true, then it is *not* possible for genetic engineering to exist
- *Premise II*: But we know *for a fact* that genetic engineering exists
- *Conclusion*: Therefore, the *claim* has to be rejected

The three-step pattern that underlies the claim-attack consists of:
- Stating an equivalent of the attacked claim
- Pointing out the equivalent's inconsistency with the reality as we know it and finally
- Transferring this unacceptable inconsistency from the equivalent to the claim itself

Drawing upon Walton's argumentation schemes for presumptive reasoning (1996) and particularly the *argument from consequences*, as well as the *counterfactual device* as reported by Pontecorvo & Girardet peers' arguing and reasoning in historical topics (1993), we come up with identifying this strategy as *argument from counterfactual consequences.* Since a counterfactual consequence arising from *any* claim can be used to undermine the claim's plausibility, the *argument from counterfactual consequences* is indeed transferable to many different contexts. And this is because accepting *any* claim that bears counterfactual consequences or implications can be regarded as standing against what is held to be reasonable.

It is also worth noticing that employing this argumentative pattern actually requires to be engaged in the cognitive process of *categorization* (Billig, 1996). The claim under attack is *categorized* as 'unreasonable' on the basis of its -to use Perelman & Olbrects-Tyteca's words- *association* with something that *does* belong to the *category* 'unreasonable' since it is inconsistent with the real facts. Peers establish this crucial association here by *appealing* -although not explicitly- *to domain-knowledge*. It is clear that stating the equivalent of the attacked claim in *premise I* wouldn't be possible if it wasn't for the implicit application of the background knowledge that genetic engineering actually depends on bacterial cells.

Since this is *not* the only way for an association to be established, the first step of the *argument from counterfactual consequences* is not necessarily linked with the epistemic operation of *appealing to domain-knowledge*. On the contrary, it is worth-noticing that the two remaining steps are rather conservative in regard with their epistemic profile. Pointing out the inconsistency of the claim's equivalent with the reality always involves *appealing to real facts,* while transferring the inconsistency from the claim's equivalent to the claim itself is possible only upon the epistemic criterion of *commitment to consistency.*

**Rebutting** this claim-attack is accomplished on the basis of a third argument that consists of two *premises* and the rebutting *conclusion*:
- *Premise I*: Accepting the *claim* as true, does not necessarily imply that it is impossible for genetic engineering to exist
- *Premise II*: Genetic engineering is a *human-driven* technology
- *Conclusion*: Therefore, the *claim* still remains intact

It is worth-noticing that the rebuttal is particularly concerned with the first step of the claim-attack, which actually has the key role in the overall process of *categorization.* Breaking the *association* between the attacked claim and what had previously been considered as its counterfactual equivalent, automatically removes the attacked claim from the *category* 'unreasonable' and thus permits the re-negotiation of its validity. This is how the reverse process of *particularization* is carried out in order to give rise to peers' critical response.

But what it really takes to *dissociate* the attacked claim from its equivalent? Peers break the established equivalency by *appealing to the peculiar nature* of genetic engineering, thus by *defining* genetic engineering as a controlled human intervention. It is worth noticing that since the process of *dissociation* is rather context-bound, the inherent operation of *appealing to peculiarities* may be combined with complementary operations such as the just traced *definition* or for example the *appealing to domain knowledge* operation that is identified later in the rebuttal of the argument-attack.

**The second attack** is directed to the central argument as a whole and -similarly to the first one- consists of two *premises* in support of one opposing *conclusion*:
- *Premise I*: If the *argument* is valid, then entering bacteria must be problematic for food molecules, too.
- *Premise II*: But we know *for a fact* that food molecules do enter the bacterial cells

- *Conclusion*: Therefore, the *argument* has to be rejected

Peers seem to employ the *argument from counterfactual consequences* once more, since they are similarly engaged in all the three steps identified earlier. The epistemic operations of *appealing to real facts* and showing *commitment to consistency* are present again in the last two steps as expected, while it is worth noticing the differentiation in regard with the way that the *association* is carried out in the first step. So, how do peers establish this time the key link between the argument under attack and a counterfactual derivative that will actually withdraw the former from the *'argumentative business'* (to borrow from Billig) after the process of *categorization* will be completed?

Peers try to apply the 'cell-wall barrier'- argument that was specifically constructed to predict what happens with the entrance of plasmids into the bacterial cells, in order to similarly predict what happens with the entrance of food molecules. The epistemic tool activated at this point is *appealing to analogy,* something that actually implies *appealing to similarities*, albeit implicitly. Since the analogy on the basis of the argument under attack leads to a counterfactual prediction, the argument is considered to be associated with something within the 'unreasonable'-category and in consequence it is classified in this category itself.

The response to the argument-attack comes with a three-premise argumentative structure concluding in support of the attacked argument:

- *Premise I*: Accepting the argument as valid, does not necessarily imply that food molecules cannot enter the bacterial cells as well
- *Premise II*: Food molecules use a *particular* 'entrance-path' and once inserted into the bacterial cells, they undergo a *particular* treatment to accomplish their *particular* role for the cells' survival
- *Premise III*: Plasmids could *not* use the same 'entrance-path' and subsequently undergo the same treatment, because this would be *inconsistent* with their own *particular* role for the cells' survival
- *Conclusion*: Therefore, the *argument* still remains intact

Peers seem to engage once more in the process of *particularization* by attempting to *dissociate* the attacked argument from its counterfactual derivative, since breaking the association means that the argument will no longer be *categorized* as 'unreasonable' But how? *Premises II & III* point out that the application of the attacked argument for making predictions in a different context (namely that of food-entrance) than the one in which it was constructed (namely that of plasmids-entrance) shouldn't take place in the first place, since the different features of the two contexts overcome the shared ones and thus become limiting. The epistemic tool primarily involved is *appealing to peculiarities* than concern the entrance of food molecules into the bacterial cells compared to the one of plasmids, but it is worth-noticing that this actually requires *appealing to domain knowledge.* In other words, differentiating between plasmids and food wouldn't be possible without the now explicit application of knowledge from the domain cell biology.

## 5. Discussion

Our analysis indicates that peers, being engaged in an adversarial interaction, produced a highly argumentative discussion to accomplish their collaborative goal of making a joint prediction in regard with the outcomes of bacterial transformation in the gene-cloning process.
Peers managed to predict the luck of the recombinant plasmid vectors when mixed with the bacterial hosts by invoking -either explicitly or implicitly- background knowledge in regard with certain aspects of the bacterial cell-biology as well as with both the process *and* the essential nature of gene cloning. The conceptual difficulties encountered by peers and the implications that possibly arise in regard with teaching concepts such as the ones of 'cell wall', '*in-and-out'* of cells, 'bacterial transformation' and finally 'cloning vector' are to discussed elsewhere.

Generating knowledge-based argumentative structures in a group discussion to come up with an explanation is clearly more demanding for peers than reproducing ready-made statements in a typical teacher-led 'triadic dialogue' (Lemke, 1990). Given that the produced explanation needs to be not only plausible but also commonly accepted in the peer-group, the role of argumentation in peers' discourse becomes two - fold. Peers need to construct their arguments both as reasoning *and* persuasive tools, as it is quite clear in their adversarial exchanges towards one shared plausible prediction.

But does the aim of persuading the peer-group possibly undermine the quality of the argumentative reasoning? In other words, does the attempt to make an agreement in favor of *one* prediction, possibly shift the argument from the *dialectical* to the *rhetorical* mode? Peers' critical responses to a powerful argumentative pattern such as the *argument from counterfactual consequences* actually show that this is not the case. Although backed by something as 'universal' as the proving power of real facts, this argumentative pattern appears to be vulnerable in the light of knowledge resources that permit the activation of specific epistemic tools to be used in key cognitive processes. It is worth-noticing that what peers actually doubt is *not* the *categorization* of something as 'unreasonable' due to its *association* with something counterfactual, but the way this crucial association is processed. Thus, applying declarative knowledge that in our case regards genetic engineering seems to be inadequate for a valid association if not complemented by considerations of the peculiar nature of genetic engineering as a human practice. Similarly, making an analogy that in our case regards plasmids and food molecules may also lead to an invalid association if similarities and differences are not comparatively evaluated.

Finally, it is worth mentioning that a purposeful teaching goal might be to support peers not only in recognizing the need for *well-established* associations within the categorization process that underlies their argumentative strategy, but also in understanding what is actually required for such associations. A fruitful basis for improving peers' reasoning and argumentative skills could probably be constructed in the context of a *'meta'* - approach of the identified argumentative pattern; in other words, in an educational setting where the pattern employed by peers during *'arguing to learn',* would be subjected to close scrutiny and subsequently into practice in quite different contexts with the aim of *'learning to argue'*.

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# USE OF KNOWLEDGE AND MEANING CONSTRUCTION ABOUT CELL BIOLOGY IN COLLABORATIVE PROBLEM SOLVING IN THE LABORATORY

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## Abstract

This paper discusses the use of knowledge about cell biology while solving a problem in the laboratory to identify an unknown biological sample. The study is framed in the situated cognition perspective. The research questions explore a) which concepts and images about the cell are mobilised to solve the problem, b) how meaning is constructed both for concepts and observations, and c) how this conceptual knowledge is articulated with processes and skills related to work with microscope. The participants are two small groups of Student Teachers. The methodology involved recording the students in audio and video, and collecting their productions. Discourse analysis techniques were employed. The results show that students retrieve from previous knowledge a wide range of cell biology concepts relevant for the identification of the sample. The processes of meaning making for concepts show how students establish connections among the concepts and the context of work with microscope. The articulation of conceptual knowledge about cells and tissues and procedural knowledge is explored; the paths for constructing meaning for the technical terms in the handout through the decisions and actions, coupled with collaborative interpretation and reinterpretation of observations are discussed. Implications for work in the biology laboratory are outlined.

## 1. Use of knowledge and meaning construction in science and in the laboratory: rationale and objectives of the study

The interaction or articulation among theory knowledge, ideas or expectations on the one hand, and procedures or skills related to work with microscope has been a concern for biology educators for decades. More than thirty years ago, Medawar wrote:

> " '*Why can't you draw what you see?' is the immemorial cry of the teacher to the student looking down the microscope for the first time at some quite unfamiliar preparation he is called upon to draw. The teacher has forgotten, and the student himself will soon forget, that what he sees conveys no information until he knows beforehand the kind of thing he is expected to see.*" (Medawar, quoted in Lucas, 1969)

This paper discusses data from a wider study about problem solving in the context of practical work with microscope in the biology laboratory. The study collected data both in conventional laboratory sessions where students were asked to mount a preparation and to draw a known sample, as onion skin, and in problem-solving contexts, where they were asked to identify an unknown biological sample, as described in Jiménez, Díaz & Duschl (1999), being these problem-solving tasks the subject of this paper.

The processes of meaning making in the classroom are receiving increasing attention from educational research. There is a growing consensus about these processes, assuming that meaning is *constructed* or made by the participants (Lemke, 1990), rather than being an appropriation of a pre-existing meaning that would be 'built-in' in words. For Lemke, meanings are created through connections established among things and their context, and he calls *contextualizing practices* this type of semiotic (or meaning-making) processes: members of a community perform actions meaningful in the community, and "*the meaning we make for an action or event consists of the relations we construct between it and its contexts*". We believe that contextualizing practices are a powerful construct to explore learning in the laboratory (and in the classroom), and have used it to document meaning construction of chemistry concepts (Jiménez et al., 2005).

Mortimer & Scott (2003), in a book devoted to meaning making, conceptualize teaching as introducing the learner to the social language of school science: school science has a distinctive pattern of language, a speech genre, in Bakhtin's terms, and students must, not only recognize it, but also learn to participate in it, to use it. For Mortimer & Scott understanding requires that the students engage in some form of *dialogic activity*. Learning science involves both knowledge construction, for instance meaning making, explored in the present paper, and knowledge justification, or argumentative reasoning, discussed in a previous paper (Díaz & Jiménez, 2001) for this microscope task in secondary school. The connections among knowledge construction and justification are summarized in Figure 1.

The perspective of situated cognition views learning as apprenticeship or enculturation in the culture of a particular community (Lave & Wenger, 1991), in our case the scientific practice, and in this perspective an important goal is to reveal the processes of meaning construction for words, concepts and experiences, processes that combine cognitive and social dimensions. Discussing situated learning and cognitive apprenticeship, Brown, Collins & Duguid, (1989) compare knowledge to a set of tools, which are not fully understood until they are used. Toulmin (1972) expressed a similar idea thirty years ago, saying that we only understand the meaning of concepts when we learn to apply them, what means also to learn the practical procedures involved in its application.

The focus of this paper is on the use of *knowledge about cell biology* in the resolution of the problem posed to the students. The emphasis about practical work is usually either on the skills to be practised, on the procedures, or on introducing students to scientific work (sometimes termed 'scientific method'), and not about conceptual knowledge. But we believe that conceptual and processes learning should be integrated, that laboratory work needs to be related to concepts in order to be meaningful for the students. Integration of different dimensions in an innovative design of instruction is not always easy, for instance Chapman (2001) found that students expressed discomfort when required to apply higher-order thinking skills in the context of a molecular cell biology course, even if the innovation resulted in gains also in content knowledge. In conventional work with microscope, students have little or no need to apply their knowledge about concepts, when for instance they are asked to mount and draw a sample of onion skin or lily epidermis. This may explain why students in the conventional lab sessions in this same study (Díaz, 1999) do not look for help in books or classroom notebooks, while the students performing the problem-solving task did it. The purpose of the present study is to explore the concepts about the cell used by the students while identifying the unknown samples of tissue, in other words, while *interpreting* their observations in the light of theoretical knowledge.

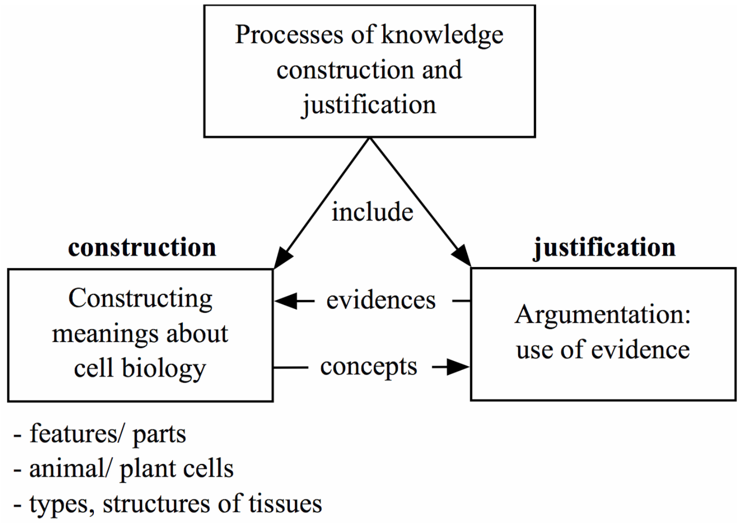


Figure 1. Connection among knowledge construction and justification

It has to be noted that although cell theory is an essential part of biology it has received little attention in the science education literature, since Dreyfuss & Jungwirth (1988, 1989) pioneer study, compared to topics as genetics or ecology. A search in ERIC produced only 33 results for "cell biology". Perhaps one of the reasons could be being considered a topic not so difficult to learn. However, as Chapman (2001) study shows, the distinction among structure and function (understanding the meaning of the cell as functional unit of life) proved to be the most difficult issue in the first year (less than 30 % of correct responses, compared with a mean of 52 %) in examinations including questions about DNA and interpretation of historic experiments. One of the problems in cell teaching is the lack of coherence, and Verhoeff, Waarlo & Boersma (2003) address it with a proposal of a learning and teaching strategy based on systems thinking.

The research questions we explore:
1) Which *concepts and images about the cell* are mobilised by students in order to solve the problem.
2) How *meaning is constructed both for concepts and observations* in the context of practical work. This is connected with the third question, and discussed together.

3) How this *conceptual knowledge is articulated with particular processes and skills* related to work with the microscope.

In their study about the living cell, Dreyfuss & Jungwirth (1988) propose 12 principles or topics grouped under three headings: unity, diversity and continuity. From them, seven relate mainly to cell functions, so we were not expecting students to use them in the task. The other five, or part of them, relevant to the task, are summarized in the left column in Table 1. The right column of the table consists of other statements related to microscopic observation and cell representation through images that, after studying the students' drawings of cells (Díaz & Jiménez, 1998), we consider also to be relevant to the task.

The ideas summarized in table 1 were used as a general frame of reference, rather than an instrument to code the students' dialogue, as discussed below. As the samples were different for each team, there are some points that may be more relevant to one particular sample. For instance, group J's sample was frog testis, which had cells in different phases of division, so the point "cells reproduce by 'division'" had to be used in order to interpret it.

Table 1. Conceptual and procedural knowledge relevant to the task

| Conceptual knowledge (from Dreyfuss & Jungwirth, 1988, modified) | Procedural knowledge (Díaz & Jiménez) |
|---|---|
| - The cell is the basic unit of life<br>- All cells have some basic features such as nucleus, membranes, ribosomes etc.<br>- Different cells perform specific functions; cells 'specialize'<br>- The shape & structure of cells vary widely<br>- Cells reproduce by 'division' | - Some structures and organelles are visible with optic microscope, and other only through electronic microscope<br>- Some features & aspects of tissues are better appreciated with lesser magnifying<br>- The same cells may appear in different shapes & sizes depending on the cut |

## 2. Methods, participants, task and data sources

The participants are two small groups, of 4 students each, of Student Teachers in the 3rd year of the Primary Teacher Certificate (age 20-21) and their teacher (first author). In each of the two groups two students were female and two male, although this balance does not reflect the composition of all teams in the classroom. The students were drawn from a group enrolled in Practical Work in Science, an optional course, and the laboratory sessions, lasting 2 hours, made part of their regular schedule and were taught by their regular teacher. About their experience with the microscope, prior to this problem-solving task they had worked with it, both with onion skin and cheek cells samples, in a more conventional setting.

### 2.1- The task

The problem given to the students was to identify an unknown biological sample, different for each small group and to produce a drawing of it. They worked in groups of four sharing a microscope. The design of the task and its differences with conventional microscope work is discussed in Jiménez, Díaz and Duschl (1999). The handout (Appendix 1) set a scenery for the identification, four 'suspects' were presented: two (a & b) with plant features and two (c & d) with animal features. The samples of the two groups studied here were animal tissues. The hints given in the handout for distinguishing the two choices of animal were the existence of only one cell type or more, the shape more or less irregular, and the distribution in layers. The students were not asked to recognise the tissue, but just to match it with one of the four choices in the handout: to decide whether it was plant or animal tissue and which one of the two options. Nevertheless, most groups tried to name the tissue, recalling names they know.

The two samples (Appendix 2) were osteoblasts in fish operculum for Group E, where the more visible feature are the cavities (sometimes identified as 'cells' by the students) lodging the osteoblasts, whose retracted soma could be observed; 'layers' could also be appreciated. Option d was the expected choice for that sample. Group J had frog testis that, as mentioned above, had cells in different phases of division, from meiotic and stem cells to spermatozoids, so option c could be a choice for it.

### 2.2- Data sources and analysis

Data collection involved recording the conversations and actions of the students in audio and video while completing the task, and collecting their productions. The audiotapes were transcribed and then contrasted with the videotapes, to match the actions with the discussion. The students are identified with pseudonyms respecting the gender and beginning with the same letter in each group.

Discourse analysis techniques were employed both in the analysis of conversation transcriptions, and of the students' actions in the videotapes. Being concepts use the focus of this paper, the students' dialogue constitutes the most relevant data. The analysis involved the elaboration of an inventory of concepts about cell biology, although most categories for the analysis emerged in interaction with the data, as discussed in the results section. Given the different nature of the samples, some of the concepts used by the students in their interpretation could be common, but other could be different, specific for each sample.

## 3. Results: use of knowledge about the cell

Two types of content analysis were performed: quantitative and qualitative. First the transcripts of both groups were searched for concepts and terms related to the cell. For the numerical analysis, a list was generated for each group, and then both lists were collapsed, and the concepts grouped under four headings:

1) *General features or parts of the cell*: including references to unspecified 'cell', to a cell (or part of it) assumed to be 'regular', to features like size or shape and to structures and organelles. We included in this first section the references to choices or dichotomies: plant versus animal cell, or similar versus different type of cells, choices that need to be made before completing the identification.
2) *Features or parts of animal cells*: only two references belong to this category, animal cell and the cheek cells as exemplar of it. Although it is a type of animal cell, we have placed 'neurone' (and also 'axon' and 'dendrite') with the tissues, because in the context of the discourse it is used at the same level that references to 'muscles' or 'epithelium'.
3) *Features or parts of plant cells*: besides two references parallel to the ones in the animal cell category, there are other to features of plant cells: wall, stomata or chlorophyll.
4) *Types, structures or features of tissues*: including types of tissues, features as regularities or layers, as well as references to functions such as cell 'division'.

Appendix 3 shows the inventory and number of references in both groups. A reference repeated twice (or more) in the same turn was counted only once. The concepts or terms mentioned because the students were reading the handout (not spontaneously) are not included. The sessions lasted 2 hours, but only the time devoted to solving the task is analyzed.

It can be seen that the number of references is higher for group E than for group J. However, this figures had to be compared to the time and total number of turns in each group. Table 2 summarizes the number of turns, the ones corresponding to students and, from these, what we consider to be substantive turns, that is, dialogue referring to the task, in contrast to utterances categorized as school rules or social interactions (for instance, discussions about turns looking through the microscope), or out of task.

The number of turns is quite different, partly because of the different times (49 compared to 28 minutes) devoted to the task. Part of the difference may also be explained because of several longest utterances of group J, particularly from Julio, but also from the other three students, compared with the short exchanges in group E. Concerning the type of turns, first, it has to be noted that the students are 'on task' most of the time; in group J, there are no 'out of task' exchanges. Considering only the substantive turns and contrasting the cell references against them, it can be seen that the proportion is highest in group J (36.5 %), than in group E (28 %), and that both percentages constitute around one third of the turns. A summary could be that roughly a third of the substantive exchanges included references to cell concepts or terms, and these were slightly higher in group J than in group E, what could be related to the different samples, being the one from group J more complex, with diverse cell types and structures so, although using less time and turns, they spend a greater proportion of time talking about cells and tissues.

Table 2. Cell references compared with the number of turns in each group

| | Group E (49 minutes) | Group J (28 minutes) |
|---|---|---|
| Number of turns | 733 | 445 |
| - Teacher | 36 | 5 |
| - Students | 697 | 440 |
| Substantive | 659 | 435 |
| Social interactions, rules | 23 | 5 |
| Out of task | 15 | - |
| Cell references | 184 | 159 |
| Percentage of turns | 28 % | 36.5 % |

In Appendix 3 concepts and terms mentioned ten or more times have been highlighted. It could be observed that, from the four headings, the higher frequency corresponds to references to tissues (82 and 83) in both groups: *layers* (frequent also in group J) *branching* and *neurone* in E, and *layers*, *new cells formation*, *pattern* ('orchards') and *epithelium*, in J. From these, only the layers could be considered as prompted by handout hints as a feature distinguishing c from d, while the other five were mobilised from previous knowledge in their efforts to make sense of the observations. Other frequent references are general parts or features of the cell, *nucleus* in both groups, choice *animal / plant* in E, both probably prompted by mentions in the handout, and *color* and *limits / membrane* in J which correspond to the students' own elaboration. The mobilisation of knowledge is discussed with instances from the dialogue in the qualitative analysis in next section.

Comparing the references in Appendix 3 with Dreyfuss & Jungwirth topics in the left column of table 1, it can be seen that the students seem to use all of them: basic parts of the cell, specialization and variation in shape & structure, and division; about the first topic, the cell as the basic unit of life, we consider that it was implicitly used because the students employed concepts from cell biology in their interpretation of the samples. The procedural knowledge about microscope in the right column is discussed in the next section.

## 4. Results: construction of meaning through articulation of conceptual and procedural knowledge

The second research question explores the *construction of meaning* both for concepts and observations in the context of laboratory, and it is discussed jointly with the third, which explores how conceptual knowledge is *articulated* with processes and skills related to work with microscope. When talking about meaning *construction*, we intend to emphasize that, rather than apply a theoretical notion to the practical task; students are elaborating the meaning for it through connection, as Lemke (1990) points, of the concept to the particular context of the microscope work. The process of construction in each group is illustrated in this section with fragments from the transcriptions, analyzing the concepts and terms mentioned with higher frequency in the context of the dialogue. In italics, between brackets, commentaries and notes from the video are included. The topics are presented following roughly the order of the students' discussions (although it was not the same in E & J).

*Groups E & J, cell type: animal or plant?, exemplars*

To choose among animal or plant was the first decision the students had to take, and in group E there were 17 references to it, and they begin discussing it.

3 Emilio: Let's see, animal or plant?

4 Emma: I believe that it is a plant

9 Emilio: Well, we took plant cells, Did we? We looked at plant cells trough the microscope

10 Elisa: Yes, here they are

11 Emilio: And, Do you remember how were they?

12 Elisa: From onion.

13 Emma: No, this (*the sample*) is not: Is it plant? The one from onion was not plant?

14 Emilio: Yes, bud! Onion skin and what else? What else did we see?

Emilio (3) begins setting the options, prompted by the handout, and because Emma, without justification, suggests plant, he appeals (9) to previous experience, in a first attempt to connect the concept of 'plant cell' to the microscope context. He asks how they were and Elisa (12) recalls onion as the exemplar of plant cell. Then Emma corrects herself, comparing implicitly the actual sample with the one from onion, and Emilio completes the reference, recalling 'onion *skin*' as the one previously observed. This shows that the use they are making of 'plant cell' is not abstract, but connected to the task.

The students in group J begin attempting to describe the sample, using the orchard analogy discussed below, and this lead them to instances of animal tissues without explicitly choosing animal versus plant:

107 Javier: This is an epithelium

109 Judit: Julio, now here *(reading from handout)* 'Do you see any element inside the structures?'

111 Javier: We see the cytoplasm: Do we? The membrane... These perhaps are the mouth bacteria

112 Jacinta: The nucleus, the folds, the endoplasmic reticule.

116 Julio: What you see is... To me... mouth bacteria. Do you see here a membrane about here that is stuck?

117 Javier: There are things broken and with dashes inside these nuclei.

119 Javier: Don't you see? Black. These black points. The mouth bacteria, perhaps.

They list different cell elements, some seen in the sample (nucleus), and other impossible to see with the optical microscope (as membrane, endoplasmic reticule). Javier (111) appeals to the exemplar of animal cell observed in a previous session, cheek cells, mentioning *mouth bacteria* (probably interpreting chromosomes as the bacteria seen in the cheek cell session), and Julio (116) supports him. Javier (117) describes what are probably the meiotic cells in their sample, relating the 'dashes' and 'black points' to the nuclei observed in the cheek cells. As in E, their use of these concepts is connected to the task.

*Group E, tissue type: neurone, branching, dendrites*

In a few turns, they depart from the handout, trying to interpret their observations;

23 Emilio: This looks like ... like... the dendrites, these things, man!
24 Eloy: How?
25 Emilio: Like dendrites, like the things of... How's the name in the head? Dendrites, neurones. Don't you see that it has things branching out?
32 Elisa: I didn't see any of that.
33 Emilio: Pay attention! Look how they are, down there: Do you see it?
34 Elisa: Wow, girl! Yes, there is one down there that seems kind of neurone. With the ramifications. But in general, no...
37 Emma: And, Why do you set it with so much magnification?
38 Eloy: You see it better.

This is the first time that they compare the sample to a neurone (there were 13 mentions), with dendrites or branching (18 mentions). Although the sample is fish operculum and does not have neurones, it has a resemblance with them, as can be seen in figure 1 (x400). The origin of the knowledge they are recalling is not from practical work, because they didn't saw neurone samples, but probably from images in textbooks. Our interpretation is that Emilio is connecting this knowledge, *neurone*, *dendrite*, until now from the theoretical domain of books, to observation of the sample, and in turn the knowledge helps him to frame the observation as an animal tissue. The students also discuss the magnification that is relevant, because the branching structures are not observed at x40 or x100.

*Groups E & J, Analogies about regular pattern: beehives and orchards*

Stephen Toulmin (1972) called *intellectual ecology* to the opportunities for innovation and concept transformation, defining it as the coexisting ideas together with other features of the social or physical situation. In the conceptual change literature it is known as conceptual ecology, and part of it are the *analogies* used in scientific work to interpret phenomena. For instance, the comparison of the osteoblasts sample to beehives in group E later reformulated as repetitions, or of the duct profiles in frog testis to 'land properties' in J (15 times).

73 Elisa: There are a lot of bee nests
(...)
626 Emilio: The structures are repeated... we believe that they are... Are them the same?
652 Emilio: Yes. We see like ... structures, we see like layers that are (...) of different sizes, but that follow the same canon.
654 Eloy: What a learned vocabulary, man!

When Elisa (73) uses the analogy of bee nests (in Spanish it means the same as beehives), she is probably not aware that Hooke had used the same analogy, also in the description of a sample (bark) that presented cavities, originating the very name of 'cell'. Later (Emilio 626), the interpretation of the regular pattern changes to a more abstract formulation: a repetition of structures, and finally Emilio (652) collapses the observation of regularities in cavities and layers using the term 'canon', that did not appear in the handout and causes the awe of his colleagues.

40 Judit: Javier, come here and see
41 Julio: You can see that it is all structured here
42 Judit: It looks like orchards with different plants.
(...)

92 Julio: It is funny, you can see an external membrane as if it were an estate, and inside little estates. I mean... sure, like land consolidation.
94 Jacinta: You see an external membrane and inside divisions

Julio (41) points to the structures in the sample and Judit (42) uses the analogy of orchards, later extended by Julio (92) to land reorganisation and consolidation, a familiar process for the students, still occurring in their country (Galicia). They will repeat it 15 times. It has to be noted that they call 'membrane' the connective tissue around the ducts, apparently unaware that a cell membrane cannot be seen with the optical microscope. Through this process the students in both groups are constructing new meanings for 'cell' and 'tissue', realizing that one important feature to consider in the identification of tissues is not only the type of cells, but also their disposition, the structures and regularities.

*Groups E & J, layers, stratified epithelium*
A regularity mentioned in the handout, because it was relevant to identify sample d, was the distribution of cells in layers, and it was the term more frequently mentioned. It provides an instance of *articulation* of *conceptual* knowledge about cells and tissues and *procedural* knowledge about how to work with a microscope, as seen in group E when the students are trying to ascertain if the sample could match 'stratified epithelium'.

289 Emilio: The epithelium or epithelial tissue is that of the muscles, of the… ok! Epithelial tissue, that of the skin, the layers there
290 Eloy: But here you can see it well, look! With the lesser magnifying you can see the layers that are there!
291 Emilio: Stratified. I think that … that about the layers, if you use the 40 magnifying power… Yes, you can see it!
292 Eloy: Yes, you see the layers
293 Emilio: And then if you put… the magnification of 400…
294 Emma: There are animals that breath trough the skin!
295 Emilio: Sure, sure! Yes, yes, yes! Sure! It could be a ... a piece of frog skin
297 Emilio: (...) stratified epithelium, from which cells easily fall...

The students appeal to biology knowledge, recalling *skin* as an instance of epithelium (even if they mention 'muscles' first); although to experts this could seem a small step, for them it is important, as enables them to know, as Medawar says, what are they expected to see. Then they realize that some structures in the sample, as layers, are better observed with *smaller* magnification (40X) than with the 400X, which enables greater detail but only of a limited area. The observations are collaboratively interpreted and reinterpreted, in this case by Emilio, Eloy and Emma, to construct the meaning of 'stratified epithelium'. Although this identification is later abandoned, it constitutes a step in the interpretation of the sample. This articulation of conceptual and procedural knowledge, which constitutes an instance of contextualization, of connection among concepts and context in Lemke's (1990) terms, is represented in Figure 2. It is also worth noting the excitement of the students, seen for instance in turn 295, very different from standard microscope sessions, where no real questions are asked.

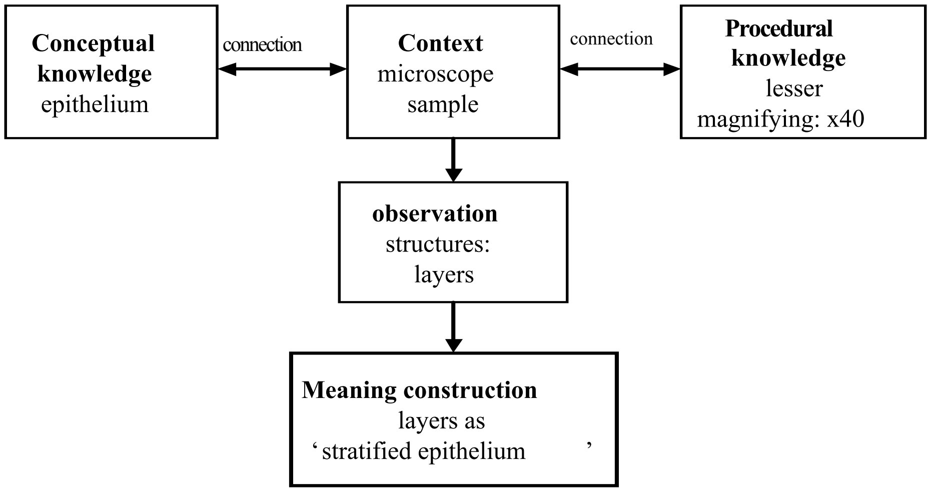


Figure 2. Articulation of conceptual and procedural knowledge in group E

In group J they strive to choose among the two animal options:

143 Jacinta: What do you see?
144 Judit: As... different sorts of thickness. How does it say the sheet? (*handout*)
146 Judit: 'Do you see any element inside the structures?' *(reading from handout)*
147 Jacinta: The foldings (*recalls 'foldings' observed in previous session with cheek cells*)
153 Julio: But the foldings are not the same (*as in cheek cells*)
154 Jacinta: No, the folds... I don't know.
155 Javier: Look at it with the other, the other magnifying.
156 Julio: It does not have more magnifying. It is as far as it goes. The last.
(...)
164 Julio: See!, it is divided into plots. Look! What you were asking before.
165 Javier: it is stratified, isn't?
166 Julio: Divided into plots, yes
167 Javier: Then perhaps is '*d*'
(...)
179 Jacinta: What happens with the structures?
180 Javier: That's it! It is all stratified, man! Is that, an epithelium and you see the cells.

The students are trying to interpret the frog testis sample (which has no 'layers'), and the observed structures (probably connective tissue around the ducts) are described first by Judit (144) as different sorts of thickness, and then interpreted by Jacinta (147) as 'folding', connecting them to their previous experience with cheek cells. Julio (153) contradicts her; in fact, while the individual cheek cells are sometimes partially folded, here the cells are not separated, but connected in a tissue. Javier (155) proposes to augment the magnification, revealing that sometimes they believe that seeing the sample augmented could solve interpretation problems, but they are already using the greatest. Then Julio (164) appeals to the analogy proposed by Judit in turn 42, and Javier (165, 167, 180)) relates this division to layers and to option d. The identification of 'plots' with 'layers' is not justified and will be abandoned later, but this episode shows how they connect the cell knowledge to their microscope experience and how data are interpreted and reinterpreted, and new meanings constructed for the observations in the process.

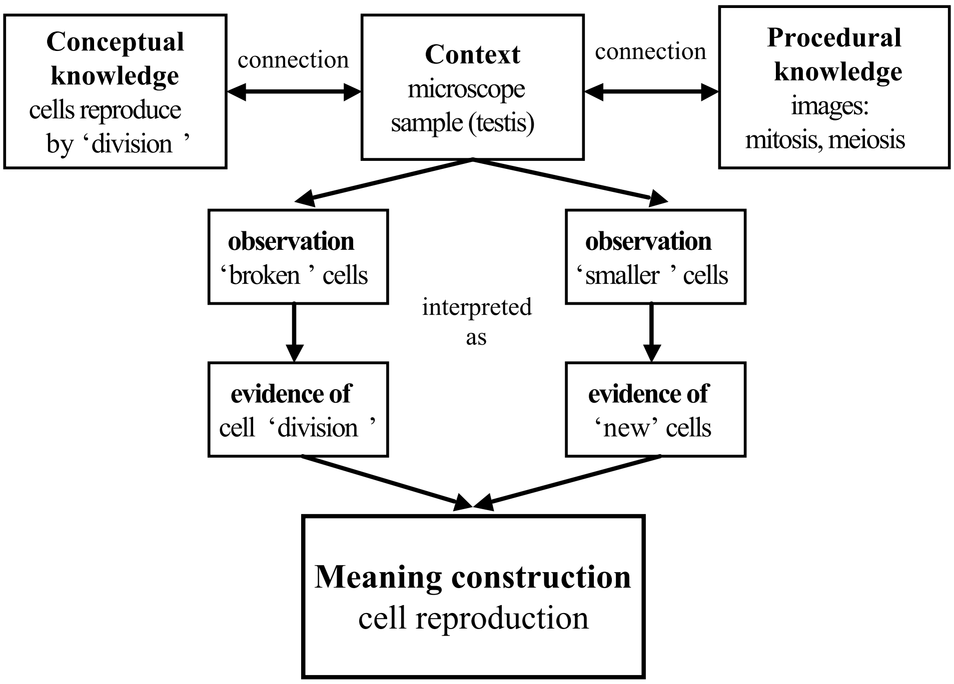


Figure 3. Meaning construction for 'cell reproduction'

*Group J, new cell formation*

While anatomical features are directly observed through the microscope, functional features have to be inferred, requiring an interpretation in the light of conceptual knowledge. An interesting example is the construction of meaning for 'cell division' in group J:

> 223 Julio: Do you know what these black spots could be?
> 224 Javier: What?
> 225 Julio: The formation of new nuclei in the cells. What it says in 'd'
> 227 Julio: (*reading handout*) 'Cells falling out easily'. Could it be that the nucleus is dividing, that's why is so dark? I don't know.
> 231 Judit: What could they be? New forms of…

232 Julio: As if the nucleus was... dividing to form... new cells.
242 Julio: Look down there...there are small cells all white. Just white. And in the middle it seems that one is broken (...)
250 Julio: Down there! Looks as they were new. Because they are even smaller
262 Judit: Yes. These cells are... smaller
267 Javier: It is a regeneration of ... new cells (...)

Meiotic cells can be seen, with x400 in the sample (Appendix 2); they refer through all the session to 'black spots', or 'dashes'. Now Julio, Javier and Judit construct it as nuclei division, relating it implicitly to mitotic or meiotic images, interpreting 'broken cell' (242) as evidence of 'division', and the presence of smaller cells (250) as evidence of them being 'new'. This is an instance of how data are cooperatively interpreted and reinterpreted, contextualizing knowledge, both conceptual, about cell biology, and procedural, in this case mitosis or meiosis images. Rather than application of concepts to the laboratory context, we interpret it as meaning construction for them, summarized in Figure 3 above.

## 5. Meaning construction: discussion and educational implications

The results show that students retrieve from previous knowledge a wide range of concepts related to cell biology relevant for the identification of the sample, for instance cell type (animal cell, plant cell, neurones…), structures and organelles (membrane, nucleus, and other described as folds, layers, etc) tissue type (epithelium, blood…), or cell physiology (division). It has to be noted that the task didn't required the students to name the tissues, but only to match the sample to one of four cases in the handout.

The processes of meaning making for concepts as, for instance, cell reproduction by 'division' show how students establish *connections* among the concepts, the cell images in textbooks and the particular context of work with microscope. These connections are made through appeal to analogies, previous experience with the microscope and disciplinary knowledge. Connecting cell biology knowledge to the task of identification of an unknown sample is an instance of Lemke (1990) contextualization, which for this author is the most important of semiotic, or meaning making practices. The students construct meaning for the cell concepts by building relations between them, e.g. *neurone, dendrites, layers, division*, and the context of the task. Along this process, they make attempts to frame their observations in the *scientific language* of cell biology, which consists not only of concepts and terms, but also of a set of images, and procedural knowledge about the use of the microscope.

We think that meaning for cell concepts is *constructed* along the task, not just applied, that students are now creating a new understanding for these conceptual tools in the process of using them in the interpretation of the sample; tools that, as Brown et al. (1989) say, could not be fully understood before using them. The focus is on interpretation because, in school laboratory as in professional scientific research, we consider data not as given facts or phenomena that have only a single, straightforward meaning, but as something being constructed and reconstructed by participants that could be interpreted in different ways by different people, or even by the same person at different times. This is the case of observed structures in group J's sample, described as layers, folds, thicknesses or land plots and orchards; or of the meiotic cells, first described as 'spots' and 'dashes' and later as cells undergoing division. But the change in interpretation is not simply a matter of time, it requires building connections between different knowledge domains and contexts.

The importance of the articulation among concept and procedural knowledge is evidenced for instance in the awareness of the benefits of smaller magnification for observing structures, or by the difficulties that students show in realizing that membranes are not visible with the optical microscope. The relevance of the familiarity with biological imagery is also demonstrated in the recognition of meiotic cells. This articulation among concepts and procedural knowledge is connected to the path from "raw" to "hard" data, which involves deciding which data –from all the available– should be used, and to other steps in the construction of scientific explanations: finding patterns, or even proposing an explanation, cell division to account for the meiotic images.

Some implications for work in the biology laboratory could be that meaning construction requires the design of practical tasks as opportunities for building these connections, allowing students to interpret observations, not just to perform technical operations or to exercise their skills. In the case studied the contextualization process, not the product (tissue names or drawings) was the important outcome. We believe that tasks designed as problem solving provide this kind of opportunities and help to close the gap among theory, problems and laboratory in science teaching and learning. As proposed by the model of instruction as a joint cognitive process, the students acquire the skills required by their role in the task. An active role solving problems will support the development of skills related to meaning construction.

## Acknowledgments

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## Appendix 1: Handout- The tracks of the thief

A video camera has been stolen in the laboratory. The thief hurt itself, leaving behind traces from its body. In the microscopes you will find slides prepared with these rests

This is the list of suspects; they came from an alien colony, and could be different from Earth animals and plants. They are suspects because some of them are fond of recording their own movies.

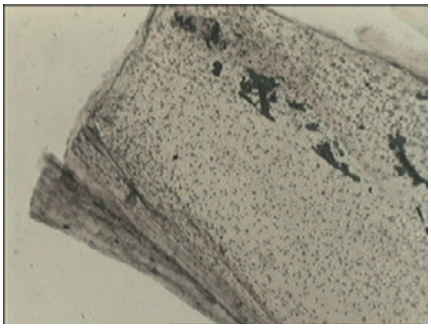
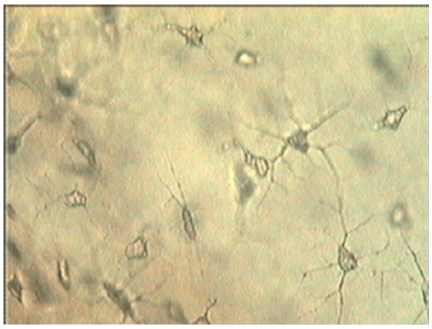
a) CLOROFILIO: its cells are like those from terrestrial plants. It has this name because it has chlorophyll (in the chloroplasts), being its nutrition by photosyntesis. Also it could have stomata to exchange gas.

b) TUNELIO: its cells are like those from terrestrial plants. It has this name because lives under the soil, and has not chlorophyll. The nuclei of cells are visible. It has no stomata.

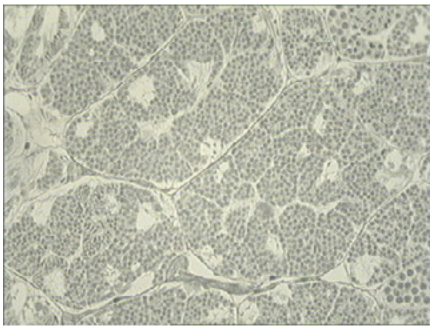
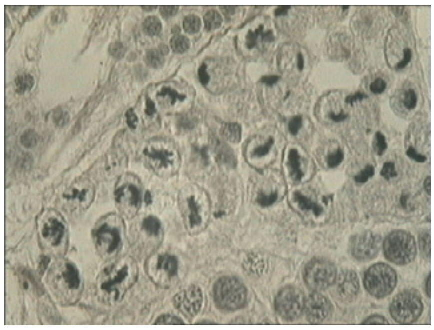
c) GALIÑOLIO: its cells are like those from terrestrial animals. It flies. Has red blood (with haemoglobine), where can be seen more than one cell type.

d) BATRACILIO: its cells are like those from terrestrial animals. Breathes through skin and has no blood. Its cells, irregular in shape, are distributed in layers, being all from the same type.

**Appendix 2:** Tissue samples given to students

| x 40 | x 400 |
|---|---|
|  |  |

Osteoblasts in fish operculum

| x 100 | x 400 |
|---|---|
|  |  |

Frog testis (cell division)

**Appendix 3:** References to cell and tissues terms in the two groups

| References to cells, organelles, tissue | Group E | Group J |
|---|---|---|
| *General features or parts of the cell* | | |
| cell (unspecified) | 5 | 9 |
| 'regular' (cell, nucleus) | 2 | 1 |
| size | 3 | 5 |
| color | 2 | 13 |
| shape | 5 | 4 |
| thickness | | 1 |
| structures (general) | 3 | 2 |
| membrane / limits | 7 | 12 |
| cytoplasm | 3 | 1 |
| nucleus | 17 | 10 |
| nucleolus | 3 | - |
| threads / 'worms' | 8 | - |
| cell type: animal or plant | 17 | - |
| cell types: similar or different | - | 9 |
| broken cells | - | 3 |
| *Features or parts of animal cells* | | |
| animal cell | 7 | - |
| exemplar (cheek cells) | - | 3 |
| *Features or parts of plant cells* | | |
| plant cell | 9 | - |
| exemplar (onion skin) | 5 | - |
| cell wall | 3 | - |
| stomata | 3 | 1 |
| chlorophyll | - | 2 |
| *Types, structures or features of tissues* | | |
| tissue (unspecified) | 1 | - |
| neurone | 13 | - |
| epithelium / skin | 9 | 11 |
| muscles | 9 | |
| blood | | 1 |
| stratified / layers/ folds | 21 | 19 |
| regular pattern (beehive, land estates) | 4 | 15 |
| united /separated | 4 | 5 |
| branching / dendrites | 18 | 3 |
| axon | 1 | |
| spots | 2 | 7 |
| lines | - | 2 |
| vases / canal | - | 4 |
| new cells formation | - | 16 |
| *Total number* | *184* | *159* |

# EXPLAINING DIFFERENCES AND SIMILARITIES IN ECOLOGICAL COMPARISONS

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## Abstract

This paper focuses on problem-oriented ecological comparisons, which require analysing similarities and differences between organisms to explain their adaptations to the environment. The first part of this study consists of a qualitative analysis of the open responses of students (age 12) who compared two fish. A theoretical framework for characterizing the structure of ecological comparisons is proposed, in which three dimensions are described: the breadth of the comparison (i.e., the number of perspectives of the comparison), the depth of the comparison (i.e., the number of different features of the organisms related to the perspective) and the explanatory concepts that are used to explain similarities and differences. The second part of this study reports on the findings of a teaching intervention that was planned on the basis of Cognitive Flexibility Theory in order to test the hypothesis that knowledge of multiple cases supports the ability to explain differences between organisms in ecological comparisons. Quantitative analyses showed that the breadth and depth of students' comparisons significantly increases if students are familiar with the ecological variety within one group of organisms. Knowledge of multiple cases enables students to analyse the adaptations of unknown organisms and supports the ability to explain similarities and differences.

## 1. Introduction

Problem-oriented comparisons can be defined as comparisons in which similarities and differences must not only be named, but also explained in light of the question that triggered the comparison. In ecological comparisons, typically, similarities and differences must be analysed, in order to explain how organisms are adapted to different environments. Adaptation being a major biological concept, ecological comparisons play an important role in biology education, as they are frequently used to enhance the students' understanding of functional anatomy and the relationship between organisms and the environment. Also, comparisons are used to create situations in which previously acquired knowledge can be applied to new organisms. However, while adaptation – the explanatory concept that is used in these comparisons – has been well-studied in the literature on students' alternative conceptions, little is known about the processes involved in comparing organisms and explaining similarities and differences.

This paper presents a framework for analysing comparisons by using a structural approach. Its focus lies on defining elements necessary for making meaning. It draws on approaches that bring together science education and studies of language and communication. A number of authors argue that teaching and learning science is communicating complex meanings primarily through language. Understanding can be conceived of as a communicative process (Edwards & Mercer, 1986) and "talking science" as a shared social practice of making meaning by contextualisation (Lemke, 1990). *Explaining Science in the classroom* (Ogborn et al., 1996) focuses on the structure of teacher explanations by setting forth a theoretical framework for analysing elements that contribute to making meaning in the science classroom. *Meaning making in the secondary science classroom* (Mortimer & Scott, 2003) provides an analytical framework for characterizing the key features of talk in school science classrooms. Here, an analytical framework is set forth to characterize explanations in ecological comparisons.

## 2. Aims

This study sets out to …

(a) …outline the dimensions along which ecological comparisons can be analysed
(b) … describe the knowledge prerequisites necessary for explaining differences and similarities in ecological comparisons.

Both aims have theoretical and practical implications. Investigating the patterns in comparisons, the specific ways of making meaning, helps understanding why some comparisons are more effective than others. In *Talking Science: Language, Learning and Values*, Jay Lemke proposed that "learning science means learning to talk science" (1990, 1). Comparisons are a prime example for "talking science" because similarities and differences need to be explained by using arguments and patterns of argumentation shared by people familiar with the knowledge domain.

Accordingly, this paper proposes a theoretical framework for characterizing the structure of explanations of similarities and differences in ecological comparisons. This framework is applied to a number of student comparisons. The second research question takes into consideration that comparisons require the application of previously acquired knowledge. Theory has significantly advanced our understanding of the conditions necessary for successful knowledge application. On the basis of these theories, an intervention study was planned to test the hypothesis that knowledge of multiple cases supports the ability to explain differences between organisms in ecological comparisons.

## 3. The structure of ecological comparisons

Here, an experienced teacher's comparison of differently adapted organisms is used to develop a framework for analysing the structure of ecological comparisons.

The teacher was given colour pictures of two fish which were labelled fish A and fish B. Fish was a northern pike (ESOX LUCIUS) and fish B a carp (CYPRINUS CARPIO). For the prompt, the teacher was given the following task: "Fish A and fish B are different in terms of their way of life and their habitat. Explain as many differences between the two fish by making suggestions about their way of life and their habitat. When doing so, make careful reference to the characteristics of the two fish that you want to explain." The teacher was asked to respond in writing and to spend max. 30 minutes on the task.

The first thing to notice is that the task description requires two things: naming specific characteristics of the two fish and explaining them in terms of way of life and habitat. Accordingly, effective responses can be expected to contain two types of statements. On the one hand, statements can be expected that describe how the two fish live and where they live. Also, effective comparisons should contain supporting evidence, for example functional-anatomical analyses. Thus, from the perspective of text linguistics, the type of text required by the prompt is an argumentative text, in which claims are made and supporting evidence is given.

Let us take a close look at the teacher's comparison (Figure 1). The text is clearly characterized by claims and supporting evidence. In the first paragraph, for example, the teacher names the northern pike's habitat – lake areas with many plants – and refers to the northern pike's colour in order to show how it is adapted to its habitat. In the next paragraph, the northern pike's ability to manoeuvre between the plants is explained by referring to its slim and long body. Text linguists have described rhetorical schemata, i.e. types of textual sequencing such as *top-down* and *bottom-up* ways of proceeding. Here – and throughout the text –*top-down strategies* are used, which can be seen by the repeated pattern of arguments that start with a general statement followed by supporting evidence.

So far, one important fact is missing in this analysis, however. The teacher is explaining *similarities and differences* between the two fish in a *comparison*. For this, he uses a number of criteria that form the basis of his comparison. Thus, it is the role of criteria that needs to be looked at more closely. From a theoretical perspective, comparisons revolve around criteria. Criteria – also called the *tertium comparationis* – are used to relate the organisms and to find differences and similarities between them. Janich and Weingarten (1999) thus speak of comparisons as a three-partite relation that consists of the relata and the criteria. In their theoretical reconstruction of the comparative method, they call attention to the fact that the choice of criteria determines the outcome of the comparison. Also, since comparisons have a purpose, the choice of criteria must be congruent with the aim of the comparison.

The role of criteria is obvious in the teacher's response: They provide the basis for the comparison and structure the comparison. This can be seen in the text, in which a separate paragraph is devoted to each of the three superordinate criteria: "habitat", "locomotion", and "feeding". Further, these criteria are detailed throughout the comparison by numerous references to specific features of the two fish. These can be regarded as subordinate criteria because they are related to the superordinate criteria and elaborate them.

| | Fish A (northern pike) | Fisch B (carp) |
|---|---|---|
| Habitat | Lake areas with many plants, because of yellow-green camouflage (like sun-spots and water plants); also, the pike is darker on top (like looking from above into the lake) and brighter on the underside (like looking from the deep water to the surface). This enables the pike to hide between the plants and wait for prey. | Lake areas with many plants, because of the green colour that acts as camouflage; also the carp is darker on top (like looking from above into the lake) and brighter on the underside (like looking from the deep water to the surface). This enables the carp to hide from predators between the plants. |
| Way of Life | | |
| a) Locomotion | Can manoeuvre very easily between the plants, because of its long and slim body shape. Can propel itself forward from its hiding place, because of its slim body that reduces the water resistance and because of quick movements of its muscular tail, supported by the big divided tail fin as well as by the anal fin located at the far end of the pike's back. | Can manoeuvre very easily between the plants because of its high and oval body shape. While doing so, the body is stabilized vertically by the big and long dorsal fin and the big anal fin. |
| b) Feeding | Stealth predator with big eyes to identify its prey; has the ability to move quickly forward from its hiding place (see above); has a pointed mouth with many sharp teeth that can get hold of the prey, which is supported by the fact that the lower jaw projects forward. | Feeds on pants and animals that live in the ground, and on detritus by using its round mouth that is surrounded by thick lips. For identifying food, the middle-sized eyes are supported by the barbels. |

Figure 1. An experienced teacher's comparison between a northern pike and a carp

In the teacher's comparison, the fairly general (superordinate) criterion "feeding" is broken down to a number of more specific (subordinate) criteria that are used to make the comparison more concrete. The teacher, for example, compared the size of the eyes and the shape of the mouth, thus elaborating the criterion "feeding".

Making a distinction between *super*ordinate criteria and *sub*ordinate criteria allows for understanding that comparisons possess two dimensions. Let us look at the first dimension - the number of perspectives used in a comparison. It is possible to argue that the superordinate criteria represent the perspectives of a comparison, giving the comparison breadth. In the teacher's comparison, differences in adaptation are approached from the perspectives of habitat, locomotion and feeding. Thus, comparisons are broad and multi-perspectival if a number of different *super*ordinate criteria are used. The second dimension refers to the number of *sub*orordinate criteria used to detail the superordinate criterion. Comparisons become more elaborate - they gain in depth - if reference is made to a larger number of specific features of the organisms. Patterns of features, for example, can be analysed only if several characteristics of an organism are referred to.

A final comment is necessary to explain the process of making meaning in comparisons. Naturally, there is a difference between simply naming similarities and differences in a comparison and explaining them. Thus, we need to look at how differences and similarities are explained. Each of the paragraphs contains an explanatory concept, a reference to a specific habitat, type of locomotion or feeding. In the paragraph about feeding, for example, the northern pike is called a "stealth predator". The teacher thus introduces an explanatory concept that he connects to a number of interrelated features of the fish – the size of its eyes, its ability to propel itself forward from its hiding place, and three anatomical details about its mouth (shape, possession of teeth, and size of the lower jaw).

In sum, ecological comparisons of differently adapted organisms possess three dimensions: On the one hand, the **breadth** of a comparison results from the number of different **perspectives that are explained**. On the other, the **depth** of a comparison takes into account the number of different **features** or **characteristics** (of the organisms) that are related to a specific perspective. Third, **explanatory concepts** which underlie the comparison, are explicitly related to the features of the organisms. The three dimensions are illustrated schematically in Figure 2.

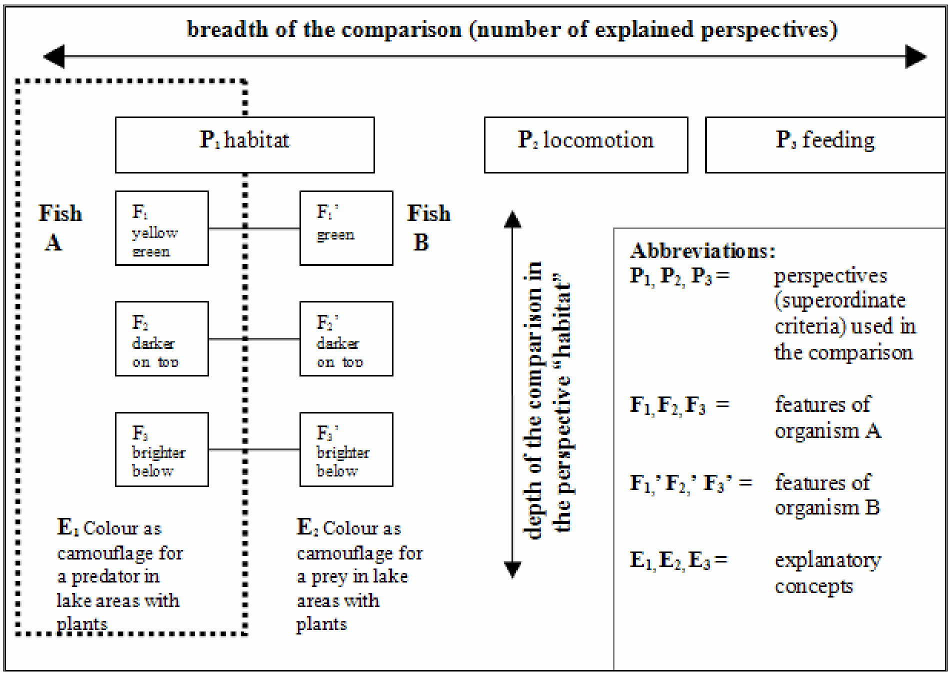


Figure 2. The three dimensions of ecological comparisons: their **breadth** (number of explained perspectives), their **depth** (number of different features of the organisms ) and the explanatory **concepts** that underlie the comparison. In the figure, the depth of only one perspective (habitat) is illustrated by examples from the text (see Figure 1).

## 4. Analysing dimensions in students' ecological comparisons

Here, the three dimensions of comparisons – their breadth, depth and their explanatory concepts – are applied to a larger number of examples in order to investigate if they can be used to measure student achievement in ecological comparisons. The dimensions prove helpful, if they are applicable to a wide variety of comparisons by different individuals and if the dimensions adequately register the differences between them.

The following comparisons were made by students aged 12 who had not received any formal education about fish (see section 5.5 of this paper for a description of the sample). The students were asked to compare a northern pike and a carp and they were given the same task description as the teacher (see section 3 of this paper).

### 4.1- Example 1

This student uses two perspectives per fish ($P_1$ food and $P_2$ habitat) in her comparison (Figures 3 and 4). She introduces the explanatory concepts "meat-eater" vs. "plant eater" and "bottom of the sea" vs. "surface of the sea" and relates one characteristic per fish to each of them. For example, the difference between a meat eater and a plant eater is substantiated by referring to the pointed teeth of fish A (feature 1 = $F_1$ in Figure 4) and the size of the mouth of fish B (feature 2 = $F_2$ in Figure 4). In contrast to the teacher's example in figure 1, this comparison is less broad and less deep. Also, the explanatory concepts used in this example are simpler than in the teacher's comparison. However, the three dimensions – perspectives, features, and explanatory concepts – are clearly visible in example 1.

Perhaps, fish A is a meat-eater because of its pointed teeth. Fish B is perhaps a plant-eater because of its small mouth.
I believe that fish A lives at the bottom of the sea for the most time because of its partly dark colour. Fish B probably lives at the surface of the sea because the colour of its scales is like the colour of the sea.

Figure 3. Student 1 (female, 12 years old): Comparison of a northern pike (fish A) and a carp (fish B)

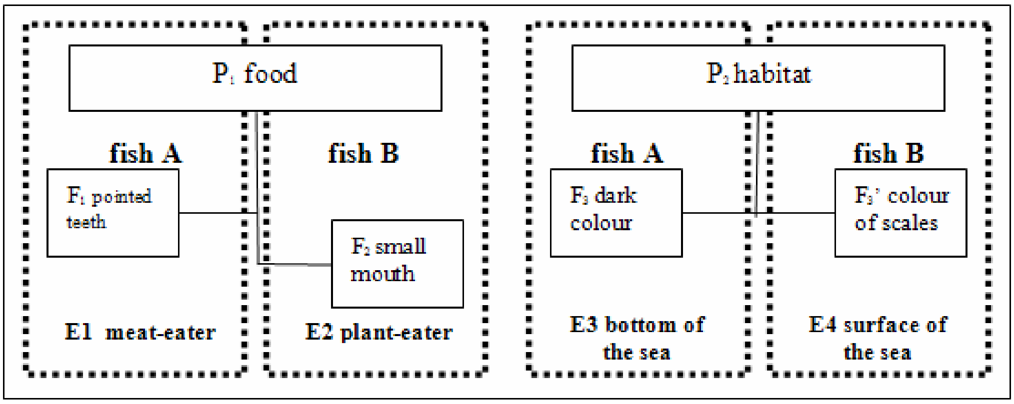


Figure 4. Structure of the comparison of student 1 (see Figure 3)

## 4.2- Example 2

Like the previous student, this student uses two perspectives per fish ($P_1$ habitat and $P_2$ food) in her comparison (Figures 5 and 6). She introduces two explanatory concepts by referring to the difference between fast-flowing rivers and lakes or ponds in which the water does not flow fast. Also, like student 1, she uses the explanatory concepts "meat eater" vs. "plant eater". In contrast to student 1, however, student 2 is able to give her comparison more depth.

Fish A: Because the fish has a long and slim body, one can suppose that it lives in rivers or in fast streams. This is also suggested by the fact that it has many fins. The teeth show that the fish is a meat-eater, also the shape of its mouth.
Fish B: Because its body is rather round and thick, this fish very likely lives in lakes or ponds, in any case not in flowing waters. Its mouth is round and smaller which shows that he may be a plant eater. The fish uses its mouth to cling to plants and to eat algae and other plants.

Figure 5. Student 2 (female, 12 years old): Comparison of a northern pike (fish A) and a carp (fish B)

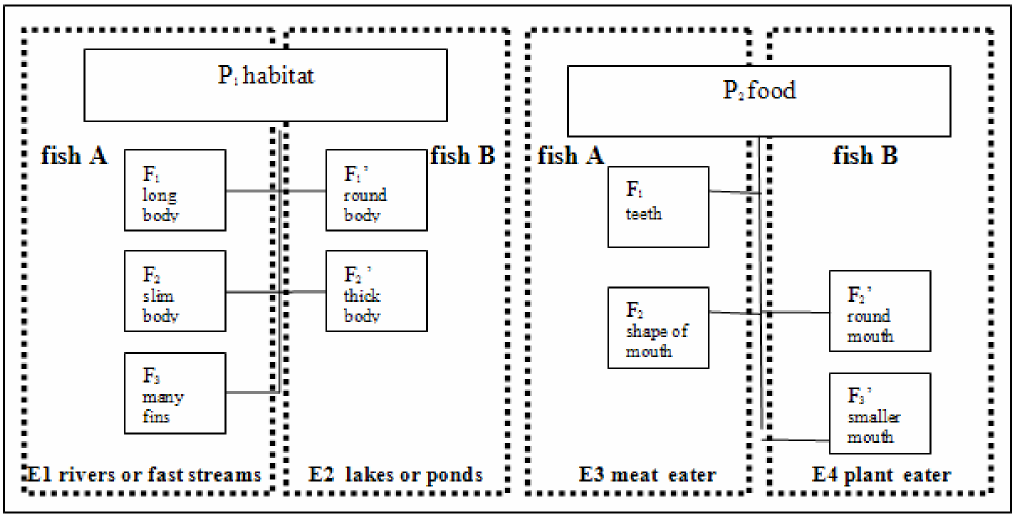


Figure 6. Structure of the comparison of student 2 (see Figure 5)

For example, she relates three features of fish A – its long and slim body and the fact that it has many fins –and two features of fish B – its round and thick body – to the criterion "habitat". Also, she relates two features of fish A – its teeth and the shape of its mouth – to "meat-eater" and two features of fish B – its round and smaller mouth – to "plant eater".

### 4.3- Example 3

In contrast to the previous two examples, this comparison (Figures 7 and 8) lacks explanatory concepts and does not contain any explained perspectives. The student quoted here wrote three sentences, each of which refers to a pair of contrasting features of the two fish. However, no statements are made about the habitats and the ways of life of the two fish. As a consequence, contrasts between the two fish are described, but not explained. Thus, it is not made explicit how the differences contribute to answering the question of the comparison.

Fish A is long; fish B is small
Fish A is slim; fish B is thick.
Fish A has teeth; fish B doesn't.

Figure 7. Student 3 (male, 12 years old): Comparison of a northern pike (fish A) and a carp (fish B)

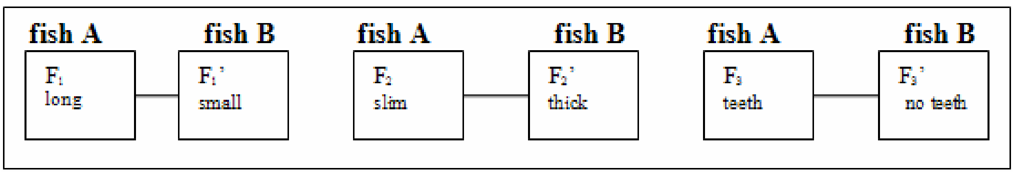


Figure 8. Structure of the comparison of student 3 (see Figure 7)

### 4.4- Example 4

This is a good example for illustrating the differences between an explanatory concept and a perspective. This student (Figures 9 and 10) specified the habitat of fish A, which he identified as the river Alster, a river close to his high school in Hamburg. However, neither does he detail why he thinks that the fish lives in that river, nor does he comment on where fish B (the carp) lives. So, although the perspective "habitat" is visible, neither is it used to compare fish A and B nor does it have an underlying explanatory concept. This is particularly obvious in contrast to the student in example 2, who reasoned that rivers are fast flowing and related the fish's body shape and the number of its fins to its habitat. In contrast, the student in example 4 did not mention any features of fish A to substantiate his argument that fish A lives in the river Alster. The two dimensions of comparisons, however, clearly stand out in the second sentence. The student specified the size of the food that both fish can eat because of the size of their mouth. Accordingly, a contrast between the two fish is related to the criterion of food.

> I believe that fish A can also be seen in the river Alster. I think, fish A eats bigger food than fish B because of its bigger mouth.

Figure 9. Student 4 (male, 12 years old): Comparison of a northern pike (fish A) and a carp (fish B)

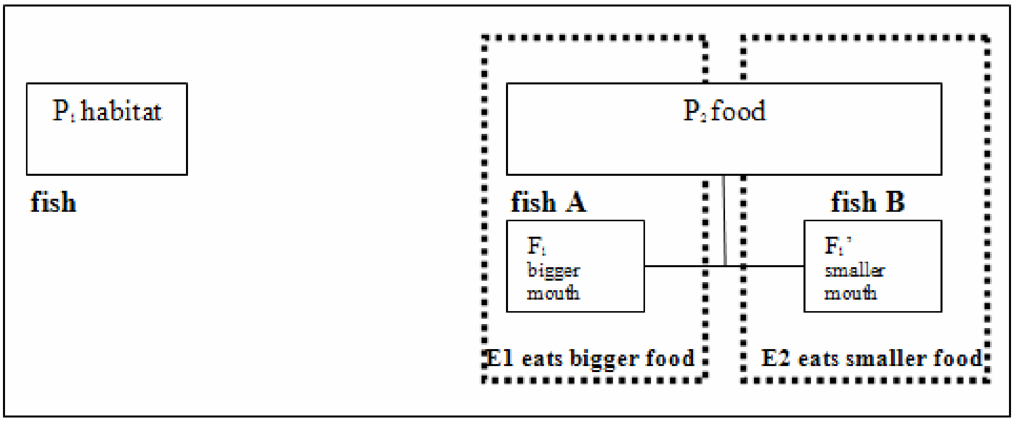


Figure 10. Structure of the comparison of student 4 (see Figure 9)

### 4.5- Summary

Comparisons come in many different forms. The reason for this is clear: "Every act of communicating, every production of meaningful signs, every understanding reached, is newly made" (Ogborn, 1996: 59). However, the dimensions of ecological comparisons – their breadth, their depth and their underlying explanatory concepts – proved helpful in describing differences between comparisons. Thus, for students to make effective comparisons of differently adapted organisms it is important to possess:

- … the ability to use multiple perspectives relevant to the question of the comparison,
- … the ability to relate multiple features of the organisms to the perspective used,
- … the ability to use explanatory concepts relevant to the question of the comparison.

Further, the examples showed that effective comparisons relate explanatory concepts to features of the organisms in order to point out their functions (see examples 1, 2 and 4 in contrast to example 3). It is evident that comparisons can be analysed according to the number of features that are explained. Thus, it is possible to differentiate between comparisons that differ in depth (see example 1 in contrast to example 2). Also, comparisons differ in breadth. Comparisons that have several perspectives – here defined as superordinate criteria used for relating the organisms – are broader than comparisons with fewer perspectives. This is evidenced by the fact that the teacher's comparison (Figure. 1) had more perspectives than student examples 1 and 2, and that the latter had more perspectives than student example 4. An important aim for classroom instruction, thus, is to teach students that adaptation is a multi-dimensional concept. Further, evidence was found that giving the comparison a perspective – for example identifying an organism's habitat (see example 4)– is different from using habitat as an explanatory concept. For this, it is necessary to refer to the features of a specific habitat.

## 5. Improving student performance in ecological comparisons

### 5.1- Theory and research question

Ecological comparisons require the ability to make comparative statements about the adaptations of organisms to the environment. For this, it is necessary to select specific features – or identify patterns of features – and to explain them as adaptations to the environment. Knowledge about the functional anatomy of the organisms is necessary in such comparisons, as well as knowledge about the organisms' ways of life and habitats (see section 3 in this paper).

Adaptive radiation created a considerable variety of forms within one taxonomic group. As a consequence, organisms can be quite differently adapted although they belong to the same taxonomic group. From a theoretical point of view, this heterogeneity can be expected to create problems for flexible knowledge application. Spiro et al. (1987), for example, argued: "If cases come in many forms, one needs to see many cases in order to represent their varieties of contextual influences and configurations of features" (186). Thus, knowledge about one prototypical representative can be expected to be of limited value when unknown organisms of the same group must be analysed and compared. In contrast, it is common practice in high school biology to introduce students to the concept of adaptation by using a limited number of organisms, especially at the early stages of knowledge acquisition. Often, a single exemplary organism is used to introduce the concept of adaptation – for example a prototypical bird for life in the air, a fish for life in the water and a terrestrial mammal for life on the land. Rarely, however, are the students given the opportunity to study adaptive radiation, e.g., they are not given the opportunity to analyse how different birds are adapted to different environments.

Limited knowledge about the ecological variety within one group of organisms has in fact been found to be a reason for problems of knowledge application, i.e., inert knowledge (Hammann, 2005). In particular, knowledge about the adaptations of different fish – i.e., knowledge about multiple representatives of one group of organisms – proved superior to knowledge about the adaptations of a single representative – i.e., knowledge of a prototype – in terms of the students' ability to apply pre-knowledge in ecological comparisons of unknown organisms. Thus, a central tenet of Cognitive Flexibility Theory (Spiro et al., 1987) was found to affect the ability to apply pre-knowledge in ecological comparisons – i.e., knowledge of multiple cases supports knowledge application in new situations.

In this study, the research question is posed if knowledge about the adaptations of multiple representatives of a group of organisms – in contrast to knowledge about the adaptations of a single representative of this group – supports students' performance in ecological comparisons in all three dimensions outlined in the previous parts of this paper, namely the students' abilities to use multiple perspectives, to relate multiple features of the organisms to the perspective used and to use explanatory concepts. These three dimensions form the dependent variables in this study and were not analysed previously by the author (2005).

### 5.2- Design of the study

The present study is a teaching intervention with two experimental groups and a control group (Figure 11). Two factors characterize the design: The first factor varies the number of cases (single case vs. multiple cases), the second factor the number of knowledge dimensions (one dimension vs. two dimensions). The research question addressed in this paper is related to the first factor only, the number of cases presented to the students. Therefore, the study will focus on pre-test and post-test comparisons between the control group and experimental group 1. The other factor – the number of knowledge representations – is related to experimental group 2 and the question if the students' ability to group the same set of animals in different ways is affected by multi-dimensional knowledge representations (Hammann & Bayrhuber, 2002).

The teaching intervention consisted of three periods (each 45 minutes). Pre-tests (2 periods, 45 minutes each) were administered the day before the teaching intervention, post-tests (one period, 45 minutes) after the intervention.

| | **number of cases:** one case | **number of cases:** multiple cases |
|---|---|---|
| **number of knowledge dimensions:** one dimension (ecology) | **control group** | **experimental group 1** |
| **number of knowledge dimensions:** two dimensions (ecology and taxonomy) | | **experimental group 2** |

Figure 11. Design of the study

### 5.3- Description of the intervention

Students in the **control group** were instructed about the ways in which the carp (CYPRINUS CARPIO) is adapted to life in the water. In the first period, the focus was on the carp's outer anatomy and the functions of its fins. This lesson was held in an identical manner in experimental groups 1 and 2 as well. In the second period, the students in the control group compared the wild form and the domesticated form of the carp. The reason for this comparison of two very related forms in the control group was to administer the same teaching method – contrasting different organisms – in all three groups. In the third period, the students in the control group were familiarized with the functions of the carp's gills, so that they learned about another general adaptation to life in the water.

The students in **experimental group 1** received lessons about the ecology of different fish guilds (ecological types). In the second class period, the students were familiarized with the adaptations of "fast swimmers of the open water", "slow manoeuvring fish of the reed zone" and with "flexible swimmers at the bottom of the lake/sea" (Schmidt 1996). Each of the types was illustrated with 3-4 different species. Particular emphasis was placed on the type of locomotion and the habitat. In the third period, the students were familiarized with 11 additional fish (sweet water as well as salt water) which were analysed and classified according to ecotype.

The first two class periods for **experimental group 2** were identical with experimental group 1. In the third class period, however, these students were familiarized with fish taxonomy (bony fish, cartilagenous fish and lampreys) and classified a group of 11 fish according to ecotype and taxonomy.

Comparisons were used as an instructional method in order to present differences and similarities between the wild form and the domesticated form of the carp (control group), between different ecotypes (experimental groups 1 and 2) and between different taxonomic groups (experimental group 2). However, in none of the groups the method of comparing organisms itself was discussed. For example, the students were not instructed about using multiple perspectives or analysing patterns of features.

### 5.4- Description of the testing materials

In the pre-test the students were asked to compare a carp (CYPRINUS CARPIO) and a northern pike (ESOX LUCIUS), in the post-test a European smelt (OSMERUS EPERLANUS) and a weatherfish (MISGURNUS FOSSILIS) (See section 3 of this paper for the task description and Hammann, 2005 for the testing materials).

### 5.5- Description of the sample

The sample consisted of 125 students (44% girls and 56% boys) of an urban high school. At the time of the study, all students were in grade 6. 97% of the students were 12 years old at the time they participated in the study. Before the pre-test, the students were asked whether they had received any lessons about fish at school (grades 1-6). This had not been the case for 89% of the students. 9 students (11%) said that they had been taught about fish at some time in grade 1-4, but they also indicated that the lessons received had been few.

The information given by the students was confirmed by their teachers who said that they had not taught any lessons about fish in grade 6.

The students who participated in this study were in 5 forms. Two of the forms were randomly assigned to experimental group 1 (n=50), two forms to experimental group 2 (n=47) and one form served as the control group of this study (n=25). No significant differences were found between the three groups concerning their grades in biology, F=0,570; p=.570, and their grades in German, F=2,280; p=.107, considering the whole sample (n=122). However, in a sub-sample of students (n=96) who wrote only sentences and no keywords in their comparisons (see 5.6), a significant difference was found. The difference concerns the post-test subsample and the German grade only and lies between students of experimental group 1 (M 8,5; STD 2,46) and the control group (M 7,2; STD 2,53), F=3,957; p=.022.

5.6- Data analysis

For characterising the students' ability to explain differences and similarities in ecological comparisons, seven variables were used. The variables are presented below as well as exemplary student statements and how they were coded.

V 1: Unexplained features
How many features of the two fish are mentioned, but not explained?
e.g., two unexplained features in: *Fish A has teeth; fish B doesn't.*

V 2: Unexplained perspectives
How often are habitat, way of life and locomotion of the two fish mentioned, but not explained?
e.g., twice "habitat" and twice "way of life" in: *Fish A: lives perhaps in rivers and eats meats. Fish B: lives perhaps in rivers and eats plants.*

V 3: Depth of the explained perspective "habitat"
How many features of the two fish are referred to in order to explain their habitats?
e.g., two features in: *Fish A has a long body form; that's why I think that it lives in shallow waters. Fish B has an oval body form; that's why I think it lives in open waters, like lakes*

V 4: Depth of the explained perspective "way of life"
How many features of the two fish are referred to so as to explain their ways of life?
e.g., two features in: *Fish A is perhaps a meat-eater because of its sharp teeth. Fish B is perhaps a plant-eater because of its small mouth.*

V 5: Depth of the explained perspective "locomotion"
How many features of the two fish are referred to in order to explain their locomotion?
e.g., two features in: *Fish A is long and slim and therefore fast like an arrow.*

V 6: Explained perspectives (breadth of the comparison)
How many different explained perspectives are used for the two fish?
i.e., If a student explained locomotion, habitat and way of life for fish A as well as for fish B, she or he received a score of 6 which is the maximum score possible (Figure 1)

V 7: **Explained features**
How many features of the two fish are explained?
i.e., the sum was formed of the variables V 3, V 4 and V 5.

Before the test, the students were instructed to write complete sentences. Only student responses that fulfilled this requirement were analysed because the students' responses were analysed for explicit explanations at the sentence level. For a feature to be classified as an explained feature, an explicit relationship had to be established between a feature of the fish and an explanatory concept by using words like "because", "so that", "that's why", "this can be seen by the fact." High counts in variables V 1 and V 2 indicate that the students described similarities and differences but did not explain them. However, it is necessary to keep in mind that these variables may contain *implicit* explanations. Variables V 3, V 4, and V5 contain explicitly **explained** features and can be used to characterise the **depth** of the students' comparisons in the perspectives "habitat", "way of life" and "locomotion" (Figure 2). Variable V 6 contains the number of explicitly explained different perspectives and can be used to characterise the **breadth** of the students' comparisons (Figure 2). Variable V 7 is a general indicator of the students' ability to explicitly explain features.

**5.7- Pre-test findings**

The pre-test can be used (a) to characterize the breadth and depth of comparisons by students with little pre-knowledge and (b) to investigate if the control group and the two experimental groups show the same abilities in comparisons before the intervention.

The pre-test findings for the seven variables as well as the ANOVA results are listed in table 1. The following description of the findings refers to students who wrote sentences and no keywords in their comparisons (n=98). Also, the means (M) and standard deviations (STD) given in the following descriptions of the findings represent sum values for both fish. The students' comparisons of the two fish contained roughly twice as many explained features, M 4,32; STD 3,439, than features that remained unexplained, M 2,21; STD 4,029. Also, their comparisons contained more explained perspectives, M 2,17; STD 1,422, than unexplained perspectives, M 1,58; STD 1,872. The depth of the students' comparisons varied depending on the perspective chosen. The students were able to refer to more than two features in order to explain the "way of life" of the two fish, M 2,68; STD 2,514. Far less features of the two fish were referred to when the students explained the locomotion of the two fish, M 1,06; STD 1,532, and the habitats of the two fish, M 0,56; STD 0,975.

When analysed across the control group and the two experimental groups, there were significant differences between the groups only in variable 6 "explained perspectives (breadth of the comparison)", $F(2,95)=3{,}629$, $p<.05$. Multiple comparisons (Tukey) showed that the difference lies between experimental group 2 and the control group, $p<.05$, but not between experimental group 1 and the control group, $p=.143$.

### 5.8- Discussion of the pre-test findings

Students with little pre-knowledge have problems giving their ecological comparisons depth and breadth. The students' comparisons contained roughly two perspectives, which needs to interpreted as approximately one perspective per fish. This is in contrast to how students use criteria in free-sorting tasks, in which they use multiple perspectives within one classification system (Hammann & Bayrhuber, 2003). Also, approximately two features per fish were explicitly explained. Thus, some of the student comparisons that were discussed in the previous part of this paper need to be regarded as fairly untypical because they contain two perspectives per fish (Figures 3 and 5) and more than two explained features per fish (Figure 5).

Also the students did not always analyse anatomical features of the organisms relative to the perspective chosen which can be seen by their unsubstantiated statements about the organisms' way of life, habitat and locomotion. In this particular comparison of a carp and a northern pike, it was far more difficult for the students to substantiate arguments about the habitat and locomotion of the two fish than about their way of life, which includes the type of food they eat. This is particularly interesting because the argument has been made that ecological groups (ecological guilds) in fish are types of fish whose locomotion is adapted to a specific habitat (Schmidt, 1996). As a consequence of these findings, a particular knowledge prerequisite for ecological comparisons of fish appears to be knowledge about their locomotion and their habitats. Often, knowledge about the habitat is implicitly taught, rather than explicitly; however for comparisons of this particular group of organisms, the lack of knowledge about the locomotion and the habitats of the fish proved particularly limiting for effectively explaining differences and similarities.

The students in experimental group 2 gave their comparisons significantly more breadth than the students in the control group. As a consequence, experimental group 2 will be excluded from the following pre-test and post-test comparisons. This does not affect the design of this study because experimental group 1 and the control group will be compared for answering the research question of this study (see section 5.2).

### 5.9- Post-test findings

Comparisons between the control group and experimental group 1 (T-Tests, independent groups) revealed significant differences in the post-test (Figures 12, 13 and Table 1). Students in experimental group 1 explained significantly more features of the fish (($p \leq .001$; V 7) and gave their comparison significantly more explained perspectives ($p \leq .001$; V 6) than the students in the control group. In particular, the students in experimental group 1 explained significantly more features of the fish than the students in the control group in the perspectives "habitat " ($p \leq .001$; V3), "way of life" ($p \leq .001$; V4) and "locomotion" ($p \leq .05$; V5). The two groups did not differ in their means for the variables "unexplained features" (V 1) and "unexplained perspectives" (V 2).

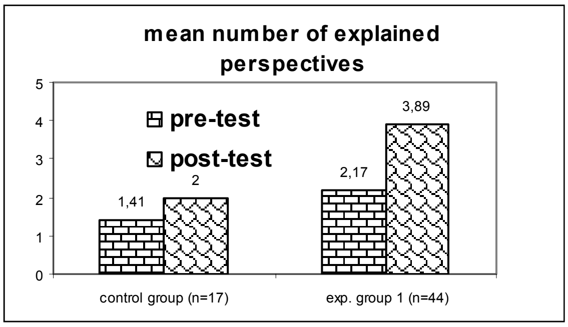


Figure 12. Mean number of explained perspectives

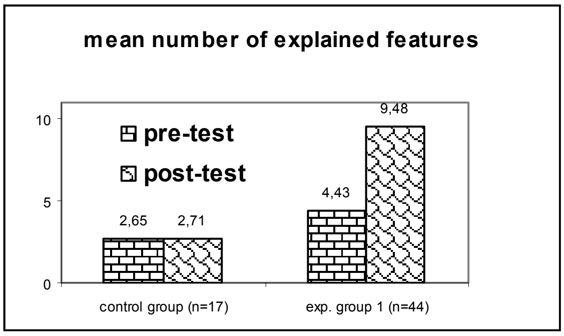


Figure 13. Mean number of explained features

Comparisons between the pre-test results and the post-test results (T-tests, paired students) revealed that students in the control group did not increase the average number of explained features (V 7). However, they significantly ($p \leq .05$) increased the breadth of their comparison in the post-test (V 6). Also, they referred to significantly ($p \leq .01$) more features in the perspective "habitat" (V 3) in the post-test than in the pre-test. In contrast, the students in experimental group 1 were able to significantly ($p \leq .001$) increase the average number of explained features in their comparisons (V 7) and they gave their comparisons significantly ($p \leq .001$) more breadth (V6) in the post-test than in the pre-test. Also, students in experimental group 1 explained significantly ($p \leq .01$) more features in the perspective "habitat" (V 3) in the post-test than in the pre-test, and significantly ($p \leq .05$) more features in the perspective "locomotion" (V 5). In the other variables no significant changes were found.

### 5.10- Discussion of the post-test findings

The post-test results reveal clear differences between the control group and the experimental group that can be attributed to the effects of the treatment. The findings support the main hypothesis of this study, insofar as knowledge about one prototypical representative turned out to be of limited value when unknown organisms of the same group of organisms had to be analysed and compared. Students who possessed knowledge about the adaptations of different types of fish – students in experimental group 1 – were able to give their comparisons significantly more breadth and depth in all three dimensions analysed than the students in the control group. Although there is a significant difference between the two groups in the post-test concerning the German grade (see 5.5), it is unlikely that the post-test differences go back to differences in language performance; rather differences in knowledge resulting from the treatment account for the difference in ecological comparisons between the two groups.

| | | Pre-test findings | | | | Post-test findings | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables (V) | | N | M | STD | ANOVA | N | M | STD | T-Test |
| V 1 unexplained features | experimental group 1 | 40 | 1,98 | 3,238 | F(2,95) =0,147 n.s. | 44 | 2,16 | 3,095 | T(59)= 0,854 n.s. |
| | experimental group 2 | 41 | 2,46 | 4,940 | | 35 | 2,51 | 3,320 | |
| | control group | 17 | 2,18 | 3,395 | | 17 | 1,47 | 1,908 | |
| | whole sample | 98 | 2,21 | 4,029 | | -- | -- | -- | |
| V 2 unexplained perspec-tives | experimental group 1 | 40 | 1,27 | 1,867 | F(2,95) =0,982 n.s. | 44 | 1,34 | 1,397 | T(59)= -1719 n.s. |
| | experimental group 2 | 41 | 1,73 | 1,775 | | 35 | 1,80 | 1,694 | |
| | control group | 17 | 1,94 | 2,106 | | 17 | 2,12 | 1,996 | |
| | whole sample | 98 | 1,58 | 1,872 | | -- | -- | -- | |
| V 3 depth of the perspec-tive "habitat" | experimental group 1 | 40 | 0,57 | 1,152 | F(2,95) =0,502 n.s. | 44 | 5,18 | 3,287 | T(59)= 4,733 p≤.001 |
| | experimental group 2 | 41 | 0,63 | 0,859 | | 35 | 2,91 | 1,597 | |
| | control group | 17 | 0,35 | 0,786 | | 17 | 1,29 | 1,213 | |
| | whole sample | 98 | 0,56 | 0,975 | | -- | -- | -- | |
| V 4 depth of the perspec-tive "way of life" | experimental group 1 | 40 | 2,63 | 2,539 | F(2,95) =1,874 n.s. | 44 | 2,23 | 1,927 | T(59)= 3,383 p≤.001 |
| | experimental group 2 | 41 | 3,15 | 2,594 | | 35 | 1,51 | 1,358 | |
| | control group | 17 | 1,76 | 2,078 | | 17 | 0,59 | 0,795 | |
| | whole sample | 98 | 2,69 | 2,514 | | -- | -- | -- | |
| V 5 depth of the perspec-tive "locomotion" | experimental group 1 | 40 | 1,23 | 1,761 | F(2,95) =1,293 n.s. | 44 | 2,07 | 2,444 | T(59)= 1,982 p≤.05 |
| | experimental group 2 | 41 | 1,12 | 1,400 | | 35 | 1,60 | 1,786 | |
| | control group | 17 | 0,53 | 1,179 | | 17 | 0,82 | 1,334 | |
| | whole sample | 98 | 1,06 | 1,532 | | -- | -- | -- | |
| V 6 explained perspec-tives (breadth of the comparison) | experimental group 1 | 40 | 2,17 | 1,483 | F(2,95) =3,629 p≤.05 | 44 | 3,89 | 1,280 | T(59)= 5,458 p≤.001 |
| | experimental group 2 | 41 | 2,49 | 1,267 | | 35 | 3,20 | 1,471 | |
| | control group | 17 | 1,41 | 1,417 | | 17 | 2,00 | 1,00 | |
| | whole sample | 98 | 2,17 | 1,422 | | -- | -- | -- | |
| V 7 explained features | experimental group 1 | 40 | 4,43 | 3,802 | F(2,95) =2,710 n.s. | 44 | 9,48 | 4,796 | T(59)= 5,668 p≤.00 1 |
| | experimental group 2 | 41 | 4,90 | 3,105 | | 35 | 6,03 | 3,408 | |
| | control group | 17 | 2,65 | 2,914 | | 17 | 2,71 | 1,649 | |
| | whole sample | 98 | 4,32 | 3,439 | | -- | -- | -- | |

Table 1. Pre- and post-test findings: The pre-test is a comparison between a carp and a northern pike. The ANOVA was done to analyse possible pre-test differences between the three groups. The post-test is a comparison between a European smelt and a weatherfish. The T-Test findings refer to post-test differences between experimental group 1 and the control group.

## 6. Summary and implications for biology education

Three structural dimensions were found for analysing ecological comparisons:
the perspectives used in the comparison, the features of the organisms related to a specific perspective and the explanatory concepts used in the comparison. The first two dimensions – perspectives and features – are superordinate criteria and subordinate criteria that are used to relate the objects of the comparison and to find similarities and differences between them. Also, the point was made that differences and similarities must not only be named, but also explained. Thus, the third dimension consists of explanatory concepts that are used to show the meaning of differences and similarities in light of the question of the comparison.

The three dimensions proved helpful for analysing ecological comparisons The pre-test – a comparison between a carp and a northern pike – showed that students with little pre-knowledge in the domain were unable to give their comparisons breadth and depth. That is, neither did the students use many different perspectives in their comparisons nor did they explain a great number of features or even patterns of features. However, a teaching intervention was administered and it could be shown that the breadth and depth of students' comparisons significantly increases if students have been familiarized with the ecological variety within one group of organisms. In particular, this study shows that students who possess knowledge about the adaptations of different ecological types that exist within one group of organisms explain more features, use more explained perspectives, and give the perspectives more depth by referring to more features of the fish in their comparisons than students who possess knowledge about the adaptations of only one prototypical representative.

The post-test results of this intervention study underline that there is a strong influence of the students' pre-knowledge on performance in ecological comparisons. The findings illustrate that adaptation should be taught as a multi-dimensional construct. Further, the questions arise if students' comparisons would benefit from (a) teaching adaptation explicitly as a multi-dimensional construct rather than implicitly and (b) giving students an explicit training for making effective comparisons by pointing out to them the importance of using different perspectives in their comparisons which need to be substantiated, of course, by functional anatomical analyses.

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# SECTION 3

# TEACHING BIOLOGY IN TECHNOLOGY-SUPPORTED EDUCATIONAL ENVIRONMENTS

# SCAFFOLDING LEARNING THROUGH RESEARCH ARTICLES BY A MULTIMEDIA CURRICULUM GUIDE

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## Abstract
We developed a guide for a developmental biology curriculum for high-school students based on adapted primary literature. The curriculum guide was designed on a CD-ROM, enabling us to present authentic teaching episodes and a vast pool of questions and activities to be edited by the teachers, both aimed at providing the teachers with environment-effective advice while enhancing their feeling of autonomy. To characterize the teaching process using the guide, we interviewed four implementing teachers. It seems, according to the idiosyncratic interpretation of the tools provided in the guide by the interviewed teachers, that the curriculum guide was effective in both educating and emancipating the implementing teachers.

## 1.Introduction

Learning biology through adapted primary literature, has been promoted as a novel requirement in the syllabus for high-school biology students in Israel. The topics to be learnt using adapted primary literature are expected to be from cutting-edge biological research, which is only seldom used in secondary schools. The aims of this curricular change are to enhance the inquiry skills of high-school students and their understanding of the nature of science and scientific communication (Israeli Ministry of Education, 2003).

Primary literature (research articles) is used by scientists in order to communicate their research work to the scientific community (Beall et al*.,* 1999). Learning through primary literature at the university and college level has been shown to have many benefits, the main ones being exposure to the nature of scientific reasoning and communication, critical reading, practice in writing and analytical skills, improved design of the students' own research projects and gained confidence in their ability to reason, research and apply knowledge (Epstein, 1970; Janick-Buckner, 1997; Bandoni Muench, 2000). Primary literature has also been successfully used in journal club forums which serve as a tool for professional development of in-service biology teachers (Brill et al., 2003).

We predicted that the use of adapted primary literature at the high school level would enhance different aspects of scientific literacy and improve students' acquaintance with the nature of scientific research. We expected the students to improve their understanding of the rationale behind the research plan and methods, to critically assert the goals and conclusions of the scientific research and to become acquainted with the characteristic language and structure of scientific communication (Yarden et al., 2001).

It was recently shown that high-school students that read adapted primary literature better understand the nature of scientific inquiry and raise more scientific criticism of the researchers' work compared to students that read the same research presented as secondary literature (Baram-Tsabari & Yarden, 2005). Congruent with these views, we developed a curriculum in developmental biology based on adapted primary literature for high-school biology students in Israel (Yarden & Brill, 2000). The curriculum includes an introductory unit and three research articles that address central topics in the field of developmental biology: differentiation, genetic control of development and cell migration. The articles retained the basic structure characterizing primary literature (abstract, introduction, materials and methods, results and discussion) and have been processed as previously described (Yarden et al., 2001), to accommodate the cognitive level of high-school students.

Learning through adapted primary literature requires novel and challenging modes of teaching, as high-school biology teachers' use of scientific articles in class is almost exclusively limited to secondary literature (Wellington, 1991; Wade et al., 2000; Jarman et al., 2002; Brill et al., 2003). The novelty of the teaching strategies required, stems from the fact that besides coping with new content knowledge, teachers are concomitantly faced with the promotion of skills which are associated with learning through research articles. To assist the teachers that implement teaching using adapted primary literature and to convey them our perspective on the pedagogical content knowledge (PCK) that we considered adequate for the teaching process (Shulman, 1986; Shkedi, 1998), we recently developed a teacher's guide for this developmental biology curriculum (Falk et al., 2003).

When designing the guide, we took into consideration several factors found to influence the use of curriculum guides by teachers: (a) teachers' lack of motivation in using curriculum guides; (b) the variety of teachers' expectations; (c) the teacher's autonomy; (d) the context, language and system of beliefs; (e) the appropriateness of the written medium:

*Teachers' lack of motivation in using guides*: As a general rule teachers overlook the use of curriculum guides even though they recognize their importance (Fullan, 1991; Shkedi, 1995). It has been reported that teachers use the students' books as their guideline in teaching, thus impeding the necessary communication between the developers and the teachers expected to occur via the guide and promoting the tyranny of the textbook (Ben-Peretz, 1990).

*The variety of teachers' expectations*: When teachers do consider using a curriculum guide, their expectations are diverse, as they stem from previous content, pedagogical knowledge and experience of each teacher (Abulafia 2003). Some reports have found that teachers are mainly interested in class activities and subject matter, both very practical subjects; they are much less concerned about the intents of the developers (Ben-Peretz, 1981; Shkedi, 1995).

*The teacher's autonomy:* Another important aspect of curriculum guides is the amount of autonomy that the guide should provide to the implementing teacher. There is evidence that teachers tend to cherish their curricular autonomy, and that the autonomy feeling is an important element in facilitating the teachers' appropriation of the curriculum (Ben-Peretz, 1981; Ben-Peretz, 1990; Shkedi, 1995). The requirement for autonomy reflects the teachers' professionalism in the field and their refusal to hand it over to outside experts (Skedi, 1995). Others view the autonomy requirement as stemming from the educators' opinion that teaching is a craft in which teachers must inventively adapt general precepts to each teaching situation (Harris, 1983), hence rigid recommendations are unproductive. While Eisner's idealized vision is of good curriculum materials, that both educate and emancipate teachers (Eisner, 1990), Shkedi is convinced that, in the eyes of the implementing teachers, the curriculum guide cannot fulfill both functions simultaneously, i.e. combine a clear pedagogical content approach and autonomy (Shkedi, 1998). Shkedi's data seem to argue that there is no equal partnership between teachers and curriculum developers and that teachers do not view the suggestions and approaches of the teachers' guides as an emancipating tool for innovation and change.

*The context, language and system of beliefs*: It has been suggested that for a curriculum guide to fulfill its role and be used by the teachers, it should stem from the context in which the teachers work. It should advice from the teacher's point of view and use the language that teachers use in their working context. Moreover, the writer of the guide should understand, consider and use the same system of believes as the teacher (Harris, 1983; Olson, 1983).

*The appropriateness of the written medium*: The complexity of the class situation in which the teachers have to implement the PCK of the curriculum raises additional problems as it is difficult to train professionals for complex practice environments, and still enable flexible responses (Spiro et al., 1988; Eilam et al., 2004). Learning to function in ill-structured situations, like the classroom, cannot be achieved by the compartmentalization of knowledge that may lead to oversimplified interpretations and decision making. This compartmentalization is inherent to written media. Westbury (1983) also raises questions about the appropriateness of the written medium for the communication of practical understanding. Westburry (1983) asked "Is it possible to encode information about something that is as action oriented as is teaching within the limitations that are inherent in the static conventions of a written medium?". Similar doubt was raised by Shkedi's (1995) research that stressed the advantage of workshops compared to curriculum guides in conveying educational practices.

All of the aforementioned considerations lead us to design the curriculum guide for the unit "The secrets of embryonic development: study through research" as a multimedia guide on CD-ROM. The main characteristics of the guide are the inclusion of a pool of questions and activities that can be edited by the teachers and a collection of video-taped authentic teaching episodes. Both were aimed at providing the teachers with environment-effective advice while enhancing their feeling of autonomy. We expected the guide to provide a scaffold for the acquisition of the pedagogical and content tools provided and support the teachers in the appropriation of these tools. Moreover, we hoped that at a later stage of the process of curriculum implementation, the teachers would feel confident to devise, with the help of the teaching models provided in the guide, their own tools oriented toward the same pedagogical aims.

The specific questions we faced while designing the guide and evaluating its effectiveness were:

1. What novel teaching models and pedagogical tools could be offered to teachers, in order to facilitate the teaching of biological contents and skills associated with teaching and learning through adapted primary literature?
2. What are the most effective ways of enhancing the permeation of the provided tools into classroom practice?
3. To what extent would the teachers appropriate the tools and strategies we offer and develop self-confidence in teaching through adapted primary literature?

## 2. Methodology

### 2.1- Designing the guide

A curriculum guide to the unit "The secret of embryonic development – study through research" was gradually developed during the first three years of the unit implementation. According to the design research principles which we adopted, we developed teaching strategies and tools, used them in training workshops and circulated them among the pilot group of teachers that implemented the unit. We used different forms of inquiry, in order to establish the suitability of the strategies and tools to the class setting and the teachers' readiness to use them. Subsequently, we altered the materials provided, developed additional materials and adapted new teaching tools, which were suggested by the teachers themselves.

#### 2.1.1- Teachers' population during the design stages

A group of eight high-school biology teachers volunteered to teach the curriculum in three iterative teaching cycles during the initial stages of development of the teacher's guide (two teachers during the first year, three teachers during the second year and three teachers during the third year – one of the teachers taught the curriculum during three consecutive years). An additional group of five teachers participated in a workshop during the last stage of the development and in parallel implemented the curriculum in their classrooms. All the participating teachers taught the curriculum in $11^{th}$ and $12^{th}$ grades, who studied towards the matriculation exam in biology, in urban high-schools in Israel. The syllabus for the biology studies in Israel includes, in addition to basic topics, advanced topics, designed for 30 hours of teaching. The matriculation exam includes open questions on these advanced topics.

#### 2.1.2- Design stages

1. The conversational model for teaching and learning through research articles (Yarden et al., 2001), as well as additional teaching strategies, were presented to the teachers during 2 to 3-hour developers-teachers meetings.

2. A first collection of guiding questions and activities for the introduction of the curriculum and for the research articles as well as their answers was developed and given to the teachers.

3. Teaching sessions, in three different schools were video taped. The video tapes were

used during training workshops in order to follow up on the teaching process, identify students' difficulties, and illustrate the teaching process through adapted research articles to teachers that have had no previous experience in teaching through this genre. At a later stage, the episodes were edited and included in the curriculum guide.
4. Some of the difficulties met by students who learnt through adapted research articles were mapped and remedial measures were designed in order to overcome the problems that had surfaced.
5. The last stage in the development of the guide was used as the basis for a teachers' workshop (56 hours). A group of five teachers participated in this workshop, and in parallel implemented the curriculum in their classrooms.

### 2.2- The implementation process

In order to characterize the extent in which the teachers succeeded in implementing the pedagogical aims of the curriculum and the curriculum guide impact on this process, we interviewed four teachers that implemented the curriculum in their classes. The four high school teachers we interviewed - Hanna, Noa, Sigal (female) and Gil (male) (not their real names) are experienced teachers (more than five years of teaching experience) and had MSc degrees (three teachers) or a PhD degree (one teacher) in Biology before they began their teaching career. Noa's and Gil's research involved topics in developmental biology. Even though several years have passed since they finished their biological research, all four teachers still enjoy recollecting episodes from their previous research experience.

These teachers volunteered to teach the curriculum based on adapted primary literature following previous acquaintances with the developers (Gil), or following a training workshop of 56 hours. During the training workshop the developers taught the articles of the curriculum by implementing the conversational model and other teaching strategies. The teachers began to teach the unit in 12$^{th}$ grade (Hanna, Noa and Gil) and in 11$^{th}$ grade (Sigal) during the 2003-2004 academic year. From the start of teaching the curriculum we provided the teachers with the "Pool of questions and tasks" and with the section "Why and how to teach through research articles?" from the curriculum guide.

During the interviews the teachers were also exposed to a teaching episode from the curriculum guide and were asked to comment on it. The 60-90 minutes semi-structured interviews were conducted at the teachers' homes or schools, recorded using a Sony mini-disk recorder device and transcribed by one of the authors. The interviews were analyzed using the ethnographic-qualitative approach (Guba & Lincoln, 1998).

## 3. Description of the curriculum guide

The CD-ROM format was chosen for the curriculum guide because it enabled us to present the teachers with:
1. Authentic teaching episodes;
2. Visual models of molecular topics;

3. A gallery of all the pictures in the student's book in a format that allows their use for presentations in the classroom;
4. Web-quest assignment in bioethics;
5. A pool of questions and activities to the introductory section of the curriculum and to the research articles.

In addition, the guide contained the following textual information:
1. An introductory section entitled: "Why and how to teach through research articles". This section presents the developers' opinion about the need to expose the students to research articles and their recommendations about possible means to teach through adapted primary literature;
2. Remedial measures for the difficulties encountered by the students;
3. Activities aimed at enhancing the understanding of different forms of scientific communication;
4. A list of the main biological principles of the articles;
5. Assessment questions from matriculation examinations.

Here we shall further describe and discuss those sections of the guide that we consider to be most relevant to the process of studying through primary literature and which were purposely developed in order to provide support to this novel mode of teaching biology in high-schools in Israel.

### 3.1- Teaching strategies

The teaching strategies presented to the teachers in the section "Why and how to teach through research articles?" were previously described in detail (Yarden et al., 2001). The main strategy we developed was the "conversational model" based upon an iterative process of constructivist discourse between the students and the article, according to the following stages:
1. The article is read in class, section by section. The students raise questions on each section of the article.
2. Some of the questions are answered by the students by reading the following section.
3. The students make predictions about key elements of the research (research questions, results, suitable methods, conclusions) before reading about them in further sections of the article.
4. This study process can be repeated for each section of the article.

Other teaching strategies proposed were peer-group cooperative reading, and answering questions and jigsaw-groups presentation of different methods or experiments from the article. The teachers were told to choose the strategy that suits them best or to use any strategy they felt would suit their pedagogical aims. Only two main recommendations were given: (a) to proceed gradually, using more guided strategies at the beginning of the teaching process and moving toward strategies that offer the student more independence, and (b) to vary the teaching strategies as much as possible.

### 3.2- Authentic teaching episodes

The video taped teaching episodes, lasting from 3 to 10 minutes were subtitled and accompanied by the following texts:

1. Description of the background of the recorded episode: school, class grade, previous articles studied by the students, the aim of the study session and the teaching sequence of the session including the recorded episode;
2. Description of the episode: stage-by-stage description of the events occurring during the episode, without any comments (e.g. "The teacher waits for a long time before the first student answers");
3. Pedagogical comments on some of the main didactic and cognitive processes which occurred in the episode. The teachers are explicitly told that these comments solely reflect the authors' view and they are prompted to elaborate upon their own interpretation of the events whenever they feel it necessary.
4. Open questions, asking the teachers to compare the interventions in two or more episodes, or to elaborate on alternative teaching strategies.

The episodes can be watched without viewing the accompanying texts or concomitantly with the scrolling of one of the texts.

We expected that watching the teaching episodes and analyzing them would lead the teachers to:

- Realistic expectations which may enhance the self-confidence needed for successfully coping with the novel teaching environment of using adapted primary literature
- Context-sensitive modeling stemming from a "virtual" apprenticeship of the novice teachers with the "role models"
- Critical analysis which would include an inherent comparison between the novice teacher's personal teaching style and the "role model" teacher performing in the episode

### 3.3- Pool of questions and activities

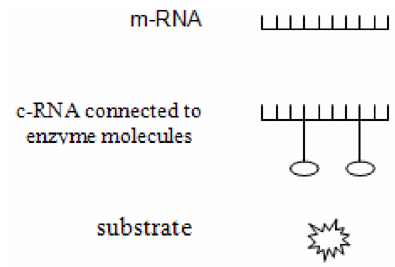
A copious number of questions and activities were developed for each section of the introductory unit and research articles. The teachers were presented with the questions and their answers and in some cases pedagogical comments were added. In the introduction to this section of the curriculum guide, the teachers were presented with a categorization of the questions and were encouraged to use the examples provided (similar to the ones presented in Table 1) as a template in order to formulate their own questions.

By integrating a variety of questions into the teaching process through primary literature, we hoped to facilitate the creation of a dialogue between the student and the content of the article. The logically structured order of the article sections sometimes conveys, to the novice reader, a false feeling of comprehension. The questions on the article are supposed to unravel this false feeling and to compel the student to look for a deeper understanding and for new connections between the ideas presented in the article and the students' previous knowledge (Brill et al., 2004). The teachers were encouraged to use only those questions and activities they feel are best suited for their aims and their students' cognitive level and to modify them using the standard Word tools. It was thought that the fact that teachers can choose from a collection of questions and modify them according to their needs, may enhance the appropriation of the questions and their usage.

We categorized the questions provided according to the cognitive skills required from the student and the content field sampled by the question, as shown in Table 1. We found this categorization to be suitable for addressing the main aims of teaching through adapted primary literature (Yarden et al., 2001): acquaintance of the students with the nature of scientific research, understanding of the rationale behind the research plan and methods and critically asserting the goals and conclusions of the scientific research. Some of the activities are in accordance with the stages of the "conversational model"- formulating questions, making predictions and finding answers in the subsequent sections of the article. Several questions and activities were added as remedial measures after mapping students' difficulties in studying the adapted primary literature (data not shown).

Table 1. Sample questions or activities from the teacher's guide

| Category | Sample question or activity from the teachers' guide |
|---|---|
| Knowledge organization | Write down the differences between maternal and zygotic genes that determine the embryonic development, considering: the cells in which these genes are transcribed, the transcription time since the fertilization and the stage in which the protein products of these genes are active in the cell. (for the article "Genetic regulation of the developing Drosophila embryo head"). |
| Inquiry skills: | Design an experiment in order to investigate the hypothesis that during two and a half hours after fertilization, the embryo's genes are not transcribed. (for the article "Genetic regulation of the developing Drosophila embryo head"). |
| Critical assessment of the article conclusions | "1From this evidence it is possible to conclude that *myogenin* is not essential when cells begin to differentiate to muscle cells, but… [2]without *myogenin* expression the differentiation will not occur." Write down evidence for each part of this statement from the Discussion section. (for the article "Lack of skeletal muscles in new born mice bearing a mutated myogenin gene). |
| Application of the main ideas of the article in other contexts | The biotechnology company "Moneygen" reported a sensational success: the production of myogenin containing pills for athletes interested to improve their performances without sweating. The competing company "Musclegen" is also advertising a natural product intended for athletes: their product is a natural plant extract that was shown to increase the myogenin production in mice embryos. As a gym fan, would you use these products? Justify for each of the applications. (for the article "Lack of skeletal muscles in new born mice bearing a mutated myogenin gene). |

| | |
|---|---|
| Understanding the methods rationale | Which of the following methods could be used in order to establish when and where are the myogenic genes expressed during embryonic development?<br>a.extraction and analysis of DNA from different embryo tissues<br>b.extraction and analysis of m-RNA from different embryo tissues<br>c.in situ hybridization of embryo tissues with c-DNA of a myogenic gene<br>d.protein extraction and analysis<br>e.in-situ reaction of embryo tissue with antibodies against myogenic proteins<br>f.detection of muscle cells in different tissues. (for the article "Lack of skeletal muscles in new born mice bearing a utated myogenin gene).<br>Draw the molecular complex that is formed in embryos when using the c-RNA detection method. (for the article "Genetic regulation of the developing Drosophila embryo head")<br> |
| Highlight the main developmental biology ideas of the article | Three groups of genes influence the embryonic development according to the following hierarchy:<br>- genes that regulate the expression of the *bicoid* gene<br>- the *bicoid* gene that encodes for the morphogene of the head formation<br>- genes involved in the head tissue formation and controlled by the product of *bicoid* gene<br>Which group would you expect to be expressed earlier during the development?<br>If a mutation occurs in a gene belonging to one of the three groups, in which group is it expected to have a more critical influence? (for the same article). |

## 4. Evaluating the use of the curriculum guide through teachers' interviews

To expose the reactions and comments elicited by the teaching episodes included in the guide and to recognize their possible benefits, we watched, together with each teacher, one videotaped episode from the curriculum guide. We were interested in the extent to which the teachers would be aware of the complex classroom situation presented by the movie and how they would react considering their experience in implementing the curriculum. Hence, an additional focus of this analysis was the variation in the teacher's comments, expected to implicitly and explicitly reflect their previous experience with teaching through adapted primary literature. After watching the episode, we asked the teacher some of the questions provided in the section "Questions to think about" that accompany the movie, without the teacher is being aware that the questions were included in the guide.
In the episode presented to the teachers, a class studying the Methods section of the article "The Hedgehog gene mediates the activity of the polarizing zone of the limbs" is shown. The students are attempting to understand how it is possible for a virus, which they previously encountered only as a pathogen, to be used as a vector in order to introduce a gene into tissue-cultured cells. The impression of the authors was that in order to deal with students' difficulties, the teacher merely repeats her explanations several times, and does not implement any focused strategy while waiting for the students to understand the concept of the virus as a vector. The four teachers had not seen this episode previously and were not acquainted with the teacher involved.

### 4.1- The reasons for volunteering to teach the curriculum

To further analyze the outcomes of the teaching process, we investigated the reasons the teachers had chosen to teach the curriculum. We found that the teachers' choice stemmed from three main reasons:
1. The content of the curriculum - Noa's and Hanna's enthusiasm to teach a molecular subject in general, or developmental biology in particular.
*"I said to myself, this is almost the only subject you teach that is based on 20th century research instead of 17th or 18th century"* (Hanna).
2. The genre of the curriculum - the belief that high-school students need to learn a subject through research articles.
*"To show the students the real world. They study, but they don't know what happens beyond. The one that studies biology doesn't know what the expert is doing. Is he a biologist? What is he doing? So I teach them and they begin to know. …because in the school laboratories they are doing everything in the opposite way. A real researcher never comes and the technician hands him a tray with all the materials and the protocol. He first of all asks questions"* (Gil).
3. Practical reasons to become acquainted with the curriculum before it becomes compulsory in the high-school syllabus (Sigal).

### 4.2- The teaching process

Two main aspects surfaced when teachers elaborated on the way they teach the developmental biology curriculum. They found that the main difference between using

research articles versus textbooks for teaching was being able to raise inquiry questions and answer them. In addition, all the teachers noted the relatively large number of inquiry questions which were raised by the students when learning through research articles.
"*Now I remember, they had questions I didn't know how to answer. For instance, they told me, look, you use a complementary probe, right, c-RNA, you have to know the right sequence in order to prepare it, right? So how will you know? It didn't bother me that I didn't know how to answer, it shows that they understand, that they begin to ask nice questions*" (Hanna).

The second aspect emphasized by the teachers was the research methods. The methods are the main characteristic of research articles that are usually absent from textbooks. The teachers reported feeling that they had to focus on the methods because of their importance and because understanding them was one of the main difficulties met by students.

The "conversational model" was implemented by all the teachers, to different extents. The teachers expressed satisfaction from the model and reported that the strategy suited teaching through research articles.
"*The dynamics that is created with all these questions and this deliberation, you almost don't study contents, you learn to deal with an article. So the discourse is at a completely different level. There is a discourse. It's not one-way traffic of information, as when the teacher teaches and the students answer or ask. That's what I like*" (Noa).

Sigal reported that she also enjoyed "the conversational model", for different reasons.
"*As they work in the class it becomes easier than when I give them home assignments. They all participate and they don't drag out some unprepared assignments. So there is an advantage, kind of a dialogue, class work*" (Sigal).

Noa reported applying the "conversational model" for all the three articles included in the unit, while other teachers reported only being able to apply it to the first article studied as the students got bored with its slow pace and were interested in applying other, more independent strategies.
"*I also had the feeling that after they get it [the conversational model] students internalize it and they apply it already by themselves*" (Hanna).

Gil mentioned that the common denominator of all the teaching strategies he used was their student-centered nature, in which the students play an active role in the teaching process. His choice of teaching strategies was dictated by the students themselves since "*if I would have begun to use frontal teaching I would have found myself alone at the end of the session*"(Gil).

#### 4.3- The pool of questions and activities

We were aware that teachers might feel compelled to use all the questions provided in the guide, thus making the teaching process unreasonably slow and tedious. When presenting the rationale underlying the pool of questions and activities, we urged the teachers to use only those that they thought might be useful for their students. We hoped that the fact that they were able to easily edit their own worksheets, would encourage a discerning approach.

In spite of this, Noa reported to have used all the questions, with no difficulty for her or her students. She was video taped in a sequence of three episodes which were subsequently used for the teachers' guide, leading a whole session around two questions from the guide. Gil used mainly activities requiring the students to use molecular concepts in explaining cellular processes, or activities requiring the mapping of molecular concepts. His preference was congruous with the fact that his students had difficulties dealing with molecular concepts. Sigal reported using only questions referring to the introductory unit of the curriculum, arguing that in her opinion in the introductory unit she had to focus on teaching content whereas while studying the articles, the focus was on understanding the rationale of the research.

All four teachers elaborated on the importance of the pool of questions and activities, in contrast to possible superficial reading of the article which may occur without the usage of the questions.
"*Sometimes the better students feel it's too easy… again the same old story of thinking science. They [the scientists] take from here, move there. It seems trivial to the good students. These questions, it's the same experiment they know, but suddenly a small twist [by a question from the teachers' guide]… these things are very important*" (Gil).
A somehow unintended outcome was the fact that the teachers used the questions and the answers to the questions as an ad-hoc guide to content knowledge.
"*Some of the questions opened my eyes to see the things, pointing to a difficulty that I didn't pay attention to when I read the article*" (Hanna).

#### 4.4- The videotapes of teaching episodes

A variety of comments surfaced in response to the videotaped teacher's attempts to help her students understand the rationale behind using a virus as a vector. Hanna considered this to be a process of focusing on the important points of the method, by distinguishing between the main rationale and the less important details. Gil also agreed with the teacher's strategy and defined it as "guided inquiry" – he considered the slow pace that the teacher deployed as an advantage, as it provides the students with the required "time on task" to reach understanding by themselves. Noa interpreted the teacher's behavior as "flowing" with the students: first of all she allows them to try and understand by themselves and her intervention is no more than a "translation" of the students' own words into a better formulated style.

The only one critical of the teacher's reaction was Sigal: "*It will only take longer time, the way she wants to make them understand by themselves, it will take a long time*". As the interview progeressed, Sigal exposed her beliefs about teaching, further clarifying her attitude towards teaching through research articles: "*The way I see teaching, I think that today we exaggerate; we want the students to reach everything by themselves. I feel that they didn't acquire more knowledge or comprehension…you can't manage all the teaching like this, as comprehension should be based on knowledge*".

Her view that content knowledge should be explained explicitly by the teacher and constructivistic approaches should be used only to acquire inquiry skills is further detailed in the following: "*First of all, I would say, that the student should arrive to the article only after he already knows 70% of its contents. The methods and everything. Because the article should elicit thinking but it can't be that it will all be new to the student. I want to teach inquiry skills through the article, but in my opinion the article should come later, after the student has acquired the knowledge*". Sigal's comment was important to us as it illustrates a perspective which is different from ours, but probably prevalent among high-school teachers: that the acquisition of knowledge and skills should be separated.

The role of the teaching episodes presented in the guide were viewed by the teachers on several levels:
1. Presentation of the teaching environment unique to this curriculum and its characteristics such as students' questions, situations that reflect the students' lack of essential prior knowledge. This simulation of the classroom situation challenges the teachers to perform adequately: "*To figure out to what point you should drift with them [the students] and ask yourself should I join them, shouldn't I, should I take them into another direction?*" (Hanna).
2. Watching and appropriating different teaching strategies: "*Here, she [the teacher] is using it nicely, here she is focusing on how to conclude from the experiment. That I buy*" (Sigal).
3. Planning of teaching using research articles: "*You learn what to emphasize*" (Noa).
4. Allowing the experienced teachers to compare the performing students to the students in their own class: "*This is a question that my students raised as well, this virus matter, will the virus harm the cells or not*" (Gil).
6. Enhancing the self confidence of the novice teacher, before he starts teaching using research articles: "*Yes, I think he will see that he is capable of doing it, he might think that it will be difficult, a subject at the leading edge of science, 'maybe I will not make it',* [but] *you see it's possible* (Gil).

## 5. Comments and conclusions

The use of adapted primary literature with high-school students to study a biological subject may enable the achievement of many scientific literacy goals, including understanding the nature of science and developing inquiry skills. Adequate teaching strategies are required to harness the benefits of the adapted primary literature genre toward the fulfillment of these goals. The purpose of the multimedia curriculum guide was to convey our view on the PCK of study through adapted primary literature, without impeding the teacher's requirement for autonomy.

Since the beginning of the implementation of the curriculum based on adapted primary literature in high-schools, two studies have been performed to characterize the learning process using this genre. The first was a laboratory study (Brill et al., 2004), in which the learning processes of two students reading an article and answering questions from the pool were characterized. The other study reported on an increase in the number of higher-level thinking questions formulated by students during the study of an article from the curriculum (Brill et al., 2003). The present study was a first attempt at characterizing the teaching process through adapted primary literature using reports from teachers who had implemented this teaching in their classrooms. As several parts of the curriculum guide were offered to the interviewed teachers from the beginning of the implementation process, the teachers' opinions about the guide were very strongly connected to their opinions of the teaching process.

While investigating the process of teaching using research articles with the aid of the guide, we found that the videotaped class episodes that are included in the guide facilitate the simulation of teaching situations that occur while studying through adapted primary literature. We found the teachers' stimulated reactions to be consistent with their teaching experience and values, and to a certain extent with their short experience in teaching our curriculum. We assumed that the comments that the teaching episodes elicited were influenced by the reductive bias known to manifest itself when interpreting recorded events (Spiro et al., 1988; Eilam & Poyas, 2004). We harnessed this bias in order to tap into important information on the teaching philosophy and strategies of the interviewed teachers.

By analyzing the teachers comments on the pool of questions and activities, we understood that it not only provided them with an easily adaptable teaching tool, but that through this tool we had also conveyed our PCK perspective. However, since we prompted the teachers to edit and thus appropriate only those questions they felt were suitable for their students, the usage of the questions also reflected the teaching values of the individual teachers. For example, in the belief that the article should not be used in order to teach contents, but only inquiry skills, one of the teachers used only the questions provided for the introductory unit. Considering the molecular concepts and transfers between macro-micro levels to be a main difficulties for the students, one of the teachers used mainly tasks addressing this topic. The teachers even adapted the questions and activities to pedagogic usages which we had not intended. For example, one of the teachers used questions from the pool as a central axis for a teaching session. We encountered this approach while videotaping one of the teaching episodes and, due to the design research approach that we had adopted, in the final version of the guide, this opportunity is mentioned to the teachers. Moreover, the pool of questions and their answers were used by the teachers to gain self-confidence with the content knowledge of the curriculum. These various usages strengthen the opinion that curriculum materials are far richer in their potential than is envisaged by their developers (Ben-Peretz, 1990).

The teachers reported that by providing them with an ample and flexible pool of questions and activities, we influenced the learning discourse in class, leading to a question-rich culture eliciting students' questions. "*They had questions I didn't know how to answer*" (Hanna); "*The dynamics that is created with all these questions and this deliberation, you almost don't study contents, you learn to deal with an article*" (Noa). The importance of teachers' questions to the enculturation of students in asking their own questions has been previously reported (Morgan, et al. 1991; Durham, 1997). The question rich environment created during studying through adapted primary literature is also in accordance with previous reports about the usage of research articles (Brill & Yarden, 2003) and case studies (Dori et al., 1999) as catalysts for students questions. In this study, we cannot separate between the effect of the adapted primary literature and that of the conversational teaching strategy applied during the study sessions in eliciting students' questions, since all the interviewed teachers implemented the unit by applying the "conversational model". Sadly, it seems that this beneficial effect is not of long duration and that both students and teachers associate it only with the adapted primary literature curriculum. When one of the teachers (Sigal) was asked if the "different discourse" continued when the students started to learn a new subject, she said that it completely stopped and that she herself considers it to belong only to study through primary literature.

The conversational model (Yarden et al., 2001), the aim of which is to lead the students to actively build their own knowledge structure while reading an article, uses elements of text-based learning (Pearson & Gallagher, 1983; Epstein, 1970). The fact that this model was used by the teachers when teaching through the research articles indicates that they were prone to adopt the main teaching strategy offered by the guide, negating our former concerns that it is difficult to promote change in teachers' strategies. Our interpretation of this finding is that when dealing with a subject based on new content (developmental biology) and presented in a novel way (research articles), teachers adopt new teaching strategies more easily. However, further analysis of the teachers interviews indicated that although most of them (Noa, Gil, Hanna) reported to have used teaching strategies conveyed by the developers, they mainly adapted previously held beliefs and teaching strategies. The advice in the guide merely rendered these strategies legitimate and their usage more conscious. Furthermore, with respect to this outcome, we cannot at this stage separate between the contribution of the guide and the contribution of the workshop in which the teachers participated (Shkedi, 1998). In other words, we can interpret the changes that occurred in the teaching strategies used by the teachers as belonging to their professional development within their zone of proximal development (ZPD) (Vygotsky, 1962).

The application of the ZPD concept in relation to teachers' development through curriculum materials (Eisner, 1990; Pontecorvo, 1993; Wells, 1999) implies "bringing to life those functions [of teachers] which are embryonic and require conscious control" (Pontecorvo, 1993). Our results indicate that the implementing teachers that we monitored by us were acting within their ZPD, on the growing edge of their competence and the guide provided them with the scaffolding necessary for growth. This is the reason why, in analogy to Smith, di Sessa and Roschelle's recommendation to gradually recraft existing novice knowledge instead of attempting to create a cognitive conflict when teaching new concepts (Smith et al., 1993), we feel that such an attitude can also be fruitful when dealing with teachers' development and when designing curriculum guides.

The different ways in which the teachers chose to implement the unit demonstrate the flexibility of our materials, allowing the teachers to express their individual approaches to teaching and to their classes (Ben-Peretz, 1990). As good curriculum materials should provide resources that amplify the teachers' ability given the circumstances (Eisner, 1990), it seems, according to the idiosyncratic interpretation of the tools provided in the guide by the interviewed teachers, that the curriculum guide we designed both educated and emancipated the implementing teachers.

However, it should be borne in mind that the teachers that volunteered to implement the curriculum are in no way representative of the average biology high-school teacher. Not only are their education level and research experience higher than required for teaching biology in high schools in Israel, but their educational values, as expressed when referring to the reasons for teaching the unit were very similar to the values of the developers. Gudmundsdottir (1990) stated that teachers' values, "passion combined with a sense of mission", can influence the restructuring of curricula. These values permeated the narratives of three of the interviewed teachers, whereas one of them (Sigal) held values which are different from the developers'; she remarked that one cannot teach contents through primary literature, only inquiry skills and she found the implementation process more frustrating. We feel that it may be common to evaluate curricular material by monitoring the teachers whose values induce them to be among the first to volunteer to implement that curriculum. Therefore, when studying through adapted primary literature becomes a compulsory requirement of the syllabus in Israel, we plan to evaluate how teachers who hold other values and have no previous research experience are able to implement it and how helpful the curriculum guide is in assisting them in their endeavor. Analyzing a larger sample of teachers, supplied with the complete curriculum guide, will also enable us to evaluate what sections of the guide are most useful to the teaching process. In addition, we shall attempt to determine whether observing the teaching episodes will also model the teaching strategies to be used by teachers who teach another primary-literature-based curriculum in biotechnology (Falk et al., 2003), for which no teacher's guide is yet available.

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# LEARNING GENETICS THROUGH AN AUTHENTIC RESEARCH SIMULATION USING A WEB-BASED LEARNING ENVIRONMENT IN BIOINFORMATICS

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## Abstract

Following the rationale that learning is an active process of knowledge construction as well as enculturation into a community of experts, we developed a novel web-based learning environment in bioinformatics for high-school biology majors in Israel. The learning environment enables the learners to actively participate in a guided inquiry process by solving a problem in the context of authentic research in genetics. Through the learning environment, the learners are exposed to a genetics problem which was developed on the basis of a research in which a mutated gene, which causes deafness, was identified. They follow, step by step, the way scientists try to solve it, using the current geneticists' toolbox. The environment uses an adapted version of the BLAST program (a bioinformatics tool which enables to find similarities between sequences), which was modified in a way that enables the teachers and students to use it easily. Using quantitative and qualitative research approaches, we were able to show that learning through the bioinformatics environment promotes construction of new knowledge structures and influences students' acquisition of a deeper and multidimensional understanding of the genetics domain. In addition, learning through the bioinformatics environment influences students' comprehension of the practices and scientific ways of thinking.

## 1. Introduction

According to the constructivist learning theory, individuals have their own ways of constructing knowledge, and learning can be achieved through an active process of construction (Greeno et al., 1996). Curricula in science education should, therefore, encourage active learning, and allow students the opportunity to construct their own knowledge. According to the situated learning theory, learning is a process of enculturation into a community of experts (Brown et al., 1989), and the retention and application of knowledge depend upon the context in which it is acquired (Lee & Songer, 2003). Therefore, science educators should integrate authentic 'real-world' tasks from the scientific community in order to support the culture of science in classrooms (Lee & Songer, 2003). These two views are not necessarily contradicting, since learning can be viewed as a combination of these processes (Cobb, 1994). One practical way to combine these two views is to provide learners with opportunities to engage in cognitive activities similar to those carried out by scientists, while adapting the content of the activities to the learners' cognitive level.

Biology education, like in any other discipline, strives to familiarize biology students with the knowledge, practices, and thinking processes of the scientific community. Over the past two decades, advances in the field of molecular biology coupled with advances in genomic technologies, especially due to developments in the human genome project, have led to an explosive growth in the biological information generated by the scientific community (Collins et al., 2003; NCBI, 2004). The deluge of genomic information has led to an absolute requirement for computerized databases to store, organize and index the data and has pushed for the development of specialized tools for viewing and analyzing it. These have brought about the emergence of a new field: bioinformatics (NCBI, 2004). Progress in this field has changed some of the aspects of research currently conducted in biology. For example, the current geneticists' toolbox is composed of classical genetics approaches, lab-based molecular biology methods and computer-based bioinformatics tools, which are all put to use for the study of the function of genes in relation to phenotype.

The work presented here should be viewed in the context of the recently expanding research on students' understanding of the structures, processes and mechanisms of genetics. A few researchers have reported on students' difficulties in acquiring a coherent cognitive model of the domain, and claimed that the students' major obstacle is to form a conceptual continuum between the characters and the molecular mechanism involved (Marbach-Ad & Stavy, 2000; Stewart & Rudolph, 2001; Knippels, 2002; Lewis & Kattmann, 2004). Lewis and Kattmann (2004) reported that many biology students (ages 15-19) hold an 'everyday' alternative conception of genes as an abstract component equivalent to phenotype and are not aware of their chemical characteristics. They suggested that this alternative conception might restrict students' ability to develop an understanding of the scientific explanations.

These findings led researchers in the field to explore means of helping students recognize the inadequacies in their explanatory model of the genetics domain in order to close the gaps in their cognitive model. For example, Stewart and Rudolph (2001) used conceptual problems in genetics as a tool for constructing new knowledge. Knippels (2002) used problem-solving across biological organization levels. Hickey et al. (2003) developed GenScope software which represents the various levels of organization, and Lewis and Kattmann (2004) recommended beginning teaching with a discussion of observed phenomena related to heredity and connecting them to the molecular mechanism involved. In addition, Cartier and Stewart (2000) suggested that for students to truly understand genetics, they should understand how the specific subject-matter knowledge had been generated and justified through the process of inquiry. Combining these views, we have developed a learning environment that exposes students to the inquiry process in the field of genetics and bioinformatics (Gelbart & Yarden, 2001), by introducing them to a scientific problem that scientists were concerned with and that could be solved using procedures and tools that are commonly used by geneticists. The learning environment enables the learner to participate in an inquiry process in the context of an authentic scientific problem with the aim of identifying a particular gene in the genome.

Our aim was to examine the possible influence of learning genetics through the bioinformatics learning environment on students' comprehension of the genetics domain and their acquisition of inquiry skills. In this paper we introduce the recently developed learning environment of bioinformatics, present an initial characterization of the way students learn and comprehend genetics concepts, and demonstrate the development of inquiry skills using this environment.

## 2. Description of the learning environment

We focused our efforts on developing an environment that would drive the students to use existing domain knowledge structures in genetics, as well as construct new structures and represent knowledge in different ways, with the aim of solving a real problem within the discipline of genetics. To emphasize the authentic context, the learning environment begins with a brief description of the genome project, followed by invitation: "*We offer you the opportunity to participate in an exercise in which you will actively take part in the Human Genome Project. During the exercise, you will learn about some of the applications of the project from the viewpoint of a scientist. And who knows? Maybe one day you'll be taking part in it too.*"

The learning environment is composed of three main inter-related parts: the first consists of an interactive multiple-choice test, which can give an indication of the students' prior knowledge in genetics which they should be able to tap into, in order to succeed in the research simulation section. The test is accompanied by feedback that may support the students in answering the subsequent questions. The students' achievements on the test are graded on an evaluation scale. Thus, a teacher can use this test as a diagnostic tool to determine the students' actual knowledge.

The second part contains scientific information about the genome project, adapted to the cognitive level of high-school biology majors. This information includes the goals of the project, the main characteristics of the genome and some of the methods used in the genome project, such as mapping, sequencing and locating a particular gene in the genome. This part serves as a scientific background, which connects the high-school biology majors' curriculum in genetics, to knowledge and practices in the field. Since students make sense of what they are learning when they see a need or a reason for its use (Bransford et al*.*, 1999; Lewis & Wood-Robinson, 2000), a narrative story was included in the environment. The story is about Fernando, a talented 18-year-old rock singer, who would like to start a rock band. However, he may carry an inherited mutation that causes deafness at the age of 40, and in order to plan his career he would like to know whether he carries the mutation that causes this kind of deafness. Students are invited to give Fernando an answer by participating in the simulation.

The third part includes a simulation which was developed on the basis of a research paper that describes research in the field of genetics in the current genomics era: a mutated gene, which causes deafness in an Israeli family, was identified (Vahava et al*.*, 1998). In this research, a combination of classical genetics, molecular biology and bioinformatics approaches was utilized. The students participate in a guided inquiry process, in which they are exposed to a genetics problem and solve it step by step, similar to the way scientists tried to solve it, and in this way are introduced to the scientists' modes of thinking (see further on).

In this third part, the students are required to follow five different assignments which are designed to use approaches similar to those used by scientists who try to solve similar problems:
**i.** In the first assignment, students are asked to harness their knowledge and skills in inheritance problem-solving to determine the most reasonable inheritance pattern of a progressive deafness character that is present in a pedigree. This activity is anchored in the learners' prior knowledge and is common in genetics studies in high school. However, in contrast to typical school inheritance problems, in the problem presented to the students in this activity, finding the most reasonable inheritance pattern of a character that is present in the pedigree and its probability of occurring is not a complete solution, but rather the first stage in linking the phenotype to the genotype, i.e. connecting between the character and the molecular mechanism involved, as can be seen in the next assignment.
**ii.** In the second assignment, students are asked to map the mutation which causes deafness, as they learn about genetic markers and linkage maps using a worked-out example.
**iii.** In the third assignment, students learn about a model organism and how to use the bioinformatics BLAST tool (BLAST http://www.ncbi.nlm.nih.gov/) to find a candidate gene in a genome database. The environment uses a version of the BLAST program which we modified such that the teachers and students could use it easily. It also contains a genome database, which we downloaded to our server (last updated April 2001).
**iv.** In the fourth assignment, students compare the normal and mutated alleles using the BLAST-2-SEQUENCES tool (http://www.ncbi.nlm.nih.gov/), which was also modified for easier use by the biology students and teachers.
**v.** In the fifth assignment, students learn about the function of the protein encoded by the gene they have found and are invited to suggest their own future research questions.

Each of the assignments includes interactive multiple-choice and open-ended questions, in order to support the learner's understanding of the relevant genetics concepts. The questions focus the students on the problem that needs to be solved. In addition, they guide the solvers' attention to the main issues of the problem. Each assignment ends with a brief summary of the scientific ideas and concepts that were learnt through the previous assignment, and a question that may guide the learner to hypothesize the scientists' next step.

Preliminary results of the research we conducted in order to examine the possible influence of learning genetics through the bioinformatics learning environment on students' comprehension of the genetics domain and their inquiry skills are introduced in the following chapter.

## 3. Research methodologies

### 3.1- Sample

Twelfth-grade high-school biology majors (n = 19, 17-18 years old, 12 females, 7 males) gathered from two different classrooms towards the end of 30 hours of genetics instruction, who had learnt through the bioinformatics learning environment, were asked to respond to a questionnaire prior to their exposure to the bioinformatics learning environment (pre-) and to a similar questionnaire (post-) about a month after the learning process terminated.

In addition, six students from one of the two former classes, grouped into pairs, were observed and videotaped while learning through the bioinformatics environment in a laboratory setting. The students, who volunteered to participate in the experiment, were considered good students with above class average grades in mathematics and biology.

### 3.2- Quantitative analysis

A quasi-experimental design was used in order to evaluate the influence of the learning environment, using pre- and post-questionnaires which were distributed before and following the intervention. Students' questionnaires included 14 content-based comprehension and inference True/False questions. The students were required to respond to each statement and to provide an explanation for each of their responses. Students' explanations for eight of the True/False statements in genetics, which were emphasized in the bioinformatics learning environment, were collected and analyzed.

Twelve different types of explanations were identified in the students' answers. These explanations were classified according to their content, and the frequency of the different types of explanations in the pre- and post- questionnaires was calculated. In addition, students' were scored according to the explanations they used (0 – no explanation, 0.5 – an incomplete explanation, 1 – a complete explanation). Average scores for the 19 subjects (pre- and post-questionnaires) were calculated by Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988).

### 3.3- Qualitative analysis

A qualitative approach was employed in order to study the students' learning processes while using the bioinformatics learning environment. Six students, grouped into three pairs, were observed and videotaped while learning through the bioinformatics environment in a laboratory setting. The students were requested to start with the interactive multiple-choice test and then continue with the main problem-solving activity, and to speak aloud while doing it. The learning activity lasted for about 4 hours.

## 4. Results and discussion

### 4.1- Quantitative analysis of students' explanations

To study how using the interactive bioinformatics learning environment influences high-school biology students' comprehension of genetics, we examined the students' acquisition of domain knowledge and understanding of genetics concepts and processes, using the pre- and post-questionnaires. Students' explanations for the True/False statements dealing with genetics concepts which were emphasized in the learning environment were collected and analyzed. Twelve different types of explanations were identified in the students' answers and these explanations were classified into the categories of structural explanations and structural-functional explanations according to their content (Table 1). The structural category was further sub divided according to relation to the actual genetic material or to genome organization. The structural-functional category was further sub divided according to the relationships formed between the genetic material and the phenotype, or between genome organization and phenotype (Table 1).

Table 1. Explanations given by students to true/false statements in genetics, classified to structural explanations and to structural-functional explanations, according to their content.

| Structural explanations | | Structural–functional explanations | |
|---|---|---|---|
| Genetic material | 1. Different alleles of a particular gene have different DNA sequences. | Relationships between genetic material and phenotype | 4. The DNA sequence of a particular allele may be involved in the determination of a dominant/recessive phenotype.<br>5. Different alleles (stemming from different mutations of the same gene) may influence the probability of having a genetic disease.<br>6. An examination of the DNA sequence of an individual enables to determine if he has a tendency to become affected by a genetic disease.<br>7. A change in a DNA sequence of a particular gene may change the activity of the protein it codes for. |
| Genome organization | 2. The genes in almost all humans are located in the same position on the same chromosome.<br>3. The genes in almost all humans are located in the same position on the same chromosome, but the alleles of each gene may be different. | Relationships between genome organization and phenotype | 8. Differences in alleles almost always indicate normal differences between individuals.<br>9. A particular allele of a gene which exists in every human may affect an inherited disease.<br>10. Different alleles (stemming from different mutations of the same gene) may be involved in the determination of a similar phenotype (of a genetic disease).<br>11. A comparison between DNA sequences of affected and unaffected individuals enables to determine if an individual has a tendency to become affected by a genetic disease.<br>12. Most of the phenotypes resulted from multiple genes expression. |

The frequency of each of the explanation types in the pre- and post-questionnaires was calculated and the results are shown in Figure 1. The calculated students' average score for the pre-questionnaires was 4.053, S.D. 1.025, and for the post-questionnaires was 5.526, S.D. 2.017, $P < 0.05$. The difference in students' scores was not found in a control class that learned genetics using other instructional methods (data not shown).

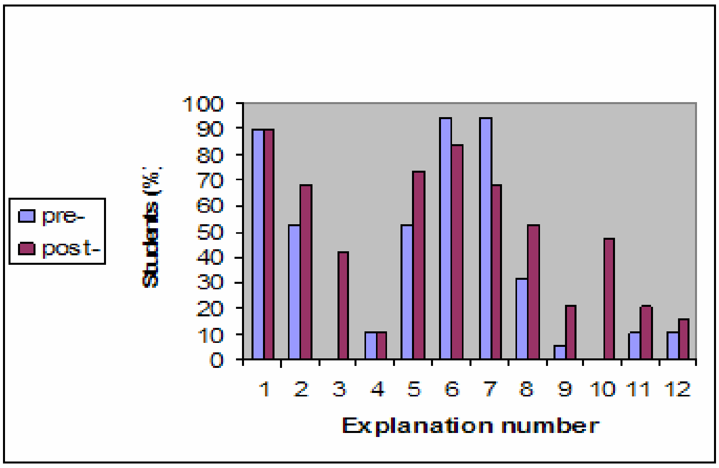


Figure 1. Students' types of explanations to True/False statements in genetics. Twelve different types of student explanations for True/False statements in genetics were identified using pre- and post-questionnaires. The frequency of each of the explanations was calculated as the percentage of students (out of the total number of students) who formulated each explanation. The explanation numbers correspond to the numbers that appear in Table 1.

Analysis of the students' explanations indicated an increase in the frequency of 8 of the 12 types of explanations (explanation nos. 2, 3, 5, 8, 9, 10, 11, 12) following learning with the bioinformatics learning environment. Six out of those eight explanations were classified in the structural-functional category. In addition, a decrease was observed in the frequency of two explanations (explanation nos. 6 and 7) and no change was observed in the frequency of two explanations (explanation nos.1 and 4) following learning with the bioinformatics learning environment.

Detailed content analysis of the types of explanations used by the students revealed that at the structural level, the students mainly acquired the knowledge that, in addition to the fact that genes in almost all humans are located at the same position on the same chromosome (explanation no. 2, Table 1, Figure 1), the alleles of each gene may be different (explanation no. 3, Table 1, Figure 1). At the structural-functional level, students mainly acquired knowledge of the relationships between the genetic material and the phenotype (explanation no. 5, Table 1, Figure 1), as well as in terms of the relationships between the genome organization and the phenotype (explanation nos. 8-12, Table 1, Figure 1).

The findings presented here indicate an improvement in the students' ability to formulate explanations that integrate genetics concepts after learning in the bioinformatics learning environment. These explanations represent the possible integration of the concepts of allele and DNA sequence with genome organization and phenotype. For example, the explanation "a particular allele of a gene which exists in every human may affect an inherited disease" (explanation no. 9, Table 1, Figure 1) involves an integration of concepts from various levels of organization within the genetics domain, such as gene-allele-chromosome and genotype-phenotype. Such an ability may indicate a deeper understanding of the biological mechanisms of genetics. The explanation "the genes in almost all humans are located in the same position on the same chromosome, but the alleles of each gene may be different" (explanation no. 3, Table 1, Figure 1) may indicate a meaningful understanding of genome organization and therefore the conception of a gene as a physical entity which has a specific DNA sequence and a specific location in the genome. This understanding was previously suggested by Lewis & Kattmann (2004) to be important in truly understanding the genetic mechanisms. It also indicates an understanding of the relationships between allele, gene and genetic polymorphism.

The decrease in the usage of the explanation "a change in a DNA sequence of a particular gene may change the activity of the protein it codes for" reinforces the same conclusion. This connection, which is emphasized during genetics instruction, deals only with the molecular level and neglects the phenotypic level. Marbach-Ad (2001) found that most 12th-graders' answers about the relationship between DNA-trait and gene-trait were correct, but that their explanations were general. We suggest that the improvement in the students' ability to formulate explanations which represent a possible integration of genetics concepts can be explained by their use of the bioinformatics environment, which contributed to their acquisition of a deeper understanding of the genetics concepts and processes.

**4.2- Qualitative analysis of students' learning processes**

In addition to our examination of students' acquisition of domain knowledge and understanding of genetics concepts and processes using a quantitative approach, we explored the students' learning processes while using the bioinformatics learning environment using a qualitative approach. For this purpose, we videotaped three pairs of students learning in a laboratory setting. Stewart (1983) argued that traditional classroom assessments of knowledge (simply having students solve school inheritance problems) do not provide adequate insight into what students know or do not know. In contrast to such traditional activities, students who used the bioinformatics learning activity were thinking aloud, explaining to one another, looking for further explanations, and asking questions, while using texts, worked-out examples, and illustrations. There were episodes which demonstrated students' usage of prior knowledge and acquisition of new knowledge while concentrating on learning the scientific steps required solving the scientific problem. The videotaped episodes demonstrated a possible influence of the learning environment on students' acquisition of a deeper understanding of genetics concepts and processes and on their comprehension of the nature of the inquiry process. Examples of these episodes are presented below:

*I. Episodes which demonstrate alternative conceptions*

The knowledge-acquisition process sometimes led to contradictions with prior knowledge,

which exposed alternative conceptions. One example of a student's alternative conception was exposed while trying to answer a question:
*Student A: "Is it possible that it [the affected allele] is dominant?"*
*Student B: "Yes, if it is Aa."*
*Student A: "But it does not make sense… because we said it [the affected allele] is rare."*
*Student B: "Because the trait is rare."*
*Student A: "It is a bad trait and it is rare, so is it possible that it is dominant? If it had been dominant it should have been dominant in the population."*

In this example, the students' conversation demonstrates that one of them (student A) cannot distinguish between the scientific model that explains the relationships between the inheritance probability of a dominant phenotype which is affected by a dominant allele in a family, and the frequency of a particular allele in the population. However, we suggest that although the student holds an alternative conception, the questions she asked indicate her attempt to integrate different models in genetics, and can therefore be an important stage in the process of constructing new knowledge structures of the domain.

In addition to students' alternative conceptions in the genetics domain, we found episodes which demonstrate students' alternative conceptions of the goals of the scientific work:
*Student A: "I don't know if it leads to a solution, I mean, the goal here is to help people, isn't it?"*
*Student B: "No, the goal is to locate a gene in the genome."*

In this example, student A perceives the research goal as finding the solution to a specific problem, while student B perceives it as a basic inquiry process. These two perceptions are not necessarily contradictory since according to Dewey (1938) inquiry progresses by the determination of a genuine problem that may lead to various activities in order to search for a solution. These two views are likely to emerge in the context of research in the field of genetics, which has basic and applied aspects. Nevertheless, the way the students perceived the research goals may influence their understanding of the inquiry process as an ongoing process which is motivated by scientists' curiosity to acquire new knowledge as well as by their desire to improve quality of life and to find solutions to various problems.

*II. Students' understanding of the role of scientific practices*
The learning environment exposes students to current practices in genetics and provides them with insight into scientific ways of thinking. The possible influence of this approach on students' acquisition of a deeper understanding of the genetics domain and on their comprehension of the role of scientific practices and scientific thinking processes can be demonstrated by the following example:
*Student A: "To locate a particular gene, is it like you already know the gene and then you find it, or are you searching for something and you find it and only then you determine its function?"*
*Student B: "So we are actually taking a trait and looking for its gene?"*

In this example, the students' questions demonstrate that they understand the genotype-phenotype connection, and that the specific knowledge of genetics is generated and justified through the process of inquiry. This was previously suggested by Cartier and Stewart (2000) as a necessary factor for the development of a coherent cognitive model of genetics. We suggest that the students' questions demonstrate their assimilation of the scientific thinking process and stem from their awareness of the role of methods in the scientific process.

Another example of the influence of students' exposure to scientists' practices and scientific thinking can be given by student's responses at the beginning of the activity and towards the end of it. When the student solved the first assignment of the activity (which deals with classical genetics), he noted: *"So, we determined that an offspring of a deaf individual in this family has a probability of 50% to become deaf in his adulthood… but it is only the probability… this is the reason I don't like genetics…"*. But towards the end of the activity, considering the ongoing nature of the inquiry process, he concluded: *"So in all of these assignments they, in principle, investigated one case? We started from… first we found how it is inherited, then the markers. After the markers we found exactly the gene. Now we are checking what happened to the mutation?"*. And after the researcher said that this was correct, he continued: *"Oh, I wonder what will happen at the end… maybe we will do gene therapy…"*. We suggest that these two responses indicate a change in the student's perception of the genetics domain which occurred during the usage of the learning environment.

## 5. Conclusions

The findings presented here using a quantitative approach, indicate that learning through the bioinformatics environment improves the students' ability to formulate explanations which integrate between phenotype (a character), genotype (gene, allele, DNA sequence) and genome organization. These findings suggest that using the bioinformatics learning environment promotes the construction of new knowledge structures of the genetics domain and therefore influences students' acquisition of a deeper, multidimensional understanding of the domain. These conclusions are also supported by the findings obtained using a qualitative approach. Moreover, the findings suggest that use of the bioinformatics learning environment also influences students' understanding of the scientific practices and the ways of thinking.

Learning often occurs when students are aware of the goals, in a context which is relevant and meaningful to the learner (Collins et al., 1989). Real world activities are believed to provide learners with the motivation to acquire new knowledge and an opportunity to apply that knowledge (Mistler-Jackson & Songer, 2000). Thus, we suggest that taking an active part in solving an authentic scientific problem, which has the rich contextual realistic component of an authentic research situation, provides the students with a context to apply existing genetics domain knowledge, acquire new knowledge, and present that knowledge in different ways. In addition, the use of classical and molecular genetics tools and bioinformatics tools introduces the learner to the practices of the genetics community through the process of inquiry, and may promote the beginning of the enculturation of students in class into the community of geneticists and bioinformaticians. The influence of the learning environment on students' acquisition of a multidimensional and deeper understanding of the genetics domain and its influence on their comprehension of the nature of scientific inquiry cannot be separated. Further analysis is still needed to characterize the exact components of the learning environment, both the content knowledge-dependent components and the structure-dependent components.

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# EXPLORING GENETICS EDUCATION IN PRIMARY SCHOOLS

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## Abstract

Up to now the Dutch primary core curriculum does not draw special attention to inheritance. The website www.bogi.nl could rectify this deficiency, but how does this website actually work in the classroom, and how wise is it at all to start genetics education in primary schools? To find this out, an explorative study, which comprised desk research and empirical classroom research, was carried out. Focus was on meaningful genetics learning from the children's perspective. Studying relevant documents and scientific literature, going through the website, and probing its usability and readability were part of the desk research. The multi-method design of the classroom research entailed participatory observation, in-depth interviews with students and teachers, written tests and content analysis of completed worksheets. In spite of some shortcomings, the technical quality of the website is rather good. However, browsing which is typical of this medium, may frustrate conceptual development. Students and teachers value the website as interesting and instructive, but the website overestimates students' capacities to grasp the cellular and molecular level. Emphasis should be on an observational base for heredity and on introducing simple genetic vocabulary. Without carefully interrelating organs, cells, chromosomes, genes and DNA, these terms remain meaningless.

## 1. Introduction

Empowering the public to be informed consumers of genetic technologies and services should start already during schooltime (Terry & Davidson, 2000). The Health Council of the Netherlands (Gezondheidsraad, 2002), referring to a series of picture books which inform middle-elementary readers on the inner-workings of the body (Balkwill & Rolph, 2002), even recommended to start genetics education in primary schools. However, genetics is known as one of the most difficult topics in secondary biology education for both students and teachers (Lewis, 2000; Knippels, 2002). Nevertheless, the Erfocentrum, a genetic resource and information centre connected with the Dutch Alliance of Genetic Support Groups (VSOP), has taken up the challenge of teaching young children genetics and developed a website www.bogi.nl based on a quick scan of curriculum documents and on five interviews with teachers from the last two classes of primary schools. Up to now the Dutch primary core curriculum does not draw special attention to heredity.

To find out how this website actually works in the classroom, and how wise it is at all to start genetics education in primary schools, an explorative study was carried out, emphasizing meaningful genetics learning from the children's perspective. The study sought to answer the following two research questions:

1. *How do teachers and students in upper primary schools handle the website www.bogi.nl and are there any evident faults in the website?*
2. *Does the website contribute to meaningful genetics learning in upper primary schools?*

Because 'the single most important factor influencing learning is what the learner already knows' (Ausubel, 1968) the focus will be on mapping students' prior knowledge and ongoing understanding of inheritance through this website.

## 2. Bogi in a nutshell

The content of the website was based on interviews with teachers, content analysis of attainment targets and quick scan of school books. Bogi, the main figure of the website, is a mix of his parents Boris and Gillian. He acts as a guide through the website. After having introduced himself and his parents, upper-primary students are enabled to gradually acquire knowledge on inheritance through short stories, followed by explanatory information. The titles of the successive parts are:

- What is inheritance? ('good' and 'bad' traits, hereditary and acquired traits, pedigree)
- Cells, chromosomes and DNA (including genes which determine traits)
- Plants and animals (natural breeding to satisfy human needs).

In addition, the website contains a game, a rap song and a told story. The website is primarily meant to serve as a learning resource for preparing a paper or talk and refers to other sources of information in the library or on the internet as well. In addition, worksheets included in the teacher guide (available on www.erfelijkheid/winkel), enable differential group work in the classroom using the website.

The teacher guide states the following objectives. After using the website students know that

- they have got inheritable traits from both parents;
- hereditary information is passed down through reproduction cells;
- this information varies by fertilization resulting in siblings who are different;
- some traits are inheritable and the environment comes into other traits;
- hereditary diseases can be passed down as well;
- in cases of hereditary diseases physicians are attentive to preventive measures so as to reduce health problems;
- inheritance also plays a part in plants and animals and that natural breeding aims at obtaining plant and animals with desired traits.

Bogi explains why a child inherits from both parents. He himself has an intermediate skin colour in comparison with his parents. Bogi is very limber and goes in for sports. He has got that from his mother. He is also good at maths. He has got that from his father. Bogi also got unpleasant traits from his parents. Just like his father he has reduced vision. Bogi's mother is the only one in the family with red hair. Bogi got his dark hair from his father, but what about his mother's red hair? None of her parents has red hair.

Bogi learns about cells, chromosomes and DNA during biology lessons: the body has been made up of cells; every cell has a nucleus. Every nucleus contains chromosomes that are made out of DNA. DNA looks like a winding stair. Several steps make a gene. One or several genes determine a trait. In the garden centre Bogi sees plants with favourable traits. They have been purpose-breeded. Bogi's rap song in a word-for-word translation reads as follows:

*Funny or not*
*Blue eyes, a good set of teeth*
*Dad rheumatics, mum back pain.*
*Gift of languages, megawart,*
*Grandpa this and grandma that.*

*Are you lazy, or just fond of sports,*
*Just make do with something.*
*For funny or not, talent or disease,*
*We all inherit.*

## 3. Methods

The study, which was carried out in the autumn of 2003, comprised of desk research and empirical classroom research. The mainly evaluative desk research also aimed at providing points of special interest to address in the classroom research.

### 3.1- Desk research

The desk research focused on studying relevant documents and scientific literature (see also introduction), checking how well the website meets its design criteria set in advance and how well it covers the stated objectives, and exploring the usability and readability of the website. The relevant documents concerned the report of the preliminary investigation that outlined the context and opportunities for primary genetics education, and Bogi's teacher guide and worksheets (available on www.erfelijkheid/winkel). By means of research-based web design and usability guidelines the quality of the website was assessed (http://usability.gov/guidelines and www.useit.com/papers/heuristic/heuristic_list.html).

The quantitative readability test addressed reading ease of the text based on counting, in 5 samples of 100 words, the number of words in sentences and the number of syllables in words. The calculated means (S and W respectively) were fed in into a formula: RE = 206.84 - (0.77 x W) - (0.93 x S). This formula is called the Flesch-Douma formula (Lamers, 1989). The RE score was interpreted through consulting a table, e.g. 0-30 means 'very difficult' (i.e. university level) and 70-80 means 'rather easy' (i.e. upper primary school).

Langer's qualitative readability test (Langer et al., 1974) addressed the reading comprehension and focuses on four dimensions of a text: simplicity, structure, density of information, and extra stimulus. Every dimension contains semantic differential scales, i.e. sets of bipolar, evaluative adjectives with five response-options (e.g. concrete 1 2 3 4 5 abstract; inspiring 1 2 3 4 5 plain).

### 3.2- Empirical classroom research

Six average primary schools (grade 6, age 11-12), both maintained & denominational and urban & rural, participated in the empirical classroom research. A multi-method design (Knight, 2002) was chosen, i.e. using mixed and complementary data sources to try and get more valid and reliable conclusions. The research entailed participatory observations of classroom (n=5), group (n=12) and individual activities (n=12) concerning the website, in-depth interviews with teachers (n=2) and students (n=12), written tests (i.e. word association test, open and multiple choice questions, writing assignment) (n=75), and content analysis of completed worksheets.

Participatory observations were carried out by one of the authors who walked around in the classroom as a helper, answering students' questions, and sometimes asking them questions with a checklist in mind. This checklist was derived from the findings of the desk research. He also joined groups of students so as to have a close look at what they are doing and to listen to their talks when involved in a website activity. In addition, he had informal talks with individual students and the teachers. The in-depth interviews with teachers focused on their common classroom practice concerning genetics, how they value inheritance as curriculum content, on how confident they feel about their personal content knowledge, and how they assess the practicability of the website and teacher guide. The written tests elicited students' prior knowledge and monitored the learning outcomes. Details on the written tests can be found in the Results section. Additional interviews with individual students focused on their interest in and their understanding of genetics. The interviews allowed more in-depth probing of their understanding. The same applies to content analysis of completed worksheets.

Because of the exploratory nature of the study and the accompanying advancing insight of the researchers, these methods were used in various arrangements in the different contexts.
Through inspecting and interrelating data from different sources an impression of the technical quality of the website and its power to promote meaningful genetics learning in upper primary schools was gained.

## 4. Results

### 4.1- Desk research

Relevant scientific literature on this subject turned out to be rare. Smith & Lipscomb (2003) included written commentary of primary school students in their review of the Enjoy Your Cells Series (Balkwill & Rolph, 2003). Although primary school students are fascinated by science, they are full of misconceptions and struggle with the amount of abstract information. The books cover information that is not yet at their developmental level.

Project 2061 (www.project2061.org) has created research-based conceptual strand maps so as to help achieve learning goals for different age and ability groups. Cell structures and functions are put in grade 6-8 and DNA and genes in grades 9 through 12! Project 2061 states: 'Building an observational base for heredity ought to be the first undertaking. Explanations can come later. The organisms children recognize are themselves, their classmates, and their pets. Learning the genetic explanation for how traits are passed on from one generation to the next can begin in the middle years and carry into high school. The part played by DNA in the story should wait until students understand molecules.' In sum, these findings alerted us to overly ambitious designers of the website.

The preliminary investigation that preceded the design of the website revealed that inheritance is not part of the curriculum, but comes up for discussion in response to topics like family tree, talents or diseases. Teachers are attentive to not frighten students concerning the passing on of diseases. Instead they focus on the passing on of talents and external traits. Implicit references in the curriculum concern history (family tree), society (traits and differences of groups), health promotion, and science (reproduction). School books also deal implicitly with inheritance.

The website actually starts to link inheritance to favourable traits, e.g. external traits like hair and eye colours, and talents in the family. Diseases like partially sighted, allergy, asthma, diabetes, cancer and migraine are only be considered at a later stage and doctors are presented as care takers. The examples used in Bogi tune with students' everyday life, and motivating elements (game, rap song, stories) have been built in. The website starts on the concrete organismic level students are familiar with, gradually descends to the cellular level, and ends on the organismic level again (Knippels, 2002). The worksheets do not fully cover the website and consequently some objectives may be underexposed; passing on hereditable information through reproduction cells, and breeding plants and animals are lacking.

The website meets common quality criteria for design and usability, i.e. page length, font, page layout, graphics, navigation and content organization. However, after a mistake the 'undo' function is obscure and a 'back' function is lacking. Using the 'back' function of Internet Explorer results in returning to the 'log in' page of Bogi. Furthermore, the navigation pictures are without titles, so additional information to support the structure of the webpage is lacking. The users sometimes may not realize that the nondescript mouseovers refer to links. Reading the text requires scrolling and as a consequence the user may miss 'continue reading'.

The Reading Ease score was 85, which says that the text is suitable for grade 5. In spite of some technical terms (chromosome, DNA, gene), which have been explained in the text, the text is rather simple. On condition that students do not browse through the website, its structure is rather logical: inheriting favourable and unfavourable traits; family tree and reproduction; cell, DNA and genes; back to traits. Main issues and side-issues correspond with main text and pop-up screens respectively, although some pop-up screens tend to be full of information. However, browsing is possible and may result in incoherent information. Illustrations, a rap song, story and a game contribute to a motivating website.

### 4.2- Empirical classroom research

*The website in use*

The students enjoyed working with the website and valued it as interesting and instructive. The boys valued the rap song as 'cool'. Due to some technical flaws or unclear instructions students did not have enough time to read some pop-up texts or they spent too much time on playing the Bogi-game. Using a worksheet often resulted in being focused on answering the questions and not reading the complete web texts. Due to a mismatch of the website and the worksheets students neglected the plant and animal section and they (partly) missed the explanation about sperm and egg cells in the pedigree section. These findings should be kept in mind when interpreting the following results.

*Students' prior knowledge*

To assess their understanding of inheritance students were asked to respond freely to the word 'inheritance' under different research conditions: class (orally: constructing a word field) and individual (in writing and interview). Six categories of word associations emerged: exterior traits, inner traits, diseases and defects, technical terms, social inheritance, and remaining associations. The percentage of classes or students that responded in each category has been calculated.

Table 1. Response profiles concerning the word 'inheritance' under different research conditions. The proportions of classes and individual students associating in six extracted categories have been represented.

| Response categories | Conditions | | |
|---|---|---|---|
| | Class (n = 4) | In writing (n = 18) | Interview (n = 12) |
| Exterior traits | 100 | 33 | 83 |
| Inner traits | 100 | 22 | 42 |
| Diseases / defects | 100 | 33 | 50 |
| Technical terms | 50 | 6 | 0 |
| Social inheritance | 100 | 39 | 33 |
| Remaining | 25 | 17 | 8 |

Table 2. Range of associations to the word 'inheritance' under different research conditions. The numbers of different responses in each category have been represented.

| Response categories | Conditions | | |
|---|---|---|---|
| | Class (n = 4) | In writing (n = 18) | Interview (n = 12) |
| Exterior traits | 18 | 7 | 11 |
| Inner traits | 8 | 5 | 7 |
| Diseases / defects | 14 | 4 | 9 |
| Technical terms | 2 | 1 | 0 |
| Social inheritance | 15 | 3 | 3 |
| Remaining | 3 | 5 | 1 |

Social inheritance in terms of properties after someone's death was rather familiar to these students. The same applies to exterior traits like hair and eye colour. A few times words like height, reduced vision, freckles, skin colour, baldness, flap-ear, shoe size, thickness, curly-haired, shape of face, left-handed and birthmark, were mentioned. Inner traits include words like behaviour, being sullen or forgetful, taste, and cleverness. A frequent response is just 'disease'. Only a few cases concern specific diseases or defects like aids (!), allergy, dyslexia were associated. Technical terms like DNA ('D and A') and gene are almost absent. The remaining category refers to inheriting a name, teasing, untimely death, and passing on of ill-treatment and smoking. It must be noted that students' associations with inheritance are rather negatively connoted in terms of death, disease and abnormal traits.

The twelve interviewed students have been presented with different samples out of eleven traits and asked to indicate in each case if the trait could be hereditary. With the exception of scar this applies to all traits mentioned in Table 3.

Table 3. Possible hereditary traits according to students (n=12). Students have been presented in interviews with different samples of traits.

| Traits | Hereditary? | | | |
|---|---|---|---|---|
| | Yes | No | Don't know | Totals |
| Hair colour | 12 | | | 12 |
| Reduced vision | 8 | 1 | 1 | 10 |
| Height | 8 (+1)* | 1 | | 10 |
| Good at playing football | 2 (+5) | 2 | | 10 |
| Allergic to cats | 5 | 6 | 1 | 11 |
| Being musical | 6 (+1) | 3 | | 10 |
| Freckles | 8 | 3 | 1 | 12 |
| Scar | | 11 | 1 | 12 |
| Good at arithmetic | 3 | 2 | 2 | 7 |
| Being clever | 3 | 2 | 1 | 6 |
| Being quick-tempered | 3 | | | 3 |

*After further questions

They have also been questioned about the following concepts: cell(s), DNA, chromosomes, gene(s), and family tree. Ten out of twelve students were aware of being made up of cells, although according to some students cells are only in blood and the brain. On being asked what is in the cell, six students had no idea. The other answers included DNA and 'gorosomes', fluid, air, and small cells. Only one student related cells to reproduction. The majority of these students linked DNA to blood and/or crime. Only a few related DNA to passing down. Students had no knowledge of chromosomes. Although half of them had heard of genes, only two correctly linked genes with heredity. With the exception of one student all interviewees correctly described a family tree and on being asked how a family tree relates to inheritance, they connected it with passing down traits.

*Understanding Bogi*

Students had few problems in ascribing Bogi's traits to one of his parents. They realize that both parents contribute. A few times Bogi's skin colour was only ascribed to his father on the principle that 'his brown colour looks more like his father's'. Although students ascribe Bogi's being good at maths to his father, they are well aware that practising or the teacher also contribute.

Half of the students had problems with inheriting hair colour due to mixing colours instead of starting from a dominant colour. Or change of hair colour contradicts their experience, e.g. red can become blond and not the other way round, because 'my cousin started red-haired and now at the age of two she has blond hair'. Other students think that parents only pass down the strongest gene contrary to chance, e.g. 'If mother is red-haired and father has black hair, than black wins, because it is more dark.' The gene concept remains fuzzy; clarification was obstructed, because they skimmed through the text. In addition, students had difficulties with interpreting the arrows in the pedigree picture.

Six students who were put to the following test question: *Sperm and egg cells pass on hereditary information. True or false*? all answered 'false'! One of the interviewees who responded to the question *How else do you get those traits from your parents*? told: 'From the man through the egg cell I guess … may be from the woman in the blood …'. Almost all students know that the body contains cells, but half of them know that the body is made up of cells and the other half limits cells to blood and brain. The number of 50 billion cells amazes them. On being asked they hold a 3D-image of a cell.

The most difficult term of the website is 'chromosome'. They had to reread it several times before they were able to pronounce this word. Most students could not reproduce it after the lesson or transformed it to 'chromosones' or 'chromosores'. Only two out of five students who were asked to complete the following sentence *Chromosomes are* … were able to do so in a correct way. Examples of wrong answers are 'small cells' or 'a kind of thread around the cell'. Anyway, the answers of three students indicated that according to them chromosomes are outside the cell. Students had a lot of trouble to describe the difference between DNA and chromosomes. Afterwards, only one student could tell that chromosomes are made up of DNA.

On being asked whether or not the following parts of the body contain DNA, all six students confirmed that DNA is in cells, contrary to skin (only three) and hair (only two). Evidently, these students did not know that skin and hair are made up of cells. Six other students were asked to complete DNA is … and five of them linked DNA to traits or 'getting partially from your parents'. A question about genes was lacking on the worksheet and consequently not all students read the text concerned. On being asked what genes are, only two out of six referred to inheriting traits, whereas three students did not have the vaguest idea.

In sum, many students are not able to meaningfully interrelate body, organs, cells and DNA, whereas chromosome and gene remain meaningless terms. The topic on plants and animals hardly received any attention; there were no reference questions on the worksheet. Twelve students have been asked to give an example of breeding; only one student was able to do so. The students of the research classes have been invited to write a letter to their grandma to tell her what they had learned during the Bogi lesson. None of the thirty letters referred to heredity in plants and animals. The interviewees, who have been asked to still read the text concerned, were quite able to mention examples like riding horses and a good milker cow. Afterwards some students think that plants do not have DNA, whereas DNA in animals is obvious to them.

*Goal based evaluation*

These students were already aware of having got inheritable traits from both parents, in particular exterior traits. Students who were not familiar with inheritable inner traits or diseases learned about it through Bogi. Especially concerning abilities, students realized already that environmental factors are important as well.

The following objectives have been reached poorly: passing down of hereditary information through reproduction cells, that this information varies by fertilization resulting in siblings who are different, that hereditary also plays a part in plants and animals, and that natural breeding aims at obtaining plants and animals with desired traits. As mentioned above, this can be partly ascribed to a mismatch in terms of coverage of the worksheets and the website. The objective dealing with hereditary diseases and preventive measures so as to reduce health problems did not live up to its promise. With hindsight the website's positive approach was helpful in redressing students' initial negative associations with heredity, like death, diseases, bad traits.

*Teachers' perspective*

Only two teachers have been interviewed in depth; the other teachers brought up relevant information during the lessons and in informal talks. These results confirm those of the interviews that preceded the design of the website. The participating teachers indicated that they are not used to discuss this topic at length, not more than in response to questions on reproduction or pedigree. They are not planning to change this practice radically, although they intend to use the website in the future due to its attractiveness and the students' enthusiasm. Most teachers went through the website in advance to extend their own genetics knowledge. In their opinion high-quality interactive e-learning resources are rare. They think a complete lesson is preferable to the preparation of a talk or paper based on the information in the website. The latter application has not been addressed in this study.

## 5. Discussion and conclusions

The technical quality of the website is rather good and some shortcomings detected in this study have been redressed in the meantime, in particular the time-consuming game, the navigation, the pedigree, and pop-up screens. However, browsing which is typical of this medium, is still possible and that may continue to frustrate conceptual development. The same applies to worksheets, which should challenge students to inform themselves completely. Students and teachers value the website as interesting and instructive; teachers think a complete lesson is preferable to a talk or paper based on the website.

Up to now the Dutch primary core curriculum does not draw special attention to heredity. The website Bogi and the accompanying worksheets actually add to purposeful genetics education in primary schools in a motivating way, but overestimates students' capacities to grasp the molecular level of DNA. Restricting the topic to the organismic and cellular level, i.e. the fusion of the egg and sperm cell and the accompanying variable distribution of hereditary traits of father and mother, seems to be recommendable. Animations, which zoom in and out on the reproduction process and the passing down of hereditary traits, might be helpful. However, on closer investigation it might be shown that even the cellular level is going too far for these students (Lewis, 2000; Knippels, 2002). Emphasis should be on an observational base for heredity and on bringing out and interrelating relevant everyday experiences and fragmentary common knowledge (passing down traits in families, talents and training, family tree, animal and plant breeding, DNA-blood-crime), raising questions and introducing simple genetic vocabulary. Without carefully interrelating organs, cells, chromosomes, genes and DNA, these terms remain meaningless.

Bogi refers to other websites on genetics for kids (e.g.http://genetics.gsk.com/kids/index_kids.htm), but these are even more technical than Bogi. It is a real challenge to take advantage of students' fascination for DNA and to experiment with other types of education as well, e.g. morally appealing and imaginative, in close collaboration with 'philosophy for children', life stance and art education (Waarlo et al., 2002; Haynes, 2002). A lesson plan for humanist ethical education on redesigning animals, which starts from newspaper articles on Bunny the green fluorescent rabbit or 'walking floor lamp', for art's sake: transgenic art (www.ekac.org/) and the glowing fish (for sale, just for fun) is in preparation. This lesson plan focuses on raising awareness and questions on and appreciation of the new genetics, so as to till the land for sowing more technical details at secondary level.

From the start, empowering the public to be informed consumers of genetic technologies, as narrowly stated in the introduction, needs to be embedded in multidimensional learning for life.

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# THE INFLUENCE OF DIFFERENT REASONING PROCESSES IN EXPRESSIVE AND EXPLORATORY SYNCHRONOUS ENVIRONMENT ON THE DEVELOPMENT OF STUDENTS' REPRESENTATIONS IN GENETICS

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## Abstract

The current study investigated the development of 53 students' problem representations about genetic issue, while working with exploratory and expressive tools in synchronous network-based environment. It was aimed to take an insight look at how different types of model-based reasoning processes, activated due to learning in two settings, might influence the learners' ways of representing the problems. The discussion log-files were used for 'microgenetic' analysis of reasoning types. For studying the stages of students' problem representation development the individual pre- and post-essays and their utterances during two reasoning phases were used. The approach for mapping problem representations was developed. Characterizing the elements of mental models and their reasoning level enabled to describe five hierarchical categories of problem representations. Learning in exploratory and experimental settings was registered as the shift towards more complex stages of problem representations. The effect of different types of reasoning applied in these learning environments could be observed as divergent development of problem representations within hierarchical categories.

## 1. Introduction

Traditionally, the reasoning with inductive or deductive arguments is considered to be the two modes of creating new knowledge in science. Besides these, the complex forms of model-based reasoning, which can be related to inductive and deductive processes, have recently been brought to the focus. The current paper deals with three types of reasoning processes in the network-based synchronous collaborative learning environment with modelling aids: the hypothetical-predictive inductive reasoning, the model-based inductive reasoning, and the model-based deductive reasoning. The influence of different model-based reasoning on the structure of problem representations in the genetics domain is studied.

### 1.1- The nature of reasoning processes

The general nature of reasoning processes has been explained by the theory of mental models (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). The theory claims that reasoning is a semantic process of model construction and manipulation in working memory. Accordingly, people's ability to think and solve problems in a domain depends on the quality of underlying mental models for that domain, which they are able to run

(Gentner & Gentner, 1983). As several types of reasoning exist, it is of interest, what the influence of different reasoning processes on the development of mental models might be.

Johnson-Laird (1983) uses the three-stages processing schema for explaining the reasoning mechanism. In the initial model-construction stage, the mental model sets are constructed of separate entities, their properties and structural and causal relationships between them. In the conclusion-formulation stage, the person who is reasoning has to integrate the mental model sets of respective premises. At this stage the inconsistent models are eliminated and consistent ones are joined in forming the integrated model. Castaneda & Rodrigo (1998) view it as the comprehension when a person updates its mental framework by combining several sources of information to the single mental framework. At the final conclusion-validation stage, the person must look for alternative models that might falsify the conclusion.

How applicable these steps of the mental model activation theory are for characterising different reasoning processes in science lessons? In inductive reasoning, starting from maximally probable premises and using correct inductive logic one should arrive at most probable conclusions. In learning situations there are two ways to practice inductive approach. In one case students gain the theoretical knowledge in the beginning. Next, some phenomena would be observed searching for patterns. These will be explained by selecting from the set of conceptual mental models, which are based on the previously learned theories. Mental models, not consistent with the observed phenomena, were to be left aside until the model that works as a rule for explaining the pattern was found. In the second case, the hypothetical-predictive inductive reasoning may be carried out. According to this, students are expected to construct initial mental models by retrieving information only from their long-term memory. This kind of reasoning should be preferably selected before starting the new conceptual topics for supporting constructivist learning. After observing some patterns, the students will be activating different propositions from their semantic network, constructing separate sets of mental representations that might give hypothetical explanations to the phenomena. The difference with the other inductive approach is that the final explanation will remain hypothetical, whereas in former case the explanation will be theoretically sound. Both of these inductive methods put the students under high cognitive load as the big number of alternative models must be constructed in working memory and compared with the observations until the rule was selected. Therefore, the inductive methods are more suitable for team learning rather than for individual scientific practices.

Deductive reasoning process is built upon the usage of connectives such as 'if-then' etc. Commonly, the method of deductive reasoning resides upon the accepted theories and controlled data on the basis of which the sound hypotheses will be formulated. True premises plus deductive reasoning should yield true conclusions and the confirming of the theory. At school, the deductive approach usually starts from approved theories, which will be tested under certain circumstances. The mental processes comprise the formation of initial mental model, the hypothesis, in the first phase. Next, testing different sets of options follows with some valid dataset, which enables to form an integrated understanding of the conditions under which the mental model works. Finally, the alternative hypotheses should be formulated and tested in order to find the contradictions in the theory. In addition to this type of learning, hypothetical-deductive methods are known (Lehrer & Schauble, 2000), which embody the reasoning with hypothetical entities that interact to produce emergent behaviour. In some cases the hypotheses may be formed by inductive, hypothetical-predictive means, but tested with deductive methods.

### 1.2- Two model-based reasoning processes in science

Scientific discovery involves using analogy, thought experiments, models, diagrams and visual imagery in the concept and theory formation by reasoning (Nersessian, 1999). Models, images, and diagrams are used during reasoning to overcome the working memory limitations. When composing the model or when conducting inquiry with the model, different model-based reasoning processes may take place. According to Lee (1999), model-based reasoning is the symbolic processing of an explicit representation of the internal workings of the system (mental models) in order to predict, generate and explain the resultant behaviour of the system, given details of its structure and the behaviour of its components. In this study two modelling methods were applied. In one case, students were supported in the expressive environment (electronic whiteboard) with the possibility to compose the schematic figure as the problem representation. Second modelling approach enabled the usage of conceptual inquiry model for testing certain aspects related to the problem with the valid data. Web-based models represent the exploratory type of learning environment. It was supposed that the nature of these modelling methods might have an influence on reasoning processes and the mental model development.

Mellar and Bliss (1994) distinguish between qualitative, semi-qualitative and quantitative modelling, which can be related to reasoning with qualitative, soft and hard models introduced by Lee (1999). The qualitative models capture only the fundamental aspects of the phenomena, while suppressing much of the detail. This facilitates the basic understanding and manipulation of the problem. According to Lee (1999), such models are normally based on strong theories that exploit the principles knowledge rather than heuristic or empirical data. Qualitative models are often run only internally. Composing the schematic figure is an example of turning the inductive reasoning processes with qualitative models external. Expressive modelling supports students with initial elements of the model. The students must relate them in order to explain the phenomenon. Cornuéjols et al. (2000) use the metaphor of "tunnel effect" when describing the mechanism of model-based reasoning with a singe situation where the knowledge transfer between the conceptual domains takes place. A "tunnel effect" occurs when model becomes autonomous from its initial justifications in another domain. This reinterpretation reveals some inconsistencies of the model and leads to its re-conceptualisation in the target domain as well (Cornuéjols et al., 2000). The construction of external model on whiteboard can enable the students to recognise the faults in their initial interpretation, activating the "tunnel effect". As the whole model is constantly accessible visually, it enhances the mental model revision processes in working memory, and contributes to the formation of the integrated set of problem representations. This type of model-based reasoning process could be seen as moving from initial whole mental model to the revised model, whilst every time when some element or relationship was changed, the revisions were made considering the whole mental representation (Yu, 2002).

Soft models represent complex and ill-defined systems (e.g. ecosystem, economy, social systems), which can be characterised by the deficiency of data, and the application of unreliable or partially formed theories that are not well grounded in accepted knowledge (Lee, 1999). The usage of such models enables to perform semi-qualitative modelling (see Mellar & Bliss, 1994) and detect the patterns that are not apparent due to the complexity of systems and generate inductively new rules and theories. Reasoning with soft models was not tested in this study.

Hard models focus on particular well-defined problems, they are accurate and precise being formed on the basis of reliable and confident data, and well grounded by the strong and accepted domain theories (Lee, 1999). Many computer-based inquiry models applied at school qualify into this category. Analogical deductive reasoning is often practised when studying with hard models. Mellar and Bliss (1994) describe reasoning with hard models as quantitative modelling which allows to build models by using algebraic relations between variables. According to Cornuéjols et al. (2000) analogical reasoning involves the comparison of well-known source case and the target case that must be understood, whereas interpretation takes place in both source and the target domains. The relationships between the entities of the mental model of new problem must be predicted and tested one after another with the analogical conceptual model in hand. This type of modelling tends to break down the initial mental representations of the problem during the investigation, and presumes the operation with two separate models (Pata & Sarapuu, 2004). Differently from the model construction activity, the model-based reasoning process during inquiry with models could be described as running the mental simulation of conceptual model and matching the results with the problem model.

### 1.3- Representations during the reasoning

In case of model-based reasoning in teams the students must operate with three kinds of representations: internal mental models, external shared verbal and visual representations (models), and conceptual visual representations (models). The peers can comprehend the structure of each other's internal representations when these are made explicit by writing, talking or visualising during the joint activity. In order to facilitate certain types of reasoning processes at school educators commonly compose conceptual models with limited facilities. Such models convey theoretical knowledge and facts that represent the complex understanding of the phenomena. Therefore, they often do not match with students' internal representational framework. Students must simultaneously operate with their own mental models of the phenomena and interpret the conceptual external representations during model-based reasoning (Pata & Sarapuu, 2004). The nature of conceptual models applied during learning and the activity design (e.g. inductive/deductive, theoretically sound/hypothetical-predictive) can be the factors influencing students' model-based reasoning patterns, and thereby, the development of their internal problem representations.

The researchers can capture the structure of mental models at certain phases of the problem-solving activity when the students are asked to write down, verbalise or visualise their explanations. Secondly, the discussion recordings enable to follow the current state of each student's mental model at selected time intervals without intervention. The discussion transcripts could be used for re-establishing the reasoning process with mental models. Yet, it cannot be assured that the whole mental model structure and the nature of reasoning could be traced with this methodology because people may not externalise all what is processed in working memory.

As the basis for the analysis system for mental models about complex natural phenomena, three notions should be considered. Firstly, it is necessary to determine the common elements of representations for specific problem domains. Secondly, the representation level of these elements and their properties must be taken into account. Thirdly, the inter-relations between the elements must be determined not only inside one representation level but also between several levels (Pata & Sarapuu 2003; Pata et al., 2004). In written representations like short essays about the problems people usually describe most of the important elements and relationships in a complex and related way. The person's verbal contributions during discussions, on the other hand, do not have that structured nature. When representations of different origin are intended to compare, part of the complexity of mental model structure (e.g. inter-relations between elements) must be reduced in order to determine the person's characteristic representation level.

In this study the two-folded relationships of different reasoning processes and the structure of mental representations were of interest. The following research questions were formulated: What characterises model-based reasoning in expressive and exploratory environment? What influence does different type of model-based reasoning have on the development of problem representations? How does the students' initial problem representation level influence their development during model-based reasoning?

## 2. Methods

### 2.1- Participants

The participants of the study were 53 secondary school students (aged 15-17) from 4 schools. These students had different knowledge about genetics – at one school the students had studied the topic in the previous year, at other schools they were not familiar with the topic. This sample was chosen because it was of interest does the students' different knowledge of genetics have influence on their development during model-based reasoning. The students of each school were randomly divided between two different settings of the experiment. 10 groups were formed with 3-7 people working together. The online activity was guided in chat room by a tutor.

### 2.2- Learning environment and tasks

The freeware software of synchronous network-based learning environment Collaborative Virtual Workplace 4.0 (CVW) (*http://cvw.mitre.org*) was used in the study. Client interface of CVW allowed students to gather in the virtual rooms to talk through chat with one another and share web-links. All the interactions that occurred in a certain room were displayed to the users in the textual scroll-back window. In expressive modelling activity it was possible to use an electronic whiteboard facility. For modelling purpose a background image was provided on the whiteboard. It contained images of a ladybird, the pesticide, and the chromosomes (Figure 1). The students could model their problem representation by adding texts, arrows and symbols.

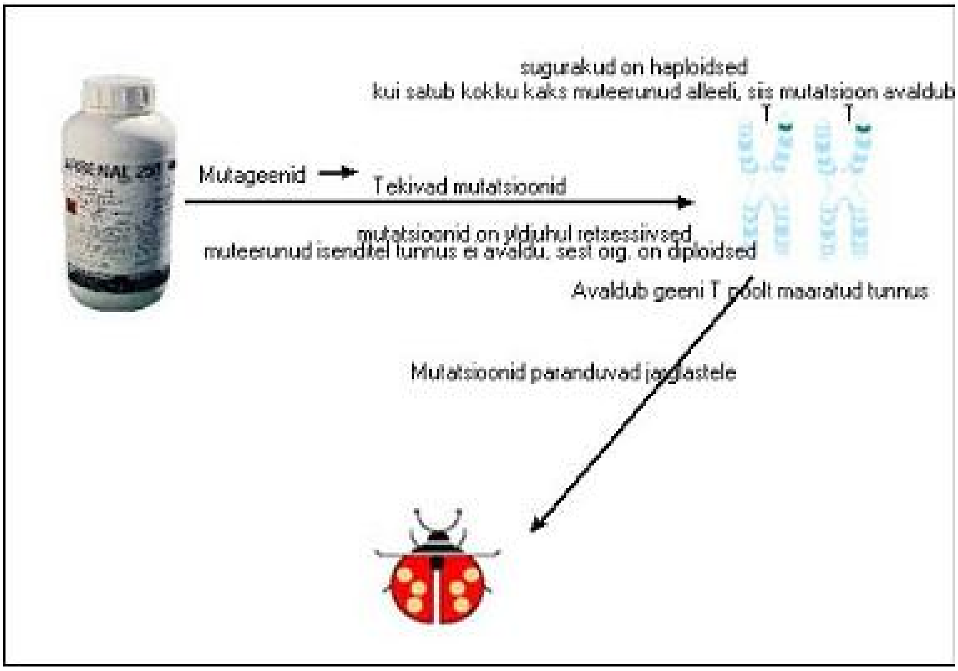



Figure 1. An example of the completed template model on whiteboard

For exploratory modelling activity, the web-based inquiry model 'Ghosts' (http://mudelid.5dvision.ee/tondid/) was composed. Students, who worked in virtual CVW environment, could access the model by clicking the web-link deposited in the chat-room. The model (Figure 2) enabled to test the causal effects of different mutagen levels on the appearance and the genes of young and elderly 'ghosts' and their offspring. After selecting the mutagen level (low, medium, high), it was possible to study the phenotype of young ghost parents and their offspring. Next it was possible to observe what might be the appearance of offspring if the ghost parents lived in the environmental conditions with certain mutagen level and had children later. Besides phenotype changes (emerging spots on skin), the students could investigate if the gene alleles of somatic and generative cells were dominant or recessive.

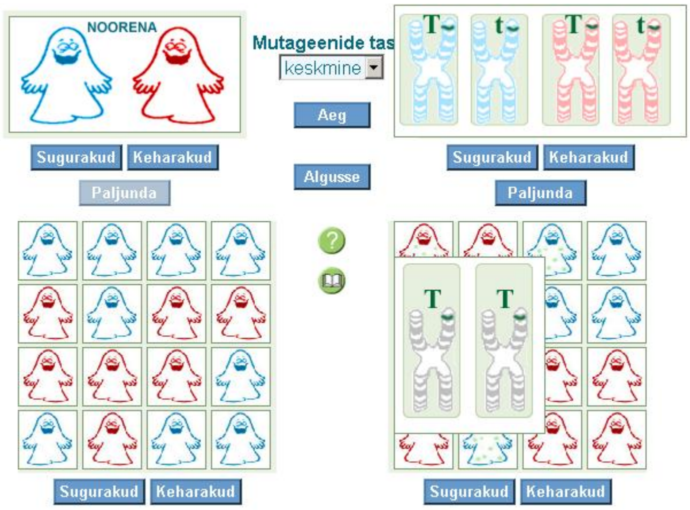



Figure 2. The screenshot of the 'Ghost model' for exploratory modelling in genetics

The students had to solve the genetic problem: *Why have the outside traits of ladybirds changed after pesticide treatment?* In this context the 'Ladybird' model template on whiteboard described the situation directly, whereas the 'Ghost' model served as an analogy to the case of ladybirds. It was aimed that both models facilitate the students to link the problem representations at concrete observable level with those at abstract microscopic and symbolic levels when explaining the ladybird situation.

The two-group design of the study comprised four activities (Table 1). The experimental groups were referred to as Group I (they used expressive modelling setting) and Group II (they used exploratory modelling setting).

Table 1. Phases of the collaborative modelling activity

| Phases | Activities in Group I | Activities in Group II |
|---|---|---|
| *Phase I* | Introducing the *'Case of ladybirds'* from situational context by text on web-page. Composing an individual Essay 1 on the question '*Why have the outside traits of ladybirds changed after pesticide treatment?'* | |
| *Phase II* | Collaborative hypothetical-predictive reasoning in chat room without conceptual information. | |
| *Phase III* | Introducing conceptual information about the influence of mutagens on the inheritance by text on web-page. Collaborative model-based reasoning in chat room in expressive environment (Group I). | Introducing conceptual information about the influence of mutagens on the inheritance by text on web-page. Collaborative model-based reasoning in chat room in exploratory environment (Group II). |
| *Phase IV* | Composition of individual Essay 2 (analogical to Essay 1) day after the collaborative activity. | |

The tutor's process-related support was applied during the hypothetical-predictive reasoning, and its conceptual scaffolding prompts were practised during the modelling phase. The tutor's prompts focused on guiding students towards representing all the relevant objects and processes about the current genetic problem at concrete and abstract levels of the emergence.

### 2.3- Methods of analysis

The qualitative investigation of reasoning activities, and the combined qualitative and quantitative analysis of individual students' problem representations were used in the study. The transcripts of group discussions, recorded by the CVW system during the activity, and the individual pre- and post-essays about the problem were used for 'microgenetic' content analysis. Frequent observation of rapidly changing competence and the in-depth qualitative analysis of this process in the dimensions of path, rate, breadth, source, and variability of the change are characteristic to 'microgenetic' method (Siegler & Svetina, 2002).
From these dimensions of 'microgenetic' analysis, the path of change, concerning the sequence of used knowledge states, could be applied for finding out about the nature of reasoning processes. In this study the verbal examples of the reasoning processes in time-line were interpreted for describing the nature of different reasoning patterns.

The 'microgenetic' dimension of change rate was applied for describing the extent of qualitative shifts in the structure of students' problem representations. For investigating the changes, each individual's pre- and post-essays and their contributions during hypothetical-predictive and model-based reasoning (Lee, 1999) were extracted. Thus, four different representations could be analyzed for each person. The content of representations was separated into elements. All the elements were categorized either as concrete entities that were described by the macroscopic level names and properties, or as abstract entities that were described by using the microscopic or symbolic level explanations.

Each student's overall problem representation type was found after detecting all the used elements and their representation levels in essays and during the two reasoning phases. The following hierarchical categorization scheme was applied for representations:

- *Concrete:* Objects and events are described only at concrete level.
- *Semi-abstract:* Objects and events are described mainly at concrete level; the entities described at abstract microscopic level do not belong to the framework of the current problem situation.
- *Concrete-abstract:* Objects and events are described both at concrete macroscopic and abstract microscopic levels.
- *Abstract:* Objects and events are described only at abstract microscopic level.
- *Meta-abstract:* Objects and events are described at concrete macroscopic and/or abstract microscopic, and symbolic levels (the usage of alleles symbols).

The non-parametric analysis methods – Wilcoxon Signed Ranks Test and Wilcoxon Rank-Sum (Mann-Whitney) Test were used for determining the changes in the problem representation categories due to different types of reasoning. The SPSS. 11.0 and MS Excel 2000 were used for data analysis.

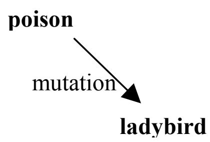
## 3. Results

### 3.1- Characteristics of model-based reasoning in expressive and exploratory mode

Two divergent reasoning patterns were observed during modelling in expressive and exploratory environment. In the former activity (see Example 1) students operated with the general level theoretical model without discussing the concrete details (amount, count etc.). Example illustrates the development of problem model with similar reasoning phases as described by Johnson-Laird (1993).

Initially the group developed the problem representation during hypothetical-predictive reasoning without discussing the abstract genes/chromosomes component. Next, the model construction during expressive modelling activity started from the same elements, including now the genes that were seen on the template model. The initial conclusion was formulated on the whiteboard after brainstorming about the role of several theoretical properties of the model. The three elements – poison, ladybird, and the genes – were integrated starting from concrete entities and moving towards abstract ones. The visualised model revealed some discrepancies of this solution. This triggered the second round of model construction and the formulation of the new conclusion. Building the second problem model started from abstract elements (mutagen, genes) and ended with visible changes at concrete level (spots of the ladybird). All the reasoning during model building took place with the whole representation of the ladybirds' problem.

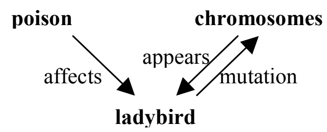
Example 1. Model-based reasoning in expressive environment (translated from Estonian)

| Discourse example | Interpretation |
|---|---|
| Team's initial hypothesis from hypothetical-predictive reasoning phase: *The ladybirds' spot colour changed after using the poison because the poison caused mutation and due to this colour changed. These were not hazardous mutations, because the life quality of the insects did not change, but moreover it was beneficial because the mutation caused the insects' immunity to this poison.*<br><br>bio6 says, "In the bottle there is poison for insects, does everybody agree?"<br>bio3 says, "Probably."<br>bio4 says, "Yes."<br>bio1 says, "Yes."<br>bio6 says, "And there is the ladybird."<br>Tutor1 says, "Let's speak about the poison first. What kind of properties it has? How does it work?"<br>bio6 says, "There may be different ones."<br>bio5 says, "For sure poisonous."<br>bio7 says, "The poison is meant for killing."<br>bio3 says, "Poison is killing the pests."<br>bio1 says, "But it affects ladybirds too."<br>bio7 says, "But pests?"<br>bio6 says, "Some of them can paralyse the important life systems?" | Initial hypothesis: *Poison affects ladybirds' spots colour due to mutations.*<br><br><br>Model construction:<br>Determining the conceptual models' elements and their relationships with each other. |

bio2 says, *"It may cause mutations."*
bio6 says, "Maybe it blocks the protein synthesis?"
bio4 says, *"Maybe it eliminated some dominant genes and the recessive ones got in control? “*
bio2 says, "This is logical that the recessive one will start to dominate"
bio3 says, "What happens then?"
bio7 says, *"Maybe these changed ladybirds are the offspring of those who had mutations in their generative chromosomes due to poison? "*
bio6 says, "Yes, they might be."
bio6 says, *"Then maybe we should draw arrows from poison to the ladybird and from there to the chromosomes?”*
bio4 says, "I've already added it."
bio1 says, *"Maybe it changed the dominant gene then?"*
bio5 says, "You meant the allele."
bio2 says, "Yes, it probably changed."
bio7 says, *"Are these generative chromosomes or not?"*
bio6 says, *"And if the dominant gene was changed the feature will appear on the offspring."*
bio4 says, *"Shouldn't we draw the arrow from the poison only to the genes?"*
bio3 says, *"Maybe we need the arrow from the chromosomes to the ladybird too?”*
bio5 says, "Probably"
bio4 says, "That is more logical"
bio2 says, "Yes, it is"
bio4 says, "Currently it is not correct"
bio6 says, "Which arrows do we need then?"
bio1 says, *"Then we need the second mutated animal as well. "*
bio4 says, *"The one who draw the arrow from poison to the ladybird should delete it. "*
bio3 says, "From chromosomes to the ladybird?"
bio4 says, "Yes."
bio6 says, *"But the poison is influencing the ladybird."*
bio7 says, *"An arrow from poison to the chromosomes and from there to the changed ladybird. "*
bio6 says, "Ok."
bio4 says, *"But the poison is influencing the ladybird's genes and the genes influence its external features!!!”*
bio4 says, "Yes."
bio3 says, "I agree."
bio5 says, "Yes."
bio7 says, "So it is."
bio4 says, *"In this case there will be no arrow from poison to ladybird. "*

Brainstorming hypotheses about the theoretical nature of causal relationships.

Conclusion formulation:
*Hypothesis 1: Poison mutates ladybirds' genes and the appearance of offspring changed.*



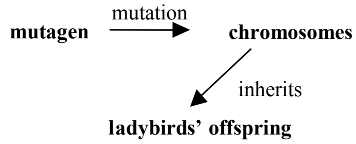

Conclusion validation: Verifying the 1st hypothesis.

*Hypothesis 2: Poison mutates ladybirds' generative genes and the offspring will have changed appearance.*

Model construction: Proposing modifications to the erroneous model.

Discussing the model consistency.

Conclusion formulation: Modifying the model according to the second hypothesis.




*Note. The contributions related to the discussed two hypotheses are shown in Italics, the discussed changes on the whiteboard model are marked with Bold.*

The reasoning pattern during exploratory modelling (see Example 2) revealed the tendency that students operated separately with the analogy model without connecting it to the situation model. During the model-construction phase they focused on the measurable properties of the model elements. After finding the solution it was related with the initial problem model elements on the basis of analogy and validated.

Example 2. Model-based reasoning in exploratory environment (translated from Estonian)

| Discourse example | Interpretation |
|---|---|
| Team's initial hypothesis from hypothetical-predictive reasoning phase: *The insects' colour change depended on the poison-caused mutations, which were inherited.* | Initial hypothesis: *Poison caused mutations, which were inherited and the colour of insects changed.* |
| Tutor5 says, *"In the beginning you should investigate how the ghost parents look like when young if there is a low mutagen level. Don't forget to study their somatic and generative cells and the cells of their offspring.* "<br>bio21 says, "*Nothing much happens*."<br>bio21 says, "How low is the mutagen level?"<br>Tuutor5 says, "Low."<br>Tuutor5 says, "Which situation in the garden is comparable with the low mutagen level on the model? Could we equalize the poison and mutagen?<br>bio19 says, "Yes"<br>bio18 says, "I think we could, it is a chemical mutagen." | Model construction: Exploring with the analogy model.<br>Discussing the analogy model elements and their properties. |
| bio17 says, *"If they are younger they have more offspring with TT genes."*<br>bio21 says, *"Here it seems that the older they are the bigger the number of recessive alleles is. "*<br>bio17 says, "Yes"<br>Tuutor5 says, "How can the low mutagen level in the garden influence the somatic and generative cells?"<br>bio17 says, "*It means the higher mutagen level is, the more effect the recessive alleles will have. "*<br>bio21 says, "Yes, a*nd the more recessive alleles, the bigger mutation will emerge."*<br>Tutor5 says, "What situation in the garden is relevant to the high mutagen level on the model? "<br>bio21 says, *"Yes, the higher mutagen level is the bigger the number of recessive alleles is. "*<br>bio17 says, *"Or could it be…the higher mutagen level is, the bigger mutability is and the higher the number of recessive alleles is that will take effect??????????"* | Conclusion formulation:<br>Explaining the analogy situation by focusing on measurable properties of model elements.<br><br>Hypothesis 1: *The ghost parents' age influences the genes of their offspring.*<br>Hypothesis 2: *The mutagen level influences mutation and allele expression.* |

| | |
|---|---|
| bio17 says, "Is it so?"<br>bio19 says, "Yes."<br>bio17 says, *"Then we have the answer."*<br>bio21 says, *"But we don't know if the level was moderate or high."*<br>bio18 says, "*The higher the mutagen level is, the more can the recessive alleles be exposed.* "<br>bio21 says, *"I think in the garden the level was moderate."* | Answer is generated from the perspective of analogous conceptual model. |
| bio17 says, *"Yes, because only some insects were different."*<br>bio21 says, *"The mutation level in the garden was moderate, this caused the recessive alleles of some ladybirds, that caused their variability…* " | Relating the results from the conceptual model with the initial situation. |
| bio19 says, "*Strange claim. It didn't cause the recessive alleles but the occurrence of them.* "<br>bio21 says, "*Mutation level in the garden was moderate (because only some ladybirds were changed in the garden) and this caused the exposure of recessive alleles of some ladybirds that caused the variability…* " | <u>Conclusion validation:</u><br>Evaluating the situation model. |

*Note. The contributions related to the discussed hypotheses are shown in Italics, the separate solutions with the model framework and with the situation framework are marked with Bold.*

To conclude, the students who performed expressive modelling operated with the whole situation model, discussed the theoretical relationships between the model elements, and used the model as an external aid to evaluate their initial mental models. The students who applied exploratory modelling operated mainly with the conceptual model, focusing on the measurable characteristics of the model elements. The connections between conceptual and situation models were discussed only after the problem was solved from the analogous perspective.

### 3.2- What influence does different type of model-based reasoning have on the development of problem representations?

In the previous section it was shown that there were qualitative differences in students' reasoning patterns in expressive (Group I) and exploratory (Group II) modelling settings. The following analysis investigated the changes in the problem representation mode of two experimental groups due to model-based reasoning.

No statistically significant difference was found between Groups I and II representation types with Mann-Whitney test. Wilcoxon Signed Ranks Test (see Table 2), which compared the development of individuals during the activity demonstrated that students in Group I changed their representation level significantly ($p=0.01$) only in the hypothetical-predictive phase of the activity, whereas in Group II such progress was not found. This indicated that the groups might not have been at equal level in the beginning. Students from Group I did not make any statistically significant advancement in their problem representation level during modelling activity, but students from Group II appeared to be developing significantly (p=0.02) towards using higher order Abstract problem representations. Surprisingly, in Group II the statistically significant (p=0.02) change towards lower Concrete-Abstract representation level was found in final Essay 2 compared with the students' Abstract reasoning level when using the model. This could be interpreted as the return to the previous representations due to performing the model-based reasoning in the context of analogous problem. In Group I highly significant (p=0.001) development was found between the initial reasoning level in Essay 1 compared with the final reasoning level in Essay 2. Group II changed their representation categories in final essays at significance level (p=0.02).

Table 2. Students' sequential problem representation development in Groups I and II

| Compared phases of the activity | Differences in representation level with Wilcoxon Signed Ranks Test | | | |
|---|---|---|---|---|
| | Group I | | Group II | |
| | Z | p | Z | p |
| Hypothetical-predictive reasoning (Phase II) Essay 1 (Phase I) | -2.54 | 0.01** | -1.35 | 0.17 |
| Model-based reasoning (Phase III) Hypothetical-predictive reasoning (Phase II) | -1.05 | 0.29 | -2.32 | 0.02* |
| Essay 2 (Phase IV) Model-based reasoning (Phase III) | -0.05 | 0.95 | -2.26 | 0.02* |
| Essay 2 (Phase IV) Essay 1 (Phase I) | -3.78 | 0.001** | -2.30 | 0.02* |

*Note.* *$p < 0.05$ **$p < 0.01$

Data from the comparison of two experimental groups indicated that the students' initial problem representation level might have influenced their mental model development during reasoning. Therefore, in the further analyses the students' data were separated into three subgroups on the basis of their problem representations in Essay 1. Subgroup A was initially able to describe problem only at Concrete level, Subgroup B had Semi-abstract representations with some flawed understandings, and Subgroup C had Concrete-abstract representations.

### 3.3- How does the students' initial problem representation level influence their development during model-based reasoning?

Table 3 reflects the three subgroups' mental model development during the activity. It appeared that students who had initially Concrete level representations of the problem (Subgroup A) developed their representations further towards higher order explanation levels only during hypothetical-predictive reasoning (p=0.04) and not during model-based reasoning.

Table 3. The different level students' sequential development of problem representations

| Compared phases of the activity | Differences in representation level with Wilcoxon Signed Ranks Test | | | | | |
|---|---|---|---|---|---|---|
| | Subgroup A | | Subgroup B | | Subgroup C | |
| | Z | p | Z | p | Z | p |
| Hypothetical-predictive reasoning (Phase II)<br>Essay 1 (Phase I) | -2.0 | 0.04* | -2.49 | 0.01** | -0.27 | 0.78 |
| Model-based reasoning (Phase III)<br>Hypothetical-predictive reasoning (Phase II) | -1.34 | 0.17 | -2.18 | 0.02* | -0.86 | 0.38 |
| Essay 2 (Phase IV)<br>Model-based reasoning (Phase III) | -1.0 | 0.31 | -0.52 | 0.59 | -1.31 | 0.18 |
| Essay 2 (Phase IV)<br>Essay 1 (Phase I) | -2.06 | 0.03* | -4.41 | 0.001** | -0.27 | 0.78 |

*Note.* *$p < 0.05$ **$p < 0.01$

The comparison of students' representations before and after the collaborative activity showed their significant level (p=0.03) development towards hierarchically higher order representation categories. In Subgroup A no statistically significant differences between students from Groups I and II were found in the development of problem representations during the different phases of the activity with Mann-Whitney test.

Students (Subgroup B), who were initially at Semi-abstract level of problem representations, appeared to develop significantly using more advanced explanation level both in hypothetical-predictive (p=0.01) and model-based reasoning phases (p=0.02). Subgroup B also showed highly significant (p=0.001) development in their Essay 2 compared with Essay 1, representing the problem with higher order explanation levels. With Mann-Whitney test no statistically significant differences were found between students who used exploratory and expressive learning settings.

Students who were at Concrete-Abstract representation level in their initial Essay 1 (Subgroup C) made no significant progress during two reasoning phases and in their initial and final essays. Among the members of Subgroup C statistically significant (p=0.04) divergence caused by different type of model-based reasoning was found with Mann-Whitney test. More students performed reasoning at Meta-Abstract level in exploratory modelling environment.

## 4. Discussion

Due to the frequent application of new computer-based modelling facilities at school, the in-depth understanding of the influence of these learning methods has become necessary. This paper investigated activities of model construction in expressive team-learning environment and collaborative inquiry with the exploratory web-based model. Although theoretically it was predicable that model construction as an inductive reasoning activity might activate students' mental representations differently than explorations with the model, which presumes deductive reasoning patters (Cornuéjols et al., 2000; Yu, 2002), no comparative studies have been carried out in this field in respect of model-based reasoning. The findings showed the clear difference of these two types of reasoning. Model construction activated the theoretical representation of the problem from the situation framework and the changes in it were made considering the model as a whole. Inquiry with the model activated two different mental representations, but explorations were made only in the context of analogous problem. The focus of constructing the representation was on measurable characteristics of the model components that inhibited its large-scale revision and re-interpretation.

Two tendencies were observed about the influence of different type of model-based reasoning on the development of students' mental models of the problem. Students who performed reasoning in exploratory learning environment applied higher order Abstract or Meta-Abstract reasoning levels when working with the analogy model but were not able to bring this conceptual knowledge into their explanations of the initial problem situation. No similar negative development was found in expressive modelling environment. It is possible that the exploratory modelling with analogous situation is more demanding from the perspective of developing students' in-depth understanding about natural phenomena than the expressive modelling activity. The students' conceptual progress due to model-based reasoning appeared to be influenced by their initial ability of representing the problem. Students who were able to focus only at concrete objects and properties did not benefit from model-based activity. The modelling was most effective for the students who had some understanding of the abstract level objects, properties and relationships of the problem but whose interpretation was flawed. Only students, who had already Concrete-Abstract type of problem representations, appeared to be influenced by the model-based reasoning type. Exploratory modelling activity favoured their usage of Meta-Abstract representations, expressive modelling did not have same effect.

It can be concluded that the model-based reasoning should be practised with students who already have some theoretical understanding of the phenomenon. Both expressive and exploratory type of modelling influence students differently, the former is focusing on theoretical qualitative elements and properties; the latter centres on measurable quantitative features. As the exploratory modelling task with analogy model turned out to be more complex for explaining similar situations it is recommended that this type of modelling activity should be designed as back and forth movement between the analogy model and the situation model.

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# LEARNING BIOLOGICAL EVOLUTION DURING ASSESSMENT – EXPLORING THE USE OF AN INTERACTIVE DATABASE-DRIVEN INTERNET APPLICATION

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## Abstract

The overall purpose of our research is to study how students develop understanding of scientific theories, in this study the theory of biological evolution by natural selection. Taking students' preconceptions as the starting point a teaching–learning sequence has been designed, implemented and assessed in a cyclic process. During one trial a group of 18 students (grade 11) was studied using various methods. Just after the theory was introduced, an interactive database-driven Internet problem was used for formative assessment. It deals with the evolution of the length of legs in a population of reindeer and consists of seven parts. The student is at first asked to speculate about the evolution of the length of legs, given a description of its variation. Then more and more information about the actual change in the length of legs and environmental circumstances is presented. The students are offered the possibility of changing their previous answer, as they work through the problem. Already in the opening part of the problem, 16 students answered with scientific evolutionary ideas. Our hypothesis is that if the intraspecific variation is explicitly given, it promotes evolutionary reasoning. The students appreciated the problem, and considered it as an opportunity of learning.

## 1. Introduction

### 1.1- The context of this study

A teaching-learning sequence about the theory of evolution has been developed according to a model outlined in figure 1. This model is described in detail by Andersson and Bach (2005), Andersson, Bach, Hagman, Olander and Wallin (2003), and Wallin (2004). The sequence is designed for a compulsory course in biology at the Natural Science Programme of the upper secondary school in Sweden (Hagman et al., 2002; Wallin, 2004). As a general didactical orientation we take a constructivist view of the knower-known relation as described in the book 'Piaget and knowledge' by Furth (1969).

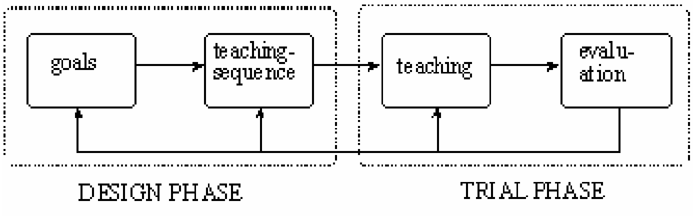


Figure 1. The process of developing a teaching-learning sequence

Taking students' preconceptions as the starting point the sequence is designed with the aim that students should learn the theory of evolution by natural selection in such a way that it becomes an intellectual tool. In other words they shall be able to describe, understand, explain, and partly predict biological phenomena from an evolutionary point of view.

Different methods were used to evaluate students' knowledge in the area of biological evolution such as a pre-test and interviews before teaching, and problem-solving, writing logbook entries, video recordings of group discussions, interviews, and participant observations during the sequence. At the end of teaching a pen–and-paper test was performed for grading the students. Approximately one year after teaching the students' long-term retention was tested by a delayed post-test. Most methods above were used or could be used for formative assessment. The internet-problem, which is the focus of this paper, turned out to have a high potential as an instrument for formative assessment.

### 1.2- Formative assessment.

The seminal work of Black and Wiliam (1998) has convinced us that formative assessment, appropriately used, can be of good help in improving teaching and learning. The authors give the following definition:

> *Formative assessment … is to be interpreted as encompassing all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged.*

The results from the pre-test and interviews before teaching were used for planning the sequence. As the teacher knew the preconceptions of his students he was able to use this knowledge in a deliberate manner in class. He was prepared to meet the students' alternative ideas and used these as a part of the instructional content. The paper-and-pen test and the delayed post-test were in the first place performed for summative assessment, but became formative for improving and planning of the next teaching-learning sequence (Figure 1).

### 1.3- Aims and research question

In this paper we will describe and discuss results concerning the use of an individual interactive database-driven Internet problem (Wallin & Andersson, 2000). The overall purpose of our research is to study how students develop an understanding of evolutionary biology as a result of teaching. The students' reasoning in different tests was carefully analysed having preconceptions, the conceptual structure of the theory of evolution, and the aims of teaching in mind. This gives insights into those learning and teaching demands that constitutes challenges to students as well as to teachers, when beginning to learn, or to teach evolutionary biology.

Before teaching started for the students discussed in this paper the teaching-learning sequence had been tested, evaluated, and developed twice. During these prior trials students were interviewed. Results from these interviews indicate that if the students are shown the intraspecific variation explicitly they start to discuss different survival rates in acceptable evolutionary scientific terms (Wallin, 2004).

This made us formulate the research question in this paper as a hypothesis: Students will more easily answer evolutionary problems scientifically correct if the existing variation in the population is explicitly shown.

## 2. Sample and methods

A group of 18 students, age 17 (grade 11), were studied during the teaching-learning sequence about 14 hours long. The students worked with this interactive database-driven Internet application directly after the theory of biological evolution had been introduced and exemplified in class and the time had come for them to begin applying it. It was introduced for several reasons:

- to get information that might be used for detailed planning of the remaining lessons
- to give the students an opportunity to solve an evolutionary problem individually and to reflect on his/her own answers
- to get information about the progress of each student

The problem was introduced and performed in the computer hall of the school. The students answered the different parts individually in front of a computer. The teacher only gave technical assistance and the researcher was observing without any interference. They used between 30 and 45 minutes answering the different parts altogether.

The problem consists of seven parts (Wallin & Andersson, 2000). In Figure 2 you can read the first part of the Internet application.

> Long ago a wildlife scientist observed a population of reindeer. She noticed a big variation in the length of their legs. She divided the population into three groups:
>
> short-legged (20%)
> somewhat longer legs (60%)
> long legs (20%)
>
> Let us now imagine that you are visiting this population of reindeer in the same area a great number of reindeer generations later. Use what you have learnt about the theory of evolution to speculate about the length of the legs in the reindeer population at this later moment. Are there still 60 % with long legs and 20 % in the other two groups or have these percentage numbers changed?

Figure 2. The opening part of the interactive database-driven Internet application (Part 1)

After having submitted an answer to part 1 to our database, the student gets new information from the base. He/she can read that there has actually been a change towards more long-legged reindeer and is asked to decide if the previous answer is still valid, and if not or only partly, he/she is asked for a new explanation. After submitting this answer, further information is given. They are told that log-legged reindeer are fast-runners compared to short-legged ones, and the possibility of changing the previous explanation is offered. In part 4 the student is informed that in the same area there is also a population of wolves. Does this fact change his/her explanation? In part 5 the student is asked to discuss the development of the wolf population. Finally, the student's answers to the first five parts are presented by the database and he/she is asked to reflect on his/hers previous answers (part 6). Then a scientific explanation from a text book is given (DeVore et al., 1974). The student is asked to compare this with his/her own answers and to write a comment (part 7). An evaluation form ends the whole problem.

The students' written answers were analysed using a category system with qualitatively different levels. Their reasoning was firstly categorized into either alternative or scientific ideas about evolution. Answers with scientific ideas were analysed with respect to the following five evolutionary components (Ferrari & Chi, 1998):

- Random intraspecific variation 'variation'
- Differential survival rate 'survival'
- Differential reproduction rate 'reproduction'
- Genetically determined inheritance 'heredity'
- Accumulation of changes over many generations 'accumulation'

## 3. Results

Of the 18 students 16 answered the opening part of the problem with scientific ideas about the evolutionary change in the reindeer population (Table 1). The numbers of components used of these students vary between two and five. The other two students answered biologically correct but didn't use the theory of evolution and hence no components (table 1; student Ivar and student Martin). All the students had answered with correct or at least acceptable scientific evolutionary reasoning after finishing part 3. Two examples of students' answer to part 1:

Student Adam: *It will altogether depend on how the environment has changed. If the environment supports long-legged reindeer, these will have the best possibilities of surviving, and their offspring will have genes for long legs, which will bring about longer legs in the reindeer population. But it is equally possible that the environment supports short legs and then they will be the best survivors and get offspring with short legs. (4 components: variation, survival, heredity, and accumulation)*

Student Martin: *The percentage will remain if the environment is the same. (no components)*

Table 1. The number of scientific components each student is using in the six different parts of the Internet-problem. An arrow means that the student considers his/her previous answer still valid. Answers not containing evolutionary reasoning is marked by a hyphen (-).

| Student | Number of scientific components in: | | | | | |
|---|---|---|---|---|---|---|
| | Part 1 | Part 2 | Part 3 | Part 4 | Part 5 | Part 6 |
| Adam | 4 | → | → | → | 5 | - |
| Anna | 3 | → | → | → | 4 | 1 |
| Berit | 5 | 5 | → | → | 4 | - |
| Bertil | 3 | → | → | → | 3 | - |
| Cecilia | 5 | - | 4 | → | - | - |
| Doris | 3 | 5 | → | → | - | - |
| Cesar | 4 | 4 | 2 | → | - | - |
| David | 4 | 3 | 2 | 1 | - | - |
| Erik | 3 | 3 | → | - | - | 1 |
| Filip | 3 | 2 | 2 | 2 | - | - |
| Gustav | 3 | → | 2 | → | - | - |
| Helge | 3 | → | 2 | → | - | - |
| Elin | 3 | → | → | - | - | - |
| Ivar | - | 3 | → | → | - | 2 |
| Johan | 2 | 2 | 2 | → | - | - |
| Kalle | 2 | 2 | → | → | - | 3 |
| Ludvig | 2 | → | → | → | - | - |
| Martin | - | → | 2 | → | - | - |

In their answers to part 1, few students are specific about environmental factors that might influence the evolution of the reindeer population. One student mentions that long legs might be an advantage when reaching for leaves on trees. A few students point out that long legs might help in escaping predators. A common suggestion (11 out of 18) is that the proportion of reindeer with 'somewhat longer legs' will increase. Some students explicitly point out that the fact that this group is 60 % of the population indicates that this leg-size is optimal for survival and therefore will be more and more dominant.

In part 4 the students are informed of the wolf population in the same area. The majority of the students (14 out of 18) consider their previous answer still valid. No student use more components in this part than in earlier parts of the problem. In part 5 the students are asked to discuss the development of the wolf population using what they have learned of the theory of evolution so far. No student considers his/her prior answer still valid. Four students give evolutionary explanations with three to five components, all the others answer without evolutionary reasoning.

> Student Adam: *The wolf population will probably develop in the way that the wolves which have genes for running fast will be better at catching reindeer now when most of these have become long-legged and can run fast. Therefore the wolves with genes for fast running will be better survivors and can more easily produce offspring since*

> *they live longer and don't die from starvation. In that way more wolves in the wolf population will become faster.* (5 components: variation, survival, reproduction, heredity, and accumulation)

Despite all students having reasoned in an evolutionary acceptable way about the reindeer population alternative evolutionary ideas are used by some students for explaining the development of the wolf population. For example Student Doris below discusses development in the alternative terms of need and learning.

> Student Doris: *Probably they have to learn to run faster. No, but first they will catch the reindeer with shorter legs which are more slow. Surely, it will always be someone born with somewhat shorter legs. But when they 'come to an end', the wolf has to become faster and perhaps becomes more long-legged so it runs fast. They will probably find out some smart way of catching reindeer.* (Alternative ideas: need and learning)

Student Elin discusses evolution in more general terms without mentioning any of the five specific components listed above:

> Student Elin: *The wolf will be pleased if the reindeer are born with short legs so they can catch them. But the reindeer will surely get longer legs so they can run faster and the wolves will have difficulties to catch up. Probably the wolf will be extinct if they don't get any food or they become more long-legged too.*

Approximately one year after teaching the students perform a post-test. The maximum score is 60 and the five top results are between 55 and 57. The four students who had discussed the wolf population evolutionary correct are all among the top five students in this delayed post-test.

In part 6 the students get an overview of their answers from the previous five parts and are asked to comment and to add an explanation if they want to. One third of the students doesn't comment at all, one third expresses that they are pleased with their previous answers, and last third choose to add something. Of these students only one (student Kalle) increases the number of evolutionary components (see Table 1).

> Student Cecilia: *All this is about whether one can manage to think around, and come up with comments of ones own and so on. I think these answers are relatively good but I probably could have used more facts or explanations. But I didn't think it was necessary since it is the same thing! At least as I know it! I feel pleased with it. Simply, the problems were good and so were the answers.*
>
> Student Kalle: *In part 4 I should have written that the slower reindeer will be eaten by the wolves while the ones with long legs, the fast ones, will be better survivors and in that way they can reproduce more times.* (3 components: variation, survival, and reproduction)

In part 7, the students are presented an evolutionary text from an English text book, and asked to compare their own answers with this text. The majority of the students think their own answers are as good or at least almost as good as the one from the text book. Some students point out that they hadn't discussed more than one characteristic of the reindeer, the length of their legs, while the text book also mentions another.

> Student Berit: *My answers are more or less in agreement with the authors', except for the fact that I didn't mention the instinct of the reindeer to flee from the wolf. I just keep to the length of the legs. But I do agree that reindeer, which don't flee from wolves, wouldn't survive, and that the instinct to flee from wolves therefore will become more common among the reindeers with time.*
>
> Student Johan: *I was chocked or something. It was rather well in agreement with what I had said, though I didn't mention the things about genes and all that, but I consider relatively obvious that the child will resemble its parent.*

This problem has an evaluation form at the end. The students are first asked to decide if they experience the problem as interesting or not, easy or difficult, and important or not on a scale from one to five (Table 2). They experience the problem as relatively interesting (mean 3.7), neither easy nor difficult (mean 3.2), and fairly important (mean 3.8).

Table 2. The number of students choosing an alternative on a scale from one to five about their experience of this problem

| Scale | Number of students | | | | | |
|---|---|---|---|---|---|---|
| 1 | Boring | 0 | Difficult | 0 | Unimportant | 0 |
| 2 | | 1 | | 2 | | 0 |
| 3 | | 5 | | 11 | | 6 |
| 4 | | 10 | | 4 | | 9 |
| 5 | Interesting | 2 | Easy | 1 | Important | 3 |

The students are also asked to answer three open-ended questions about the problem. What they thought was good or bad, and how to improve the problem. Many students appreciate that they get the opportunity to think for themselves, and that they are allowed to do changes at the end. One third of the students points out that they don't think anything is bad, but a few students think the different parts of the problem are monotonous.

> Student Anna: *You had to think and use the knowledge you had acquired from the lessons.*
>
> Student Kalle: *One learns how different animals have evolved their abilities and then one thinks about how we have evolved in time. The order of the different parts was very good since one can change opinion for the better, when one has seen all the parts on one paper.*
>
> Student Berit: *I think that I have done very many similar tasks, so it begins to be a bit boring.*

Almost half of the students choose to comment, all of them positively, on this problem in their logbook entries at the end of the lesson.

Student Doris: *The things we do with the computers are good. In other words you do it twice. You talk about it, read about it, and after that answer questions about it. That makes it go inside the head and maybe it stays there for a while instead of pushing off out through the other ear.*
Student Cesar: *Good with that Internet thing. You learn to think for yourself. Use yourself the theory of evolution.*

According to the researcher who observed the students while they worked with the problem, the students were concentrated and appeared to take the problem very seriously.

## 4. Discussion

By finishing part 3 of the problem all our students had answered with scientific evolutionary ideas in at least one part. We think that these results of the students' first attempt to use the theory are good, especially in view of the extensive documentation of students' difficulties in understanding the theory of evolution (Anderson et al., 2002; Bishop & Anderson, 1990; Brumby, 1981; 1984; Demastes et al., 1996; Demastes et al., 1995; Ferrari & Chi, 1998; Jensen & Finley, 1996; Settlage, 1994; Thomas, 2000; Zuzovsky, 1994). One possible explanation can be the nature of the problem, namely the fact that the variation is explicitly given, which we think promotes evolutionary reasoning. In that case the results from this Internet application support the hypothesis of this paper. The intraspecific variation was explicitly given in the problem and all students wrote about different survival of the individuals in the reindeer population. A key condition for reasoning in an evolutionary correct way seems to be awareness of the intraspecific variation.

All students give answers, which are categorized as containing the two components 'variation' and 'survival', but most answers analysed also include one, two, or all three of the other possible components. Many students write quite short answers and it is possible that they have a better understanding than their written answers show. One example of this is Student Johan who writes that he omitted one of the components because he thought it was obvious, in his case 'heredity'. Maybe more students think like him because the 'heredity' component is the one with lowest frequency in the answers, only five students are categorized for reasoning about inheritance.

Concerning the development of the wolf population, only four students discuss this in a scientific evolutionary way, despite being asked to use the theory of evolution. Three of these four students had relatively good preinstructional knowledge, but more interestingly all four are among the five students who have best post-test result one year after teaching. Although there is a positive correlation in result between pre- and post-tests in this group of students (Wallin, 2004), it is interesting to see the really good delayed post-test result of the students who in this problem could see that both populations are evolving at the same time. The teaching had not included any discussions about co-evolution at the time for this problem, and the result informed the teacher that this idea ought to be further developed during lessons to come. These results indicate that it is important to see both populations evolving simultaneously. Next time this problem is used the teacher will investigate if his/her students discuss both populations as evolving. If not, the next lesson will contain such a discussion.

Altogether the students seem to appreciate the problem, and it gives all students time and opportunity to think individually about an evolutionary problem during teaching. In the evaluation form the students express that they appreciate the opportunity to think individually, to be allowed to change their own answers, and to assess their own knowledge. The student evaluation also shows that they had used the problem as an opportunity of learning.

## 5. Implications

Interactive, database-driven internet applications offer new and flexible ways to arrange assessment for both formative and summative purposes, and in a manner that promotes learning during the assessment. Databases can be made searchable both for teachers and students. Thus individual students can follow their own progress from one assessment to another by searching the base. If the base is appropriately arranged, both teacher and students can look up the results of the whole class.

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# THE EFFECTIVENESS OF PROBLEM-SOLVING STRATEGIES USED IN WEB-BASED INQUIRY LEARNING

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## Abstract

Our study based on the evaluation of inquiry skills in applying a web-based situational simulation “Hiking Across Estonia”. Learners were provided with all necessary supplementary information and virtual models for collecting and analysing data. 265 students from the 6th to the 12th forms in 66 groups used the environment during a three-week competition in 2003. All participants also filled in an electronic pre- and post-test that evaluated different basic and higher level process skills in analysing graphs, tables, photos, and figures. The focus of the paper was the effectiveness of the five main strategies the learners used in solving the problems. The analysis of covariance showed that the groups who finished the simulation performed significantly better in the post-test compared with the pre-test. However, the groups of different clusters founded by hierarchical clusters analysis developed differently in gaining inquiry skills. Students’ pre-skills and attitudes played an important role in scaffolding inquiry process. Some groups spent very much time on learning but did not have significant success; the others completed the tasks very well in relatively little time. The mistakes made by each cluster in analysing different type of data are also discussed.

## 1. Introduction

The general goals of learning and teaching biology have been changed from learning factual knowledge to gaining skills and practising methods appropriate for scientists. Learning how to apply scientific methods is not as easy as learning facts and it needs more time. One possibility to overcome the problems teachers have indicated in teaching in our changed society is to use inquiry learning environments.

In this paper, we define inquiry learning as the process of discovering rules governing the relations between independent and dependent variables on the basis of experiments in which the independent variables are manipulated (Wilhelm, 2001). Web-based simulation environment offers good opportunities for inquiry learning (De Jong & Van Joolingen, 1998). Students can explore virtual processes of the world, manipulate variables, observe the effects of their operations, and do experiments to discover relations between variables. Web provides learners with a great variety of databases and information sources for educational purposes.

This paper concentrates on the problems that student groups with various learning strategies have in inquiry learning. For this reason a web-based inquiry learning environment "Hiking Across Estonia" (http://bio.edu.ee/tour/) with many problem solving tasks has been designed (Sarapuu & Pedaste, 2001; Pedaste & Sarapuu, 2002). Students learned in this environment during a three-week competition and they were divided into clusters according to their results and strategies used in solving problems. In this environment students had to solve 25 complex problems in a certain order during a three-week all-Estonian competition. The educational tasks embedded characteristics of algorithmic problems, story problems and rule-using problems (Jonassen, 2000). These types of problems have only one answer that is more correct than others and due to this these can be checked by computers automatically. The background information and virtual tools for carrying out experiments in order to solve these problems were available in the learning environment.

All the learning tasks are about environmental education and ecology. Students become acquainted with five ecosystems during the virtual hike: heath forest, meadow, grove, waterside meadow, and bog. All communities are provided with informational windows containing supplementary materials about 200 species of plants, fungi and animals (Figure 1). The information is for introducing the most common and interesting living things found in Estonia but it is also a source material for solving inquiry learning tasks.

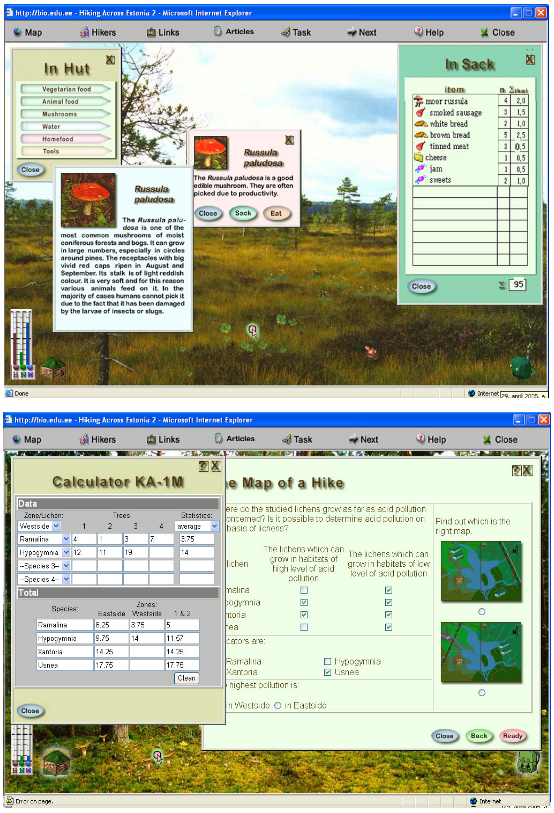



Figure 1. Bog with opened supplementary materials (above) and educational task with a virtual analyser (below)

The learning environment "Hiking Across Estonia" presents an authentic virtual world for inquiry learning in everyday-life situations. In that kind of environments lack of skills and strategies for designing and making experiments could be one reason for ineffectiveness. Apart from teaching inquiry learning skills, most training programmes provide opportunities for practice. There are several examples of training and support procedures in the literature (see De Jong & Van Joolingen, 1998). Most of these examples contain on-line facilities like a hypothesis scratchpad or an assistant providing solicited or unsolicited help. In other computer-supported simulation environments students are led through a series of increasingly complex models in the simulation environment (White & Frederiksen, 1990). This model was also applied in our case. 25 problem solving tasks of learning simulation ordered according to the level of difficulty inquiry skills embedded in these tasks. In the beginning students had to find simple linear positive relations between two variables and in the end they solved complex problems with many variables related non-linearly to each other.

Metz (1995) has also suggested that students are able to develop the necessary skills for inquiry learning by offering them authentic experiences in goal directed tasks. This can be accomplished in simulation environments, by providing scaffolding or arranging collaborative learning tasks as in the simulation "Hiking Across Estonia". Learning in groups is beneficial for inquiry learning because it allows for the formation of a supportive climate for learning, organisation, responsibility and division of work (Tingle & Good, 1990) and also offers the option to test and correct ideas from among various reasonable opinions (Aho et al., 1993). In our study the groups of students formed from volunteers who had no previous experience in working together in a web-based inquiry learning environment. Therefore, we collected the characteristics of learning groups and their members. One aim of this study was to find out what kind of problems different groups would have in inquiry learning process. If we can classify these groups before using the learning simulation, then we will have the possibility to scaffold them in the most effective way.

In an early study of collaborative inquiry, Barnes and Todd (1977, 1995) analysed the ways how small groups of students reshaped their understandings through talking with each other about what their thaughts. During such small group interactions without the teacher, students must engage independent yet collaborative thinking. Pea (1991) traced the processes by which students negotiated meanings when they used computer simulations in small groups. In a student-generated inquiry discussion, students generate comments and questions while inquiring about a topic without much intervention from a teacher. For example, diSessa et al. (1991) recorded such discussions during a five-day activity in which the sixth grade students "invented graphing" while designing a wide variety of ways to represent motion. The teacher did not manage the discourse on a moment-by-moment basis as is typical in guided discussions. She set the task, provided initial criteria, managed interactions, and provided conceptual focus on appropriate moments but the students did most of the talking. In our study the groups of students always worked without a teacher. Their explanations about problem solving process were recorded with a questionnaire filled in after pre- and post-test. It enabled to evaluate the changes in small group interactions during inquiry learning process and relate this to the achievement in problem solving.

Our research questions were:

1. How can students be classified according to their learning strategies used in solving problems in the exploratory simulation "Hiking Across Estonia"?
2. What are the levels of inquiry skills in different groups before and after the use of the simulation?
3. What kind of mistakes do students have in analysing information in forms of tables, graphs, figures, and photos?

## 2. Method

This research has a mixed design of both quantitative and qualitative methods. The general effectiveness of web-based situational learning simulation "Hiking Across Estonia" (http://bio.edu.ee/tour/) clarified with the quantitative analysis. The results of an electronic pre- and post-tests with similar multiple-choice and open-ended questions analysed with the analysis of covariance (ANCOVA). The tests evaluated learners' improvement in inquiry skills, general problem solving ability and their skills to analyse photos, graphs, tables, and figures. In this case group size, number of boys in a team, students' grade, and the results of the pre-test were used as covariates.

Both pre- and post-test contained four problem-solving items. One of these was based on analysing three graphs about the ecological relations of hypothetical organisms (see Figure 3) and the second one about the same theme started with the analysis of a table (see Table 3). The third task was based on the comparison of two photos made after five years. It also included making some predictions according to the data received. The last tasks consisted of a short text and figure-based data about food-net in a artificial ecosystem. Students had to find the quantitative relations between three species presented in two figures of different experiments. First students had to choose some multiple choice items in case of all tasks and after that they had to describe in detail why they had made that decision. The last one was an open-ended question.

In order to find qualitative differences in inquiry learning process the teams were classified into groups with hierarchical cluster analysis. Data from pre- and post-test, log-files with information about achievement and students' activities on virtual hike, questionnaire of problem analysis strategies, and form of personal characteristics were used for distinguishing groups. The general differences between clusters were determined with discriminant analysis. Non-parametric Kruskal-Wallis test applied for proving statistically significant differences in the answers the members of different clusters given in the pre- and post-test. Wilcoxon signed ranks test was used for finding general differences between specific answers in the pre- and post-test.

SPSS software was applied for all statistical analysis. MS Excel was used for ordering the results and for completing figures and tables for this paper. The data for this study was collected during an all-Estonian competition organised in April and May 2003 by the Science Didactics Department at the University of Tartu. 66 teams with 265 students completed the virtual hike and filled in electronic pre- and post-tests and questionnaires. They used learning environment after school day when the time was suitable for all members. The team size was from three to five people (4.0 in an average) and students were from the 6th to the 12th grades (aged 12-19). The majority of groups were from the 8th grade. 57% of the students were girls and the rest were boys. There where 15 male teams and 21 female teams.

## 3. Results and discussion

The general effectiveness of inquiry learning simulation "Hiking Across Estonia" was demonstrated with ANCOVA analysis. Most of the groups who finished the competition performed in the post-test significantly better than in the pre-test (Table 1). The improvement was statistically significant in all types of questions: students' general problem-solving skills and their skills to analyse tables, graphs, figures and photos. The development of problem-solving ability and its components mainly depended on students' skills demonstrated in the pre-test, their grade and gender. The characteristics that have an influence on students' problem-solving skills are more thoroughly discussed in our former articles (Pedaste & Sarapuu, 2004b). The direction of the influence varied much in different groups and so we needed to run a cluster analysis. Dividing students into groups is also an assumption for adaptive learning where the individual characters will be taken into account (Carrier & Jonassen, 1988).

Table 1. Differences between the results of the groups (n=66) in the pre- and post-test according to the ANCOVA analysis

| Dependent variable | Pre-test | | Post-test | | F | Sig. p |
|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | | |
| Solving problems | 55% | 18 | 63% | 18 | 15.0 | <0.01 |
| Analysing tables | 47% | 23 | 55% | 23 | 7.5 | <0.01 |
| Analysing graphs | 56% | 32 | 65% | 32 | 37.5 | <0.01 |
| Analysing figures | 57% | 20 | 64% | 12 | 11.9 | <0.01 |
| Analysing photos | 56% | 19 | 75% | 18 | 18.6 | <0.01 |

According to the hierarchical cluster analysis it was possible to divide all the groups of students into six clusters (Figure 2). 7 out of 66 groups differentiated from others very near to the root of the tree. These seven groups were divided into two sub-clusters but one of them had only one member and this cluster was left out of the analysis. The rest of the groups were divided into four sub-clusters. Two first discriminant functions described together 96% of the variance of our classification ($c^2 = 244$, $p < 0.01$ and $c^2 = 98$, $p < 0.01$). According to Wilks' Lambda test the rest of the functions were not necessary for describing the system. All characteristics involving the discriminant functions were divided into two groups with a significant difference – only the characteristics influencing the classification very much accounted for calculating the final discriminant functions.

In this paper we will concentrate more on the qualitative differences in the clusters and so we will give only a short description of all five clusters applied in the analysis with non-parametric tests (Table 2). The complete general description of these clusters is available in the proceedings of conference of Finnish Math and Science Teachers Association (Pedaste & Sarapuu, 2004a).

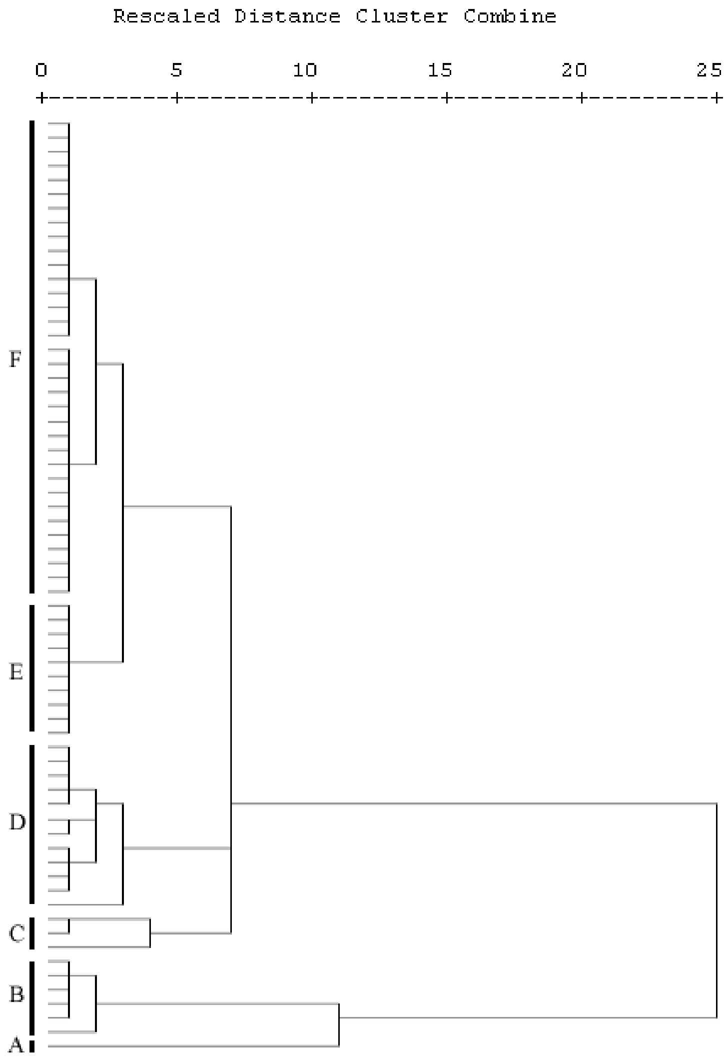



Figure 2. Division of learning groups according to the hierarchical cluster analysis (n = 66)

On the basis of the table 1 more than a half of the groups (54%) were classified into the cluster F, which had the poorest general results in the virtual hike and improved generally less than any other group. This fact showed the importance of deeper analysis of what kind of problems learners had during the inquiry learning process and how some groups of students had overcome these. In our case in can be concluded that two clusters were generally very effective (C and D) but did not develop very much compared with others in analysing figures. Other two clusters (B and E) had good results especially in analysing figures, but did not improve so much in other analysing skills. Groups of cluster B also spent too much time on learning. Cluster F showed the biggest increase in analysing photos, whereas other skills did not improve well compared with other clusters. On the basis of the variety of the results of inquiry learning in different clusters it was necessary to find out how students in each cluster reasoned their decisions. This question could be answered on the basis of the qualitative analysis of the results of the pre- and post-test.

Table 2. Description of five main clusters of groups identified by the hierarchical cluster analysis (n = 65)

| Code of cluster | Number of members | Characteristics of groups | Characteristics of problem solving | Achievement |
|---|---|---|---|---|
| B | 6 | small groups (3.8 students in an average) | spent a lot of time on solving a problem in the virtual hike (39 minutes in an average); took notes in analysing data; controlled relations found in data more than once; evaluated more than one hypothesis and solution | good results in analysing figures |
| C | 3 | the smallest groups (3.7 students in an average); consisted more of boys than any other groups (67%) | spent very little time on solving a problem in the virtual hike (15 minutes in an average); used the first idea they had for analysing data and did not consider other hypothesis or solutions | very good general results in the virtual hike (95%); improved more than other groups in analysing graphs, tables, and photos, whereas in development of analysis of figures they were the poorest cluster |

| | | | | |
|---|---|---|---|---|
| D | 12 | the biggest groups (4.3 students in an average); consisted mostly of girls (69%) | spent a lot of time on solving a problem in the virtual hike (25 minutes in an average); had a long conversation about different hypotheses and solutions; controlled some of them whereas dropped some other thanks to logical thinking | the best results in both pre- and post-test; improved in all skills although not much but still statistically significantly |
| E | 10 | consisted more than any other group of girls (91%) | did not spend too much time on solving a problem in the virtual hike (17 minutes in an average); made remarks and controlled different hypotheses and solutions only in case of analysing figures | the biggest increase in analysing figures (74%) and the poorest improvement in analysing tables and photos; did not improve in analysing graphs |
| F | 34 | the smallest groups (3.7 students in an average); consisted more of boys than any other group (67%) | spent time on solving a problem in the virtual hike less than any other group (11 minutes in an average); used the first idea found for analysing data and did not consider other hypothesis or solutions; sometimes did not think logically and just made a guess | the poorest general results in the virtual hike (44%); improved generally less than any other group; demonstrated the biggest increase in analysing photos (34%) |

Both in pre- and post-test groups of students explained what the relation between observed variables was and how they reached the decision. This specific data was collected separately about analysing graphs, tables, photos, and figures.

In analysing graphs students had to find from a set of graphs positive linear correlation, negative linear correlation and non-linear correlation (Figure 3). Additionally they had to prove once that there was no correlation between two variables. First, they had to find relations between the hypothetical organisms and ecological factors and after that students were asked to explain how they reached this result. The explanations gave information about the strategy groups applied in the analysis.

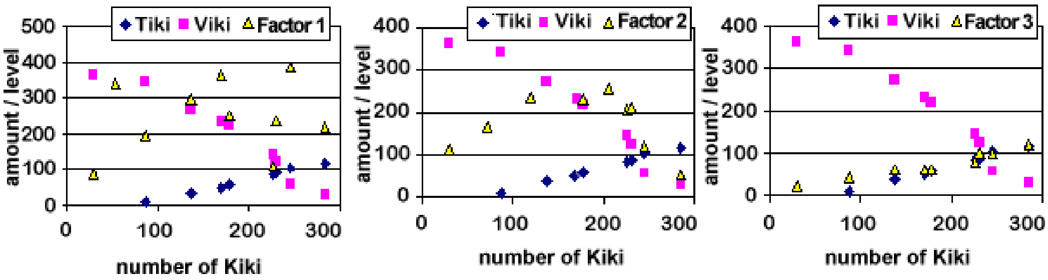



Figure 3. Graphs used in pre- and post-test

There was a positive linear correlation with some natural deviations between Kiki and Tiki, and Kiki and Factor 3. These were abstract not meaningful objects in order to avoid decisions based on pre-knowledge. This is an important problem that can misrepresent the findings (Wilhelm & Beishuizen, 2003). The results showed that this relationship is detectable most easily and 82% of the groups made the correct decision already in the pre-test. Finding the negative linear correlation between Kiki and Viki was also not problematic. 79% of the groups had the correct answer.

The problems appeared in detecting non-linear relation between Kiki and Factor 2 and in proving that there was no relation between Kiki and Factor 1. In these cases we found statistically significant improvement in post-test compared with pre-test according to Wilcoxon signed ranks test (from 60% to 78%, $Z = -2.8$, $p < 0.01$ and from 65% to 77%, $Z = -1.9$, $p < 0.05$ respectively). According to the Kruskal-Wallis test there were no differences between the clusters of groups in finding a non-linear relation in the post-test ($p > 0.05$). In the pre-test the clusters D and E performed much better than others ($p < 0.05$). The correct answer was: "If the number of Kiki increases then in the beginning the level of factor 2 increases as well, but after reaching a certain point it will decrease".

In other clusters the most common answer was: "The variables are not related because we do not find any logical relations". It seems to be the easiest explanation if students do not want to spend too much time on learning (in clusters C and F) or they have problems with logical thinking (the students of cluster B worked very carefully, but did not succeed). The lack of skills to analyse graphs is also due to the textbooks in biology. Roth et al. (1999) found that graphing resources of graphs in sections on ecology in high school biology textbooks are often lacking or that they are given in such a way that they obstruct reading and interpreting the graph.

Graphs are often used in biological research in order to find or demonstrate relations between variables. It is more difficult to find associations in tables. In analysing a table students had to detect a positive linear correlation twice, one negative linear correlation and one non-linear correlation (Table 3).

Table 3. An example table presented in the pre- and post-test

| Variables | Places of taking measurements | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Number of Keti | 86 | 198 | 153 | 41 | 202 | 159 |
| Number of Peti | 171 | 133 | 307 | 83 | 95 | 248 |
| Number of Leti | 291 | 131 | 202 | 307 | 115 | 194 |
| Level of factor 1 | 23 | 84 | 56 | 12 | 87 | 61 |
| Level of factor 2 | 135 | 183 | 64 | 107 | 185 | 201 |
| Level of factor 3 | 2 | 4 | 3 | 1 | 5 | 3 |

Students had no problems in detecting positive linear correlations. There were great difficulties in finding both negative linear and non-linear correlation. Only 29% of the groups could detect a negative correlation between Keti and Leti in the pre-test and 46% in the post-test. According to signed ranks test it was a statistically significant improvement ($Z = -3.4$, $p < 0.01$). In the pre-test only the cluster E was able to succeed in answering this question. At the same time they had the lowest improvement in analysing tables. It could be explained with their high achievement already in the pre-test. Two types of wrong answers were very common. Firstly, groups in cluster B found mostly that "there is no relation between these variables because sometimes the number of Leti' is bigger than the number of Keti' and sometimes it is not". They were not able to process all data during the same time and just took some examples of cases and did not find the correlation. Secondly, in clusters C and F students regularly found that there was a positive relation between variables observed. This error could be explained by the time these groups used – they spent less time than any other group and therefore did not understand the characteristics of this association. A second explanation to this problem can be the language we use in biology. Abrams et al. (2001) found that when pupils are taught to construct proximate explanations during biology lessons they are usually confronted with representations of quantitative data. In case of discovering a non-linear relation there were no frequent wrong answers. The groups of cluster E had the most effective strategy for analysing tables. They ordered the entire table based on the increase of Keti and in some cases made a graph based on the data. These strategies have to be introduced to other learners as well in order to increase the effectiveness of analysing tables.

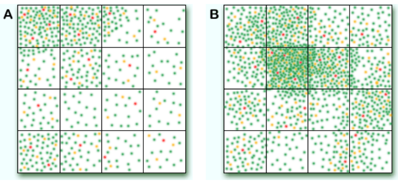
There were two photos of a forest, one of them was made last summer and the other one five years before in order to evaluate the skills to analyse photos in the pre- and post-test. There were storm damages in the latest photo. Students had to find changes that had already taken place, and to predict what will appear in the next five years. This task involved more biological knowledge compared with analysing graphs and tables and, therefore, students made a lot of mistakes in predicting in the pre-test. Especially groups in cluster B and C did not realize what information was presented in the photos and they wrote a long story based on their knowledge not on the actual data. It seems to be a common error in inquiry learning. According to Kuhn (2000) many students have absolute views of the world. They are not able to raise various hypotheses to explain ambiguous phenomena but stick to one explanation, which they consider to be absolutely true. In fact, they do not make a distinction between theory and evidence. Still, in analysing photos there were no remarkable problems in our study. This finding can be also explained by the content of photos.

Other tasks of the pre- and post-test were more abstract and without familiar content and this made the analyses more complex. Wilhelm and Beishuizen (2003) carried out a research of inquiry learning limitations where one group performed a task of familiar content, the other performed an isomorphic abstract task. As in our study, learning outcome was higher in the group performing the concrete task. In solving an abstract problem they had to find more hypotheses in order to have success. In our case especially groups of clusters C and F failed in analysing abstract graphs and tables because they did not spend enough time on solving these problems. It is expected that working in groups increases the effectiveness of inquiry learning (Tingle & Good, 1990). In analysing photos it could be a danger as well because students sometimes hear the group members and forget the evidence found in photos.

The most difficult part in our study was the analysis of figures because of the complexity of it. Firstly, students had to collect data into tables and after that find the relations between various variables (Figure 4). Finally, learners compared their outcomes with theory and worked out their own explanations. In the task based on analysing figures students had to find the numerical correlations of three species in a hypothetical ecosystem with and without additional feeding by scientists. The situation in both cases was demonstrated with different dots in two figures. These species were each from a different level in a hypothetical food chain.

It was interesting that students had no problems in finding most of the correct relations based on the figures but they made mistakes in proving these with explanations based on numbers. A very common answer was that "the figures gave us the answer". Correct numerical correlation was found only by 4 groups out of six in the cluster B. They spent on solving each problem much more time than other groups and this could be the main reason of success in case of the most complex task. Only one team (also in cluster B) was able to explain the relation between three species quantitatively. Others just named who was eating who. It seems to be a common problem of teaching biology that we are studying relations qualitatively rather than quantitatively. In prospective objectives of inquiry learning we also have to pay attention to measurable variables and quantitative analysis (Wilhelm, 2001).

You are provided with the results of a study where researchers found out how the feeding of secondary consumers (carrion crow) affected the whole food web. The figures present the results in two different areas – figure A with additional food and figure B without it.




- carrion crow (red dot)
- "Saki" (yellow dot)
- "Raki" (green dot)

Write your calculations in this table.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

What are the differences of these two figures?

There are more carrion crows in the figure A. YES NO
Explain, how you made your judgement.

There are more "Sakis" in the figure A. YES NO
Explain, how you made your judgement.

There are more "Rakis" in the figure A. YES NO
Explain, how you made your judgement.

There are more different species in the figure A. YES NO
Explain, how you made your judgement.

There is higher density of carrion crows in the figure A. YES NO
Explain, how you made your judgement.

Who is who in this ecosystem:

| Carrion crow | "Saki" | "Raki" |
|---|---|---|
| ❑ producer | ❑ producer | ❑ producer |
| ❑ primary consumer | ❑ primary consumer | ❑ primary consumer |
| ❑ secondary consumer | ❑ secondary consumer | ❑ secondary consumer |
| ❑ tertiary consumer | ❑ tertiary consumer | ❑ tertiary consumer |

What kind of relation exists between the carrion crows, "Saki" and "Raki"?
How did you find this relation?

Make two additional judgements about the relations found out on the basis of this study.

Judgement 1:
Explanation:

Judgement 2:
Explanation:

Figure 4. A task in the pre-test for evaluation the skills to analyse figures (with colour dots)

## 4. Conclusions and implications

Many researchers have demonstrated (see De Jong & Van Joolingen, 1998; Shin & McGee, 2002) that web-based simulation environment is very effective for inquiry learning. Our study clarified that there will be a statistically significant improvement generally in analysing graphs, figures, tables, and photos, but also in case of many specific operational skills. According to the comparison of pre- and post-test students' ability to find negative linear and non-linear correlations increased. All these skills are not in the list of the main objectives of the curricula of biology (National curriculum…, 2004; National curriculum…, 2002; National science…, 1996).

In general there were no problems in learning in groups consisting of volunteers. This enables to share work and to form supportive climate for learning (Tingle & Good, 1990). It also increases the number of ideas in the stage of hypothesising or making and evaluating final decisions (Aho et al., 1993). At the same time we have to remember that students in a learning community are of different age and gender, they have various pre-knowledge, pre-skills, attitudes, and motivation. Therefore, we need to know what kind of problems different groups of learners will have. In our study we applied a web-based simulation, which allows learning step by step. This also gives the opportunity to classify students according to the first steps and then to modify their support based on this group. According to cluster and discriminant analysis it was found out how divide the groups of students (Pedaste & Sarapuu, 2004a).

In this study it was demonstrated what kind of difficulties different clusters of learning groups will have, and which strategies they use in solving environmental and ecological problems. The collected data could also be a source material for science educators and researchers who will be teaching or studying the skills to analyse information presented in forms of tables, figures, photos and graphs. According to our results these skills should have more attention in science lessons because of the lack of specific inquiry skills that are very often applied in making real science.

## Acknowledgements

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# SECTION 4

# THE IMPACT ON TEACHERS OF NEW APPROACHES TO BIOLOGY EDUCATION

# CAN ACTIVE/COOPERATIVE LEARNING BE PRACTISED AT SCHOOL?

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## Abstract

The study concerns a teaching action undertaken on the grounds of the opinion that a successful use of methodologies based on active and cooperative learning could potentially obviate some of the most worrying deficiencies in current scientific teaching, while, at the same time, supporting the validity of the constructivistic theory that prompted them. A teaching action on GMOs was planned that involved the setting up of some tools (diagnostic tools, strategies imbued with problem-based learning and concept cartoons), a teaching sequence and laboratory materials (replica-plating aimed at the recognition of transformed bacteria, *Nicotiana* cultures, electrophoresis comparing protein patterns of GM and non-GM plants). It was then carried out in ten classes of six upper secondary schools (three specialised in classical and three in scientific studies) in Rome, with a total of 144 students, ranging in age from 16 to 19. The written texts of students' positions and argumentations were analysed statistically and conceptually, which led to an overall positive evaluation of the teaching action, at least as regards the mastered use of scientific terminology and argumentation. Moreover, they allow the action to be considered as efficacious with respect not only to disciplinary education but to total intellectual and social maturity as well. Though the structure and the organization of the schools involved were very different, autonomous inquiry, group work, and *plenary* discussion were not impeded in any way.

## 1. Introduction

In Italian primary and lower secondary school science education is widely based on the observation, description, and explanation of every day life objects and events, and on the discussion and solution of problems. Only Biology precociously takes a notionistic form, which is strengthened in higher secondary school and is even justified in an unequivocal notionistic essence of University entrance tests for scientific degree courses (Bandiera, 2005). So a notionistic attitude emerges and is diffused, while scientific knowledge turns out to be sure and definitive, absolutely unconnected to experimental procedures and data, and subject to rote learning and repetition.

In order to modify this trend as a whole, in recent years many in-service teacher training courses have devoted great attention not only to laboratory sessions, but also to a variety of active and cooperative learning methodologies, which promote autonomous probing, use and critical evaluation of knowledge, and which teachers have unfailingly considered impracticable at school due to the lack of laboratories, equipment suitable for group-work and time.

## 2. Rationale and objectives of the study

Educational methodologies based on *cooperative learning* can be considered the direct applied product of the constructivistic side of cognitive theories (Colburn, 2000). Indeed they systematically call for – in the more general context of *active learning* – interaction between teacher and student, comparison of their respective knowledge and conceptions, and feedback regulation of the teaching/learning process. The group work and peer interaction foreseen requires: enhancement and socialisation of individual cognitive experiences and previous knowledge, autonomous management of knowledge acquisition and construction processes and procedures, argumentation and negotiation of hypothesis and opinions, and contextualisation of disciplinary knowledge (Slavin, 1987; Johnson et al., 1991; Lord, 2001).

Successful (as regards the quality of the scientific education achieved and/or of the promoted attitudes) adoption of these methodologies, together with the personal involvement of students and a stressed correlation between the knowledge and experimental procedures and data that prompted it, could potentially eliminate some of the most worrying deficiencies of current scientific teaching and, at the same time, support the validity of the theory on which they are based. At present, however, in contrast to the widespread evidence of effective experimentation carried out in *protected* situations are a series of perplexities and problems (excessive time consumption, inadequacy of space and equipment, atypical teacher role, difficulties in performing assessments) that hamper broader dissemination (Angeli, 2002).

In order to test the above-mentioned methodologies and to cite a (hopefully) reassuring example, a teaching action, divided in two two-hour class sessions held on non-consecutive days, was designed. The action was carried out in upper secondary schools in Rome, and was dedicated to GMOs. This is a topic that requires a lot of progressive disciplinary competence/knowledge to be mastered, holds relevant socio-economic implications, and has in recent years been the object of many studies regarding public attitudes toward biotechnologies (Hoban & Kendall, 1992; Zecgendedorf, 1994; Hallman, 1996; Davison et al., 1997, Krebs, 2000; Bandiera, 2002), teaching-learning issues (Lock & Miles, 1993; Gunter et al., 1998; Wood-Robinson et al., 1998; Chen & Raffan, 1999; Sàez et al., 1999; Dawson & Schibeci, 2003), and ethical considerations (Dawson & Taylor, 2000; Hößle & Bayrhuber, 2000).

The planning of the study concerned:

a) design of an action that considers strategies and aims closely in keeping with active and cooperative learning;
b) evaluation of the actual feasibility of the methodologies employed in a "normal" school ;
c) exploration of clues concerning students' interest and change in their learning profile;
d) analysis of the terms of acceptance/refusal by students and teachers.

## 3. Methods and participants

The teaching action design required the setting up of

- a tool that allowed for students' personal involvement and for the exploration of students' previous disciplinary knowledge of GMOs (Appendix 1 and 2);
- a teaching sequence (lesson/demonstration) on requisite, basic information about genetic engineering and on its contextualisation, making reference to real cases of GMO production[1];
- laboratory materials that elucidated the experimental aspects of the teaching sequence: replica-plating aimed at the recognition of transformed bacteria, *Nicotiana* cultures (callus formation and differentiation), electrophoresis comparing protein patterns of GM and non-GM plants;
- a tool (based on problem-based learning: Barrows & Tamblyn, 1980; Bound & Feletti, 1991 ) for the group application and autonomous increase of acquired knowledge (Appendix 3);
- a tool (based on the concept-cartoon methodology: Keogh & Naylor, 1997) for the group's application, by means of argumentation and negotiation, of the knowledge acquired to real-life issues (Appendix 4);
- a so-called "perception format" for a flash evaluation of the intervention by the involved students (Appendix 5).

The teaching action was carried out in ten classes of six upper secondary schools in Rome (three specialised in classical and three in scientific studies), involving a total of 144 students, ranging in age from 16 to 19. It was conducted by one of the authors (C.B.), a university student majoring in Biology and working on her degree thesis in "Natural Science Teaching".

## 4. Results

At the very beginning of the action students who had already studied Molecular Genetics, nevertheless demonstrated scarce familiarity with GMOs. Figure 1 shows that they were not able to spontaneously cite examples of GMOs (120/144), nor to spontaneously specify the nature of the modification (138/144) of the object modified (65 "DNA", 57 "genes", 11 "genetic heritage", 3 "genetic code"). For the most part they did not respect the task and simply demonstrated their knowledge of the – above indicated – meaning of the acronym: genetically modified organism.

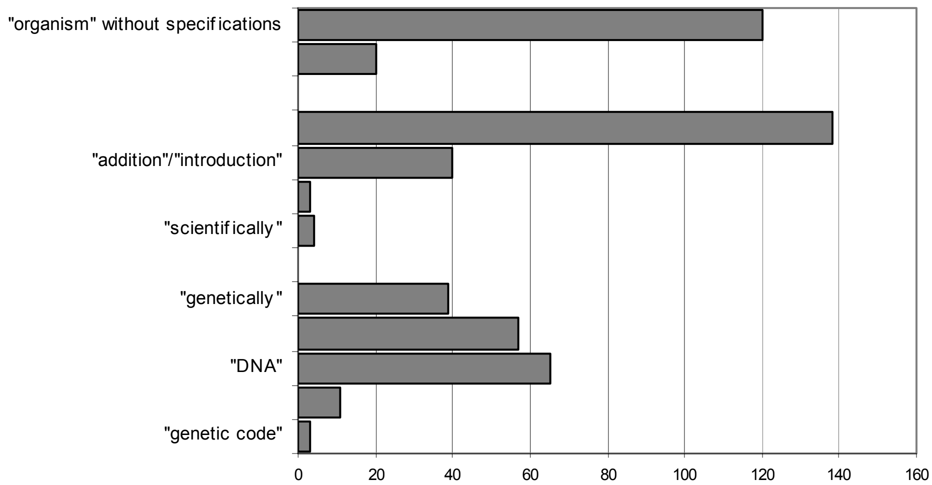


Figure 1. Words used in order to explain what a GMO is

As regards more in-depth investigation, 86.6% of the students, choosing from among five statements on GMOs (Appendix 2), agreed and upheld the following: "It is not possible to predict whether, in addition to the characteristic determined by the new gene, other characteristics will undergo change.". In the course of the discussion, the students mostly did not refer to scientific knowledge or data, and made use of a very poor and inaccurate disciplinary lexicon.

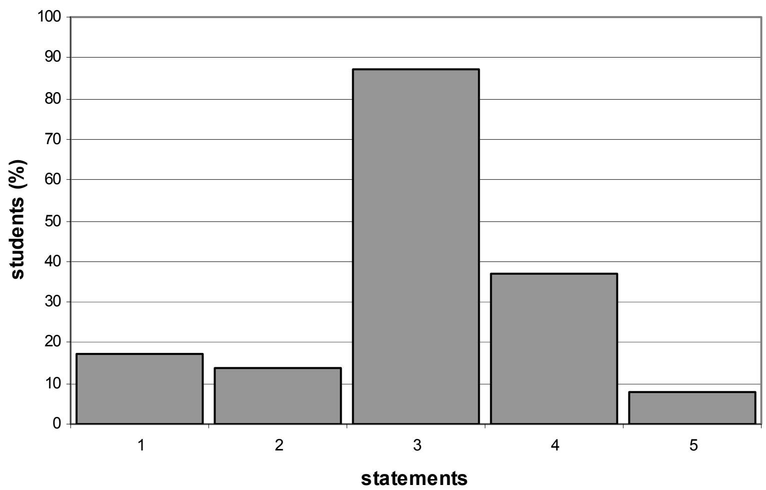


Figure 2. Percentage of students' agreement with statements presented in Appendix 2

After attending the lesson/demonstration, students were to adopt a position regarding five statements about the cultivation of pyralide-resistant modified maize (Appendix 3); to this end they had to autonomously document and complete the acquired information and to exhaustively argue their positions in a group debate. Use of the Likert scale (1-5) allowed for the recording, for example, of substantial agreement (mean grade: 4.0) with statement B ("The appearance in the long run of toxin-resistant pyralides represents a problem"), while statement C ("The gene Bt product is also toxic for useful insects that carry out the pollination of many vegetal species") raised some perplexities and was graded 3.2 (Figure 3).

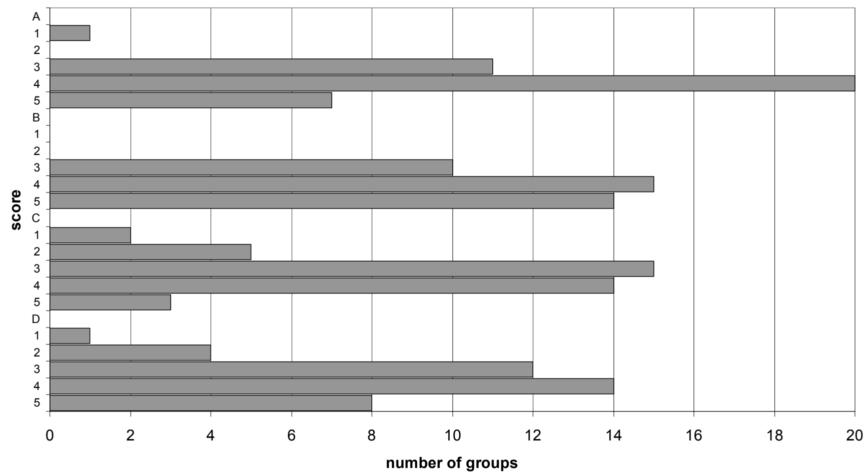


Figure 3. Grading of statements (Appendix 3) according to the level of their estimated truthfulness by 39 groups of students

The expressed justifications of the grade assigned to every statement were categorized taking into account three main occurrences: the absence of an actual justification, the recourse to information or data, the expression of personal, unsupported opinions. Data presented in Table 1 show that both a supplement of information was prevalently presented without the terms of the correlation between the global information and the grading (36.5%), and opinions and reasons on which they are based were specifically formulated (41.0%).

Table 1. Categorization of the justification of the grade assigned to the four statements (Appendix 3) by 39 student work-groups

| justification of the grade | statement | | | | tot |
|---|---|---|---|---|---|
| | A | B | C | D | |
| re-formulation/confirmation of the statement | 3 | 7 | 3 | 4 | 17 |
| scientific information supply | 17 | 10 | 21 | 9 | 57 |
| socio-economic information supply | 3 | | | 1 | 4 |
| opinion | 6 | | 1 | 1 | 8 |
| reasoned opinion | 10 | 21 | 14 | 19 | 64 |

As requested by the task, a total of 28 groups specified their sources of documentation; 27 groups indicated the use of web sites (23 groups web sites only) and consulted on the average 3.4 sites each. The search engine mainly used turned out to be "Google" and the most contacted sites were: cnnitalia.it (n° 12), greenpeace.it (n° 8), coldiretti.it, gaiaitalia.it, mybestlife.com (n° 6). Over all, 40 different sites were contacted. Four groups consulted scientific magazines (Focus, Le Scienze, Science et vie), two groups a book (M. Buiatti, 2002, "Le Biotecnologie", Bologna: Il Mulino).

Analysis of student group short texts, pondered and agreed upon within the work-groups and likely formulated with a view to exploiting the previously carried out search of pertinent information, also supplies other didactically relevant notations: first of all, the nature and the weight of misconceptions, such as the confusion between pollen and seed, or the indiscriminate use of terms such as "type", "variety", "species", and "family" (made worse by the reference to "interspecific hybridation"). Just one example of a significant statement: "The persistence in the soil of the toxins and its uncontrolled spreading can, over time, produce a *mutation* of the same toxin, which will cause the death of many insects living in the soil."

Greater involvement and perceptibly exercised skill were demonstrated by students in discussions stimulated by a concept cartoon based on a newspaper article[2] on the refusal by many African countries of PAM food relief – free, but not GMO-free (Appendix 4).

The discussions in which each student had to support his/her chosen statement were so lively that it was impossible to gather reliable data from the recordings. But they were so systematically rich that they were able to result in a positive evaluation of the teaching action, at least as regards the broad use of scientific terminology (as compared with the results displayed in Appendix 1 and 2) and the modality of discussion predominantly based on references to cases and data.

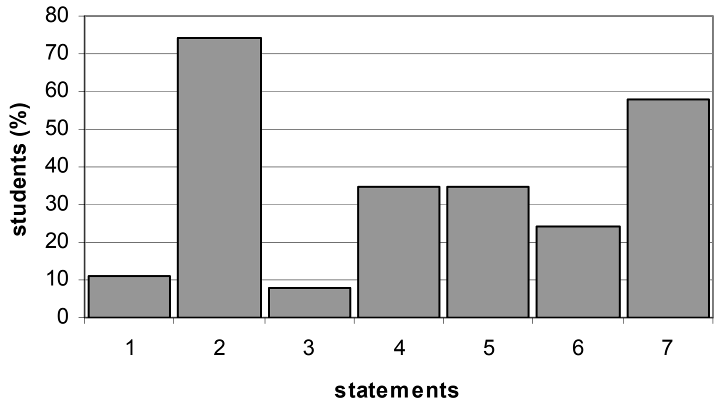


Figure 4. Percentage of students' agreement with statements presented in Appendix 4

## 5. Discussion

The teaching action was carried out under the assumption that in the scientific framework (in particular, as regards issues with socio-economic impact and ethical implications), traditional didactics, even with the support of laboratory activities, is not effective for the purposes of gaining mastery (Hammalev & Paulsen, 2001). Bearing in mind the adoption of active/cooperative learning-based methodologies, consideration focused on students' personal involvement, group work (disregarding other formative aspects that characterise, for example, the widely-practised role-play (Simonneaux, 2001) and a slant in favour of citizenship education (Kolstoe, 2000). The reflection on collected data does not intend to under-estimate the limitations represented by the size of the sample and by the absence of a *traditional* lesson on GMOs as a control.

Four notations appear relevant in reference to the project's articulation.

1. The teaching action, characterised by an illustration of the techniques of genetic engineering not in generic form, but applied to Bt maize, and by the presentation of concrete anchors (the laboratory materials), was effective both in terms of the acquisition of scientific terminology as well as the fostering of more in-depth study activities, as demonstrated by students' written argumentations and oral discussions (which, unfortunately, it was not possible to document).
2. Though the structure and the organization of the schools involved were very different, autonomous widespread internet enquiry, group work, and *plenary* discussions were not impeded in any way.
3. Students' knowledge initially appeared to be based on stereotypes and definitions (Appendix 1, Figure 1); they were not accustomed to supporting their opinions regarding scientific issues (Appendix 2). Later they were able to find new and pertinent information

(Appendix 3, Table 1) and to support their opinions by using the newly acquired data.
4. The students, in the process of providing their *flash* perceptions, expressed general and noteworthy appreciation and pleasure (Table 2) by means of the so-called "perception format" (Appendix 5). They especially celebrated (aspects 8 and 9) the competence and professionalism of the person conducting the action (C.B.). Some limited uncertainty was revealed regarding the teaching action's effectiveness in terms of the possibility of measuring interest in GMO research (aspect 2) and concerning thorough, in-depth disciplinary study (aspect 3).

Table 2. Evaluation by 133 students of 10 aspects characterising the teaching action. The mean grade refers to the use of the 1-5 Likert scale.

| aspect | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| mean grade | 4.1 | 3.8 | 3.8 | 4.2 | 4.0 | 4.0 | 4.2 | 4.7 | 4.6 | 4.2 |

Both the teaching action conductor and the teachers considered the action as fully efficacious with respect not only to disciplinary education, but to overall intellectual and social maturity as well. Nevertheless, it is only proper to temper these positive considerations with some corresponding indications of perplexity.

1. Scholastic equipment and teacher preparation do not presently allow the widespread practise of teaching activities requiring updated disciplinary expertise and availability of laboratory materials. These problems could be remedied either by dedicating the activity to topics that do not require a mastery of sophisticated experimental procedures, or else by stipulating agreements with University facilities or research institutions.

2. It seems that while students were involved in the group work – which they also worked on at home – they neglected all their other study commitments. In order to be able to exploit this sort of enthusiasm and participation it would be necessary to limit the use of this type of method to two/three times per year.

3. As far as learning is concerned, the students preferred environmentalist, pacifist and direct farming sources to scientific associations and journals. This fosters the contextualisation of the scientific knowledge concerned but probably denotes a certain reticence to becoming engaged in the disciplinary field. It is also necessary to stress that among the 64 reasoned opinions (table 1), 12 refer to and are based on a single study, and 24 justify, by means of the absence of sure data, positions oriented toward the truthfulness or the irrelevance of the statement.

4. More complicated is the summary of teachers' stances. They had a previous, detailed description of the teaching action and were asked both to give information about students' habits and knowledge, and to point out eventual objectives that were to be privileged. Notwithstanding this explicit invitation to participate, they all limited themselves to receiving and tolerating the action as a form of substitution to which they were extraneous. Attending only for a few minutes, they seemed to take more interest in students'

enthusiasm than in teaching methodology and content. Some weeks later they all formally acknowledged the feasibility and profitability – also with respect to specific learning – of the adopted strategies.

It is precisely these latter aspects that corroborate the omen of a more systematic use of teaching methodologies based on active-cooperative learning which can (and should) be practised at school.

1. The teaching sequence "How GMO is born: Bt maize" was articulated as follows: the basic procedure, how the gene can be found, how the gene can be isolated, how an exogenous gene can be introduced into an organism, how to understand if gene has been inserted, how the gene sequence proves to be functional, how the gene can be expressed in the plant sections attacked by insects.

2. «Zambia: "Cibo gratis? No, contiene OGM"» (Zambia: "Free food? No, it contains GMOs.) La Repubblica, 24 September 2002

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Appendix 1 - Explain thoroughly, in your own words, what a genetically modified organism (GMO) is. "A GMO is …."

Appendix 2 - Check which of the following statements on genetic modifications you consider plausible:

1. For an organism to display a new characteristic it is enough to insert the gene that determines that characteristic into the organism's DNA.
2. When a new gene is inserted into an organism's DNA it is not possible to predict what tissue it will be expressed in.
3. It is not possible to predict whether, in addition to the characteristic determined by the new gene, other characteristics will undergo change.
4. The insertion of an extraneous gene into the DNA could interrupt the sequence of another gene and de-activate it.

It is impossible to plan the exact point at which the new gene *shot* into the host DNA will insert.

Appendix 3 - *Session dedicated to problem-based learning*
"The case" – You are a member of a European Commission that deals with biotechnologies and you have been asked to evaluate, on a scale of 1 to 5, the following statements by your colleagues on the environmental impact of the widespread use of Bt maize. (You are asked to gather documentation and to justify your position).

A. The pollen of genetically modified maize, carried by the wind or insects, leads to crossbreeding with nearby natural maize crops.

B. The appearance in the long run of toxin-resistant pyralides represents a problem.

C. The gene Bt product is also toxic for useful insects that carry out the pollination of many vegetal species.

D. The toxin that acts as an insecticide on pyralides is dispersed onto the soil, killing the fauna (worms, insects, etc.) involved in fertilizing it.

In order to evaluate the above-listed statements and to justify your position during the debate in the next meeting, you will freely accumulate documentation and record your sources in the space provided below, specifying the type and the data necessary for finding both the source as well as the documentation.

Appendix 4 - *Session dedicated to a concept-cartoon that shows eight characters: the central one notices the rejection of GM seeds by Zambian government and the others express the following opinions:*

1. I just don't understand! They would finally have resolved the majority of their malnutrition problems.
2. These seeds would not have solved the problem: the *terminator* technology would only have served the interests of multinationals.
3. The use of Bt maize would have led to an increase in productivity and substantial savings on insecticides!
4. Don't you think that the pollen of these GMOs could contaminate natural crops and lead to their sterility?
5. Where do you think all those hungry pyralides will end up?
6. Lethal? That's going too far … rather, pollen could kill other insects useful for the fertility of other species!

They did well! The Bt gene protein could have caused allergies in man … even lethal ones!

Appendix 5 - *The "perception format"*
Listed below are some statements referring to the activities carried out in two meetings dedicated to GMOs. Check the number after each statement that corresponds with your evaluation: "1" indicates total disagreement with the statement and "5" full agreement.

1. The activity allowed me to get an idea of the methods and aims of the production of genetically modified organisms (GMOs).
2. The activity allowed me to measure my interest in GMO research.
3. The activity allowed me to deepen my knowledge of the topic (GMOs) at the disciplinary level.

4. The activity allowed me to focus on problems related to the diffusion of GMOs.
5. The activity allowed me to fruitfully experiment with group work and encounter.
6. The documentation materials and opportunities for reflection seemed adequate.
7. The activity was structured profitably and convincingly.
8. The presentation was conducted competently.
9. The presentation conductor was precise and helpful.
10. Overall I enjoyed the experience.

# BRINGING THE REAL WORLD INTO THE BIOLOGY CURRICULUM: THE CHALLENGES FOR TEACHERS

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## Abstract

This study investigates the challenges which a small but diverse group of biology teachers faced when implementing the pilot for a new advanced level biology course (Salters-Nuffield Advanced Biology - SNAB) for the first time. SNAB was developed with the intention of transforming advanced level biology in England. Using real world contexts and examples as the starting point it aims to promote conceptual understanding rather than factual recall, encourage active and independent learning and develop a capacity for critical thinking and reflection. This is in contrast to traditional courses which are increasingly seen as outdated, irrelevant, over laden with content and requiring a transmission approach to teaching. Through a series of semi-structured interviews with each teacher, supported by lesson observations and interviews with students and technicians, it identifies the obstacles which these teachers encountered when trying to implement the course as intended and the ways in which they responded to these. The most significant factors affecting their ability to implement the course as intended appeared to be their confidence in managing new approaches and activities in the classroom, their preferred or habitual teaching approach and their personal beliefs.

## 1. Introduction

This paper considers the impact of implementing a new advanced level Biology curriculum on teachers' pedagogic practices:

- What demands does it make (in what ways are teachers expected to change their normal practices)?
- How do teachers respond to these demands?
- What factors appear to influence the teachers' responses?

For the past decade the content of the school science curriculum in England has been tightly controlled by government. The result has been an excess of prescribed factual content which significantly restricts the time available for practical work or discussion of topical issues. In addition there has been a heavy emphasis on testing, at all ages, and an increasing use of test results to make schools publicly accountable for the quality of their teaching. This has led to a culture of 'teaching to the test' with an over-emphasis on factual recall of content and limited opportunities for active, independent learning and a loss of autonomy for both teachers and students. There has been a growing recognition that if school biology is to keep pace with our rapidly developing understanding of the science and to enthuse a new generation of knowledgeable young biologists then its content and approach must change. One outcome of this has been the development of a new advanced biology course (Salters-Nuffield Advanced Biology: SNAB) designed for upper secondary students aged 16-19. The structure of this two year course is similar to all other 'A' level courses in England. Each year is self contained, ending in an exam which leads to a qualification. The first year (AS) provides a foundation for the second year (A2) and completion of AS is normally a requirement for entry to A2. Not all students who successfully complete AS will choose to continue into A2 – some may prefer to specialise in other subjects. In stark contrast to 'traditional' advanced biology courses in England, the organisation and content of SNAB are very different. SNAB uses topical real world contexts and examples as the starting point for teaching biological content and aims to promote conceptual understanding rather than factual recall, encouraging students to take responsibility for their own learning and, in the process, develop their capacity for critical thinking and reflection.

The main sources of support for teachers using this new course were the training workshops provided by the development team, an extensive on-line interactive discussion forum for all participants and an extensive range of electronic resource material.

This paper follows a small but diverse group of teachers through the first two year pilot course and considers the extent to which they were able to implement the new course as intended. What were the challenges for these teachers and how did they respond? The outcomes provide some insights to the professional support and development which biology teachers might need if their pedagogic skills are to keep pace with a rapidly developing biology curriculum.

## 2. Methodology

### 2.1- Summary of methodology

To identify criteria against which implementation could be evaluated the content and ethos of the SNAB approach was compared with that of traditional approaches. The main differences were identified and used to develop a set of indicators against which the data could be analysed.

A case study approach was used to follow a small number of teachers through the two years of the pilot course. To maximise the richness of the resulting data this initial sample was selected for diversity.

The main data source was a series of semi-structured teacher interviews. The first set of interviews focussed on the teachers' initial perceptions of SNAB, the ways in which it would differ from their traditional course and the implications of this for their 'normal' approach to teaching at this level. The second set of interviews reviewed developments against baseline data from the first interview, using teaching contexts which highlighted differences between SNAB and traditional courses to probe the teacher's attitudes and approach to SNAB. The teachers were asked, for example: about the level of detail which they included in their teaching of cell division, the reasons for their choice and any difficulties they experienced in making the decision; about the activities they had chosen to use in teaching their most recent topic and the reasons for those choices. The third set of interviews used discussion of specific contexts or activities to probe the teachers' perceptions of the changes to practice which SNAB demanded of them, the ways in which they felt they had (or had not) been able to change and the factors which had influenced this. For example, they were asked if they had used discussion in teaching the most recent topic; if so, could they describe what they had done (and why); if not, had they used discussion anywhere else in their teaching (if so, where, how and why).

Lesson observations and interviews with technicians and student groups were used to consolidate and validate interview data.

All interviews were audio-taped and transcribed for later analysis against the defined indicators. Field notes (with particular emphasis on teacher actions) were made during lesson observations, which were also audio-taped.

### 2.2- The criteria

Interviews with the SNAB development team, observations of the training workshops and a review of course documentation were used to identify the main differences between SNAB and traditional courses such as AQA and Edexcel. These differences related to content, approach and the use of computer based resources.

*Content*

Traditional courses usually organise content by topic – excretion, respiration, di-hybrid inheritance etc. In contrast SNAB organises biological content around real world contexts which students can relate to - for example, the discovery of two dead bodies and the need to find the time and cause of death; the dilemmas facing a couple who are both carriers of an inherited disease. The intention is to explain a particular context by integrating relevant biological concepts from across different topic areas – so, for example, the forensic context drew on pathology, physiology, immunology, microbiology and the biology of infectious disease. The expectation is that only those aspects of a traditional topic which relate to the specific context will be taught. As the contexts are all topical, new biological concepts are introduced and some traditional content is lost. Contexts are carefully chosen to ensure that there are opportunities to develop a good understanding of key biological concepts across the course as a whole. Social and ethical issues arising from the particular context are also integrated into the teaching, with the expectation that students should learn how to draw upon their knowledge of the biology (and their understanding of the processes of science) to engage in reasoned discussion of the issues.

*Approach*

The traditional approach to biology at this level, in England, is content driven and teacher led and the large volume of factual content places the emphasis on factual recall at the expense of developing conceptual understanding. SNAB aims to develop conceptual understanding, at the expense of extended factual content, through a student centred approach in which students are actively engaged in their own learning. The expectation is that students will increasingly take responsibility for their own learning. In addition SNAB have developed a novel approach to practical assessment which encourages teachers to focus on understanding of the experimental process – assessing validity and reliability, identifying and quantifying sources of error, interpreting data etc. This is in contrast to the usual approach in which the main aim is to get the right answer and to present this in a manner most likely to maximise marks – this encourages both teachers and students to develop a very narrow view of practical work.

*The use of computer based resources (IT)*
SNAB also integrates the use of IT into all areas of the course. This is designed to:
- Support the teaching (for example, through the provision of teacher notes, worksheets and activities);
- Encourage independent learning in students (for example through the provision of interactive animations, revision tests and additional background information);
- Ease the administrative burden (for example, though inclusion of electronic mark books).

*In addition:*
SNAB provides an extensive range of activities, resources, and materials to support its approach. The intention is that teachers should select activities on the basis of educational aims and purposes and that students should engage with supporting materials on the basis of their personal evaluation of their needs.

On the basis of this analysis the following were selected as indicators against which the teachers' implementation the new course could be assessed:

Treatment of biological content – assessing the depth and breadth of content (understanding the relationship between context and content); acceptance of reduced content;

Use of discussion – the use and management of discussion;

Encouragement of 'active learning' – understanding of 'active learning'; actions taken to promote active learning and support students as independent learners;

Approach to practical work - approaches to practical work; understanding of the assessment process;

Use of computer based resources (IT) – the IT resources used, how and for what purpose;

Selection of activities – criteria for selection; understanding of purpose; modifications or additions.

### 2.3- The sample

2 teachers from each of 3 contrasting pilot centres were initially chosen for this study, with the aim of selecting a diverse group of teachers exposed to different types of experiences (Table 1). Each pair of teachers shared the teaching of a class. All the teachers had attended training workshops. At the end of the first year Crown College withdraw from the SNAB

pilot. To compensate, two additional teachers from Victoria High were brought into the study They had not attended the training workshops but had been briefed by colleagues who had.

Table 1. The Sample

| | Crown College (CC) | Brookside Grammar (BG) | Victoria High (VH) |
|---|---|---|---|
| Type of centre | A large Metropolitan sixth form centre (intake restricted to students aged 16+) | A small private (fee-paying) 11-18 school. | An average sized 13-18 comprehensive (non-selective) school |
| Biology intake | 100+ students organised into 4-5 classes | 22 students organised into 2 classes | ~80 students organised into 4 classes |
| SNAB pilot groups | 1 class | Both classes | All classes |
| The teachers | T1, T2 [AS year only] | T3, T4 [AS and A2] | T5, T6 [AS and A2]<br>T7, T8 [A2 year only] |

*Note: each centre was given a pseudonym.*

### 2.4- Data collection

Data were collected at 3 points during the two year course - at the start; towards the end of AS; towards the end of A2 - through semi-structured teacher interviews, lesson observations student group interviews and technician interviews. Details are presented in Table 2.

Table 2. Summary of Data Collection

| Data sources | Starting point | Year 1 (AS) | Year 2 (A2) |
|---|---|---|---|
| Teacher interviews | Teachers T1 – T6 | Teachers T2 – T6 | Teachers T3 – T8 |
| Lesson observations | 'traditional' lesson for teachers T1, 2, 3, 5, 6 | SNAB AS lesson for teachers T3 – T6 | SNAB A2 lesson for teachers T3 – T8 |
| Technician interviews | Technicians for BG and VH | Technicians for BG and VH | |
| Student group interviews | None | BG group3<br>VH group 4 | BG group5<br>VH groups 6-8 |

### 2.5- Data analysis

At the start of the study teacher interviews and observations of 'traditional' teaching were used to characterise the range of experience and teaching style within this group of teachers, giving some indication of their diversity and providing baseline information about their 'normal' teaching approach.

Transcripts of the second and third sets of teacher interviews were analysed for comments relating to the criteria and indicators identified in 2.1. These were then organised under the following 3 broad headings:
*Approach*: the teacher's 'normal' approach to advanced level teaching; their understanding of the SNAB approach and how this differed from a 'traditional' approach; their acceptance of the SNAB approach;
*Changes in practice:* the changes which teachers recognised were needed, and the extent to which they were achieving them;
*Problems and solutions:* the difficulties encountered and what the teachers did about these (if anything).

Any additional problems or changes to practice, not related to the indicators, were also noted. Where possible, data from the teacher interviews were triangulated against data from technician and student interviews and lesson observations.

## 3. Outcomes

### 3.1 - Baseline information on the group

Baseline information on each teacher confirmed the diversity of the group (see Table 3). Age and experience ranged from a recently qualified young teacher to very experienced senior teachers and approaches varied from strongly teacher led to a strong belief in students as active, independent learners. While some teachers were very enthusiastic about SNAB, even before they began teaching the course, others clearly had some concerns.

### 3.2- Implementation of SNAB

#### 3.2.1- Treatment of biological content

Unlike traditional courses, where contexts are used to illustrate the content (often as an afterthought), contexts are integral to the SNAB course and define the content to be taught. From the start the teachers recognised the need to change the biological content of their teaching and understood that some 'traditional' content would have to be discarded to make room for new and exciting content. All appeared to understand which ideas were to be left out and which new ideas were to be introduced. What they initially found difficult was defining the depth and breadth to which the ideas should be taught within any one context. For example, within the AS context of inherited disorders only a simple understanding of meiotic cell division, sufficient to explain how two unaffected carriers could produce an affected child, was required; initially most teachers found it difficult to recognise/accept this and continued to teach the details of the different stages of meiosis. This type of problem was largely overcome as they gained more experience and developed a sense of how the content from different contexts was related across the course as a whole.

Table 3. Baseline information on the teachers

| Teacher | Background | 'Normal' Teaching Style |
|---|---|---|
| T1, CC | Experienced senior teacher with extensive management responsibilities; positive and excited about SNAB – for students and for development of her own teaching. | Student centred, using a variety of activities designed to encourage students to take responsibility for their own learning. |
| T2, CC | Established teacher with limited experience; unclear about aims, intentions and organisation of the SNAB specification. | Claimed to be student centred, to a point, but liked to be firmly in control; uses a range of activities to engage students. |
| T3, BG | Established teacher with strong beliefs about education; enthusiastic about SNAB – to reduce expectation of 'spoonfeeding' by students; to develop his own teaching. | Teacher centred: structured activities led by himself; individual and group work used to free up class time for 1:1 administrative work with students. |
| T4, BG | Recently qualified young teacher in second year of teaching; enthusiastic, reflective, 'idealistic'; expects SNAB to justify his 'normal' approach, which students find very demanding. | 'Traditional' teaching was not observed but T4 held clear views on what teaching should be about – active learning, set in meaningful contexts, by students who have learnt to take responsibility for their own learning. |
| T5, VH | Experienced senior teacher, head of science; dissatisfied with 'traditional' syllabus and enthusiastic about SNAB; hoping to develop own and colleagues teaching skills. | Tries to access student's own ideas and thinking and to actively engage them in their learning. At the same time, likes to be in control of their learning. |
| T6, VH | Established and experienced older teacher; expresses enthusiasm for SNAB but attached to work-booklets produced for a traditional course and hopes to continue using these. | Has a very controlled, teacher centred, very focussed on what needs to be learnt for the exams; does not actively encourage discussion. |
| T7, VH | Young but experienced, energetic teacher; head of biology; conscientious, well organised, 'professional', critically reflective; high expectations of self and students. Enthusiastic about SNAB, particularly IT resources. | 'Traditional' teaching was not observed but T7 considered advanced level teaching to be her strength; had clear views on how it should be done *'… students should be listening and being interactive rather than copying and dictation'.* |
| T8, VH | Established and experienced classroom teacher; strongly committed to the use of IT in the classroom; hoped to use every aspect of the IT resources. | 'Traditional' teaching was not observed but T8 perceived it to be very teacher led with himself as the 'fount of all knowledge'. |

Despite this better understanding most of the teachers continued to include additional content of some sort. There seemed to be 3 different reasons for this. In many cases the additional material was intended to enhance, consolidate or re-enforce the specified content - *'the book's got some great examples but sometimes you just happen to know a better one'* (T8). At other times it was simply that the teacher had always included that particular idea and saw reason not to do so on this course. The third reason was an apparently deeply held belief about what a 'biologist' should know and about the role of the biology teacher in nurturing this knowledge in the next generation – a view of biology teachers as guardians of a tradition or culture that must be maintained. The deep convictions underlying this third explanation presented a serious obstacle to changing curriculum content in the radical way intended by SNAB. T3 and T6, the oldest teachers in the group, expressed this view most explicitly. T6 was deeply disturbed by the lack of traditional content relating to structure and function of the eye and felt this lack of basic content was doing real harm - '*if the students don't understand the basics of the eye they're certainly not going to understand the detail of how the rods work ...I feel the course is losing an opportunity to produce what I call a really good biologist with a love of the subject – and their understanding, I fear, is being lost with this'* (T6).

The distinctions between these three explanations were not quite as clear cut as they would appear. The first sometimes seemed to be used as a more acceptable justification of the second and the second sometimes suggested an underlying belief related to the third - *'we would like to do cones as well as rods …. in fact we did a little bit on cones because they [the students] asked about colour vision so that meant we did a little bit a bout it …I have no problem [in principle] with just doing … rods'* (T5).

Some of the 'cutting edge' content challenged the teachers' own understanding - *'It wasn't something that I'd done [a lot of] in the past … so I couldn't rely on my own subject knowledge and I felt like I was only a page or two beyond my students'* (T7). This was particularly true in the final A2 unit which drew heavily on neuroscience - *'I have found this a difficult topic to teach …the brain has only been covered in a small, small way in our [previous] syllabuses ... so I have stayed very, very close to the book'* (T6).

### 3.2.2- Use of discussion

There was a general lack of clarity about what might be meant by 'discussion'. Within the SNAB specification and supporting materials at least 3 different ways of using discussion can be identified, each with a different purpose and each requiring a different set of skills.

*Discussion of accepted (factual) knowledge*

Students develop a better shared understanding of accepted knowledge through presentations and discussion of ideas. They may develop general ('key') skills, such as IT or language, at the same time.

*Discussion of contested knowledge*

Students must recognise that some scientific knowledge, particularly at the frontiers of our understanding, is tentative and learn to evaluate alternative theories. This requires some understanding of how to evaluate scientific evidence, including an ability to identify sources of error and to judge validity and reliability. It might also require some understanding of the processes by which tentative knowledge becomes accepted knowledge and of possible social and political barriers to this transition.

*Discussion in preparation for decision making (including a consideration of ethical issues)*
Students must learn to identify key issues, present and justify their own views, listen to and evaluate counter arguments. In coming to a decision they might need to make a risk/ benefit analysis, distinguish between established and tentative knowledge, evaluate evidence, distinguish between fact and belief or recognise the limitations of science (what it can and and what it cannot do). They must also recognise that there are no right or wrong outcomes, although some might be more supportable than others.

At one level the teachers were aware of these different types of discussion but when asked about their own use of discussion they almost always referred to discussion of factual knowledge. Their approach to this usually structured, taking the form of a research based project during which individuals or small groups worked on different aspects of a topic and feed back to the rest of the class. When they considered contested knowledge or ethical issues their approach was more often unstructured – *'… how I started a discussion. The normal way is, I ask a deliberately provocative or bordering on outrageous question and see if anybody will bite - and usually that works' (T4); 'probably … short discussions prompted by newspaper articles of television programmes or current affairs … it's usually a student who said 'Oh did you see such and such a programme last night? Or did you read this?' and … [we would] …probably use 10 minutes of the lesson for that'* (T6).

In general, the teachers found discussion difficult and were reluctant to use it. Problems included the perception that it took a lot of class time for limited educational gain and a lack of confidence deriving from the teachers' belief that they lacked the necessary pedagogical skills, re-enforced by unsuccessful attempts. This lack of success often seemed to be linked to a lack of clarity about the purpose of the discussion (what they were expecting students to achieve), unease about the potential loss of control and the difficulty of managing a situation in which there were no conclusive right or wrong answer - *'It's quite a challenging role for a teacher, I think. If you've not yet got the in depth understanding of a lot of the ethics which go behind it (which isn't always your remit if you're a normal class teacher) it is quite un-nerving .. some of the questions that students can ask you … it sort of undermines your authority sometimes'* (T7).

There was no evidence of teachers attempting discussion of social or ethical issues within the classroom in the intended way. In some cases these activities had been moved to the General Studies programme, where more time was available. At others it was reduced to a paper exercise in which possible points of view for and against an issue were cross matched against an ethical framework. Discussion is difficult to include in the assessment programme and running across the interviews was a sense of teachers using this lack of formal assessment to legitimised their resistance to these activities – they recognised what was expected, in an ideal world they would very much like to do as expected but sadly, given the time constraints, it was not possible - '*it's a form I'd like to have a go at … if I get the time'* (T8).

### 3.2.3- Encouragement of 'active learning'

There was a very diverse understanding of what might be meant by 'active learning' in the context of the SNAB course and, for some teachers, there was little development of that understanding over the two years of the course. In many cases it was seen as students working on their own or in pairs, possibly using computers, to teach themselves. Some teachers found this concept threatening and were concerned about the diminished role of the teacher - '[it's] *almost distant learning. I'm struggling to find where my input fits in – which bit am I teaching? Part of this comes down to my definition of what teaching is' (*T8).

Some thought of it as something which students did in their own time and offered little guidance and support beyond directing them to relevant information and activities. Others saw it as integral to their classroom teaching and recognised the need to organise and structure activities in ways which provided opportunities for students to be actively engaged in their own learning - *'when we did dendrochronology … some were on the computers and others on the microscope, measuring, and then we rotated - I think they got the idea much more because they were actually doing something and because they were doing it in small groups'* (T8).

Two of the teachers explicitly recognised that 'active' and 'independent' learning did not mean 'teach themselves' and that students, especially when unused to taking responsibility for their own learning, might need some support - *'you give them a very brief description of something and then they go away and find the answer – and I do like that … because they are having to go through the process … and then we pull it all together at the end'…. 'so it's not* ***purely*** *coming from me. It's coming from them* ***working together*** *to generate the ideas'* (T7).

Only 1 teacher (T5) expressed his understanding of 'active learning' in terms of student development - *'students taking responsibility for their own learning'*. He was also the only teacher to have a clear idea of how to achieve active learning and to show some understanding of the problems and how to solve them. He promoted active learning through small group and individual work but recognised that this presented many opportunities for students to go off task. To counter this he developed strategies which encouraged them to stay on task – for example, shorter activities followed by targeted whole class questioning – but still found that he was too interventionist and too reluctant to let go.

### 3.2.4- Approach to practical work

Most of the teachers understood the aims and purpose of individual practical activities, although initially they had some difficulty in conveying these to their students. The practical assessment was a different matter. None understood the criteria for the practical assessment at the end of the first year – even though the practicals and the practical assessment were interrelated. They knew what the specification said but they had no idea how to interpret this (what it might mean in practice) and continued to think about the assessment in traditional ways. After experiencing the assessment process and receiving feedback from it through further training sessions, the teachers at VH developed a much clearer understanding of the purpose and were able to use their professional expertise to develop new pedagogic strategies and change their teaching practice. In contrast the teachers at BG, who received the same feedback and training, continued to feel that they had no understanding of the criteria and although they made some attempt to change practice it was half hearted at best. There were two identifiable reasons for this. The BG teachers took no personal responsibility for the poor outcomes, maintaining that these were caused primarily by problems at the exam board, so failed to recognise the need to change. They were also sceptical of what they thought SNAB was trying to achieve, or at least, the way it was choosing to assess this, and seemed to feel it was beneath both themselves and their students to engage seriously with this. This seems, at least in part, to have been based on a lack of understanding of the purpose of the practical assessment.

### 3.2.5- Use of computer based resources (IT)

SNAB offered some wonderful IT resources to support the teaching but, as with most IT developments, there were some technical glitches. These problems were multiplied out in the schools, where outdated or inadequate equipment, limited access and a lack of technical support were common. Those teachers who were highly motivated and already felt confident about their use of IT looked for ways around the problems, those who were not used the problems as an excuse for not using the IT resources. As teachers began to integrate elements of IT into their classroom teaching pedagogical problems began to emerge, some relating to classroom management, others to the teacher's personal teaching style. These were compounded when the IT resources were being used to support active learning. Teachers had to develop new strategies to deal with these before they could feel comfortable and confident about the changes they were introducing. For example, when T5 introduced computers into his classroom teaching he found it difficult to introduce the activities or organise feedback. Students were often off task or flitting through activities without a clear idea of the purpose and he had no direct eye contact - which made him unsure of the extent to which they were understanding him. He developed a number of strategies in response to the problems. He insisted on introducing the lesson or task with the class gathered round the whiteboard, away from the computers. He learnt to 'stage' the activities more carefully, taking time to set the activities in contex, give guidance on what was to be done and make the purpose explicit. At the end of each activity feedback was used to confirm and consolidate learning. To encourage students to focus he gave shorter tasks with tight deadlines, followed immediately by whole class feedback using targeted questioning or group feedback.

### 3.2.6- Selection of activities

Over the two years, as their knowledge of the specification (and how to interpret it) developed and they gained practical experience of teaching the course and using the activities, the teachers began to develop their craft knowledge in relation to SNAB. SNAB provides a very wide range of materials, resources and activities, the latter being signposted in the course text books. Initially the teachers had no clear rationale for selecting activities - unused to the autonomy and independence offered by SNAB most tried to do them all. They quickly learnt that there was not enough time for this and began to select and develop activities on the pragmatic basis of time, resources (cost and availability) and likely success rate. To some extent this very pragmatic 'cost/benefit' approach to selection aggravated the problem with discussion of social issues as these were often seen as very time consuming for limited educational value. By the end of the second year they had refined this pragmatic process through shared development of craft knowledge - '*when I'm planning the activities I ask T6 what she did and she'll say - "I did this, I didn't do that , this doesn't work…"'* (T7). In addition, as their understanding of the aims and intentions of SNAB developed, several teachers began to select more carefully on the basis of educational purpose – '*some activities seem to lack a clear educational purpose – they may be fun but they feel like 'add ons' and leave you with a sense of 'so what?"* (T5). With a sense of educational purpose came a greater awareness that presentation and management of the activity would influence its effectiveness. T5 was very reflective about his teaching and had begun to develop activities of his own to achieve particular SNAB objectives – although he didn't recognise this as being legitimate within the SNAB approach and was rather anxious, thinking that perhaps this approach was not allowed. Where no sense of educational purpose developed teachers had little sense of how to present or manage an activity and often found it difficult to recognise its possible value.

### 3.2.7- Other problems

Many students had clear expectations about how they should be taught. Initially they had some difficulty in understanding what it was that SNAB expected of them. Once they realised that they were expected to take some responsibility for their own learning students were often resistant to the changes which the teachers were attempting to make – especially when being asked to think for themselves. As the students in T5's class said *'… tell us the answer!'.*

## 4. Discussion

Emerging from a culture of 'teaching to the test', with an over-emphasis on factual recall and limited teacher autonomy these teachers initially struggled to implement SNAB as intended. At the start all but one of the teachers expected to have to change practice, and for many this was the appeal of SNAB, but the detail of how they would have to change was not very clear to them. Their understanding of the SNAB aims and approach developed as they worked through the two years of the course but better understanding did not always translate into better implementation – the teachers found some aspects of the course easier to implement than others. Most of the teachers became successful at identifying and using appropriate content and at selecting appropriate activities on the basis of educational purpose, although pragmatic concerns were also important to them. All teachers made some attempt to integrate IT into their teaching, despite the limitations of resources and technical support, but their understanding of how to use the IT resources to support their development of the SNAB approach was often limited. Practical assessment was developed well at VH, where teachers devised useful strategies to help their student's to understand the purpose, but less well at BG. The changes that all teachers found most difficult were those required to promote discussion of social and ethical issues in the classroom and to support the students in becoming active, independent learners.

Why was it that some changes were more difficult for the teachers than others? Several factors influenced the ability of these teachers to change practice, including: their understanding of the course as a whole; the assessment criteria; personal beliefs; motivation; confidence, preferred or habitual teaching styles and the attitudes of their students.

*Understanding of the course (content and ethos)*
As they gain experience teachers build up different types of knowledge which they use to inform their teaching - factual knowledge of the syllabus and related subject matter (what must be taught and how it will be assessed); professional knowledge and experience (expectations of the school; needs of the students; own teaching skills); craft knowledge (which activities work best, how they can be adapted for different purposes or modified to fit constraints of time or resources etc.). When teaching a new course for the first time, or even a familiar topic in a new way, teachers become learners again and must begin to build up some of this knowledge anew. In this study, where the stated intention of the course was to be radically different to any previous courses and were the specification and resources were still in development, the learning demands placed on the teachers were immense. Much of the content was unfamiliar and even familiar content was to be taught in different ways, for different purposes. In addition, at the start of the pilot they had no overview of the course as a whole so it was very difficult for them to see how content developed across contexts through the course. By the end of the second year they had access to the whole specification and had seen some exemplification of it through the exam process. With this knowledge they were able to make more appropriate judgements about depth and breadth of content to be included. Initially the teachers had no clear rationale for selecting activities and, unused to the autonomy and independence offered by SNAB, most tried to do them all. As they gained practical experience of teaching the course and using the activities they began to select and develop activities on a pragmatic basis (time, resources, reliability). As they developed a better understanding of the aims and intentions of the course, selection of activities was also informed by the educational purpose. Those teachers who developed a good understanding of the educational purpose also began to develop an understanding of how to present these activities in ways which maximised the learning outcomes. Where little understanding of educational purpose developed teachers had little sense of how to present or manage an activity effectively and were sometimes discouraged from using it.

Much of the above sounds obvious, and reflects what good teachers do automatically. The point is that the pedagogic skills which good teachers demonstrate are dependent on knowledge of the curriculum and its content. If the curriculum or the content change then teachers need to develop their knowledge of the new context before they are able to apply their professional expertise.

*Assessment criteria*

While the development of relevant knowledge was a pre-requisite for changing practice, it did not guarantee change and sometimes hindered it. While exemplification through assessment can have the positive effect of helping teachers to put the specification into practice, as demonstrated in the case of practical work, it can also have a negative effect – particularly within the 'testing' culture of the English education system. If the intended aims and objectives of a course are not reflected in the assessment process they are unlikely to be treated in depth in the classroom, however desirable they may be. The intended integration of social and ethical issues was negatively affected in this way, as shown by the teachers' use of discussion. This reluctance to spend time on social and ethical issues was aggravated by the teachers' pragmatic 'cost/benefit' approach to the selection of activities. Discussion of such issues was seen as very time consuming in relation to its educational value.

*Personal beliefs*

Some of the teachers held quite strong beliefs about what a good biology education should include and seemed to see themselves as guardians of this knowledge. They found it impossible not to teach some of the traditional topics which had been explicitly excluded from the specification, justifying their actions with phrases like *'I thought "Oh, they'll need to know that …"'* and '*How can you teach biology without …….'*. Beliefs about their role as biology teachers also influenced their development of active learning approaches (including the use of some IT resources).

*Motivation*

Motivation was another important factor. T6 and T7 shared the same teaching base, which was under-resourced in terms of IT equipment and support. T6 lacked confidence and expertise in the use of IT. She maintained that this under-resourcing made it impossible to make use of the wonderful IT resources provided by SNAB. During the whole of the two year study she appeared to make just one attempt to integrate an IT activity into her classroom teaching, and then only under pressure from her head of department. In contrast, T7 was an energetic and highly motivated teacher who was very enthusiastic about IT. Although she was frustrated by the lack of resources and they did limit what she could do she was not defeated by them. She booked each of her classes into a computer suite for one lesson a fortnight, borrowed equipment from elsewhere when she needed it in her base room and set self study activities for the students which encouraged them to use the IT resources. T4 was also enthusiastic and knowledgeable about the use of IT but in his case the school's lack of reliable equipment left him frustrated and demotivated, to such an extent that even when computers were available and could have enhanced the lesson he did not use them.

*Confidence*

Across the 6 areas used as indicators the greatest barrier to implementation was teacher confidence. Experienced teachers usually do what they do, in the way that they do it, for a very good reason – their professional knowledge and experience suggests that it will work. With a developing knowledge of the content and aims of SNAB the teachers in this study were quite able to select appropriate activities and identify useful teaching strategies and approaches. Despite this they were largely reluctant to put these approaches into practice in the classroom, particularly in relation to the development of active learning. Their main concern was what (and if) the students would learn if they were given more control. Unless they had developed some mechanism for supporting and monitoring the students' learning these teachers felt very uncomfortable about putting such approaches into practice. Only T5, who was very reflective about his teaching, was able to articulate both the problem and the strategies he developed to overcome these.

*Preferred or habitual teaching style*

T5 identified a further obstacle to success – his own teaching style. He became aware that his own actions and interventions reduced the effectiveness of the activities in achieving his goal of active learning. Although he could identify a number of quite simple strategies for reducing his unhelpful interventions and increasing his helpful ones (for example: wait longer after asking a question; ask additional questions to make students expand their answers; trust the students to do the work) he had no illusions about how difficult they would be to implement – '*There is a tendency always when the pressure is on to go back to the old style … I find that in myself*' (T5).

*Attitude of the students*

In changing their own practice teachers also change the learning experience of their students. Students often have clear expectations about how they should be taught and do not always respond well to change. The teachers in this study frequently met resistance to change from their students, who sometimes found the pressure to think for themselves rather than be told by their teacher very difficult to cope with. The teachers found that they needed strategies for supporting their students through these changes, in addition to all the new management strategies that they needed to develop for themselves.

Levinson and Turner (2001) noted that the consideration of social issues within the science classroom was limited by biology teachers' beliefs about what should be taught in the biology classroom, their own understanding of the nature of science and their lack of confidence in their ability to manage such teaching. It has also been suggested that teachers' personal beliefs about what it means to teach biology can make it difficult for them to change practice, even when enthusiastic about the approach, and that 'limiting' factors must be identified if teachers are to be successfully supported in achieving change (Davis, 2002; Yerrick et al., 1997). Our findings, based on a diverse group of teachers, support these observations.

## 5. Conclusions

These teachers did not find it easy to change their practice or to implement the new course in the ways intended. Factors affecting their ability to do this included: their understanding of the course as a whole; the assessment criteria; personal beliefs; motivation; confidence; preferred or habitual teaching style; the expectations of their students.

Their understanding of the aims and intentions of the course developed as they worked through it, and this helped them to overcome some of the initial difficulties. With experience they could identify required content, judge depth and breadth realistically and select activities and approaches. The effectiveness of the selected activities depended on the teacher's understanding of their purpose. When this was very clear then appropriate activities were selected and presented in ways which increased their effectiveness. When it was unclear activities were either rejected or presented in ways which limited their effectiveness. Explicit guidance on the purpose(s) of different activities, and on ways of presenting them to maximise their effectiveness, could have helped these teachers.

In some cases, for example the use of discussion, teachers were reluctant to use the activities as *intended* because they felt they lacked the necessary pedagogic skills. They might have benefited from some form of professional training aimed at supporting the development of relevant skills.

In several cases, particularly in relation to the development of active learning, teachers were reluctant to use appropriate activities because they lacked strategies for managing them effectively in the classroom - in the absence of such management strategies they were unwilling to risk change. They could have benefited from access to exemplar material which showed how such activities could be effectively managed.

Some difficulties were deep rooted and potentially difficult to overcome. These include preferred or habitual teaching style and the influence of personal beliefs. Changing these is likely to require extended and sustained professional development.

It would seem, from this study, that changing activity or approach is the easy part. The real challenge for teachers is finding the confidence and motivation to attempt change, even when it runs contra to their personal beliefs and preferences.

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# TEACHERS VIEW OF LEARNING OUTCOME AND ASSESSMENT OF LABORATORY WORK IN SWEDISH UPPER SECONDARY BIOLOGY CLASSES

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## Abstract
In this report we focus on a multiple case study done within an in-service professional development project with four experienced biology teachers in upper secondary school. The objective was to enhance the understanding of the role of laboratory work (labwork) in science education, with special emphasis on assessment. Research questions include a) What does the teacher want to achieve with the labwork and how do the students understand it? b) How do biology teachers assess labwork and how do they underpin their practice? c) Are the assessment criteria in the national syllabus applied to the labwork? Data were collected during a one semester long in-service project. Laboratory instruction sheets were collected and analysed with respect of learning objectives. Questionnaires, to teachers and students about the intended learning outcome, were carried out after different experiments. Another questionnaire was about students' views of assessment practice during laboratory work. Finally, teachers were interviewed concerning a) the role of labwork and the assessment practice, and b) the teachers' reflections upon the achieved results from the in-service project. The teachers realized that their assessment methods require more transparency to become effective. The interpretation of intended learning outcome of experimental work differs between students and teachers.

## 1. Rationale and objectives of the study

This paper addresses the role of laboratory work (labwork) in science education, with special emphasis on assessment. Labwork in science education has been discussed for several decades, and teachers, researchers and policy makers are convinced about the value of laboratory for understanding science (Jenkins, 1999; Psillos & Niedderer 2002). The role of labwork and field studies have been elaborated by, e.g. Hodson (1996), Lazarowitz & Tamir (1994) and Nott & Wellington (1996). The purpose of labwork in science education includes 1) to help students learn science by acquiring conceptual and theoretical knowledge; 2) to help students learn about science by developing an understanding of the nature and methods of science; and 3) to enable students to do science, i.e. scientific inquiry. The increased support for a purposeful learning is by being a complement to theories and by showing application of them. Furthermore, labwork should stimulate the development of analytical and critical ability and skills. An additional goal would be to create an interest for a specific matter. Most students appreciate the experiments and field studies and welcome the break from theoretical lectures (Hult, 2000).

It is well known that the assessment model used influence how and what students learn (Boud, 1995; Marton & Booth, 2000). There is a view, among Swedish students, that achievement and personal qualities are the objectives of the assessment, or their picture of what is assessed is unclear (Andersson, 2000). We do not know how the teachers assess labwork skills today, or whether all labwork is included in the assessment. Neither do we know how the assessment criteria are applied.

In Sweden, as in other countries, the national syllabus (curriculum) concerning science education stresses subject knowledge, scientific inquiry and nature of science as topics to cover. Inquiry has to be seen as both an instructional approach and a learning outcome. Relevant inquiry skills, i.e. identifying problems, generating research questions, planning and conducting investigations and formulating, communicating and defending explanations are also important to practice in school. For example, one of the goals of biology education in Swedish upper secondary school is that the students should develop their ability to work experimentally and with field investigations. This includes formulating and understanding biological questions and planning and carrying out experiments, i.e. find explanations with help of methods in natural sciences. However, there is concern about the effectiveness of labwork in facilitating the students understanding of various aspects of scientific inquiry (e.g. Lazarowiz & Tamir 1994; Schwartz et al., 2004). What the teacher want to achieve with labwork, and what students actually learn in different laboratory contexts require more attention. Often, teachers goals are to develop students' higher order thinking skills, e.g. critical thinking but their assessment practise do not support these more global achievement goals (Bol & Strage, 1996). Essential consequences will be implied for the assessment, when the science learning processes are emphasized. When students are tested in practical skills i.e. planning and carrying out experiments and investigations, it clearly shows that the science outcome is distinctly separated from what can be tested by conventional pen and paper tests (e.g. Brown, 1998; DeTure et al., 1995; Tamir et al., 1992).

Since the instruction style of an experiment influences the learning environment (Domin, 1999) and the assessment model used influence what students learn (Boud, 1995; Marton & Booth, 2000), a more formative assessment procedure in the classroom may make the students more aware of how they can improve their learning with help of experiments (Shepard, 2000; Brookhart, 2001). If instructions and formalized assessment models are developed they may give a better basis for grading and more equality in the assessment of students. To become aware of what alterations are required it is important to increase the knowledge about the teachers' view of the practice around labwork and also to investigate the teachers' assessment practice.

In this report we focus on some of the results within an in-service professional development project. The objective was to increase the knowledge and understanding of the practice around labwork. Analyses of the intended learning outcome and assessment of the labwork were included. The process of the teachers' professional development was also studied. The research questions studied were:

A) What does the teacher want to achieve with the lab work and how do the students perceive it?

B) How do biology teachers assess labwork and how do they underpin their practice?
C) Are the assessment criteria in the national syllabus applied to the labwork?

## 2. Research design and Methods

This is a multiple case study (Merriam, 1998). Four teachers were involved, chosen by the purposeful sampling method (Bogdan & Biklen, 2003). The teachers were involved in an in-service professional development project, described in 2.1, run by the authors of this paper. The two researchers involved in the project had different focus. One focused on teachers' professional development since her background is in teacher education and the other focused on assessment of practical skills in biology. A research project was connected to the in-service professional development project. The research setting and the methods used are described in 2.3. As study objects teachers and teachers practise in some of their classes were chosen.

### 2.1- Context of the in-service professional development project

Four experienced teachers in biology and natural sciences, and their classes, were purposefully chosen to carry out a project to improve the experimental practice and develop teachers' competence in assessing labwork. This project was conducted at two upper secondary schools where the teachers involved worked. The in-service professional development project started in September 2003 and progressed during one semester. All but one teacher had reduction in teaching time during the project.

The purpose of the in-service project was to improve the competence of teacher's ability to assess laboratory skills. Rather than running an ordinary course the teachers had to explore their own practice within a community of learners (Brown, 1992). The teachers participated partly in planning the content for seminars, reflected upon their practice and collaborated on labwork planning. The teachers were given an opportunity to critically examine how the assessment of labwork is carried out (in their own and others practice), study the students view of labwork and assessment, and discuss research literature on this matter. The discussions concerned the teachers' reaction upon research based literature and the investigations about their school experimental practice. This resulted in professional development among the teachers and researchers.

### 2.2- Participants and the Swedish school context

The four persons involved in the project had all more than 15 years of teaching experience in Swedish upper secondary school. The teachers worked in two different, relatively large, upper secondary schools (Teacher 1, female, school A; Teacher 2, female, school B; Teacher 3, male, school A; Teacher 4, male, school B).

The project deals with the assessment of labwork in science education in Swedish upper secondary schools. Labwork in biology and science studies were chosen as study objects.

The courses contexts are:

- Science studies A, obligatory in all programmes
- Science studies B, optional in all programmes but Natural Sciences
- Biology A, obligatory in Natural Science Programme
- Biology B, eligible in Natural Science Programme

According to the goals to aim for in the national syllabus in biology, the pupils should "develop their ability to work with experiments and in the field in order to increase their familiarity with the development of knowledge in biology", and "develop their ability to formulate and understand biological issues, as well as search for explanations using the methods of the natural sciences" (National Agency for Education 2000, pp 12). Among the goals to attain, it is stated that pupils should "be able to plan and carry out field studies and experimental investigations, interpret these, as well as present their work orally and in writing" (Biology A), and "be able to plan, carry out and interpret physiological experiments, as well as present their work both orally and in writing" (Biology B) (National Agency for Education 2000, pp 16 & 18).

The goals to aim for in the subject science studies, according to the national syllabus are, among others, that pupils should "develop their ability to describe, explain and understand the surrounding world from a natural science perspective", and "develop their knowledge of the research and scientific investigative methods used in science, and how results can be presented" (National Agency for Education 2000, pp 112). The goals to attain at the course Science studies A states that the pupils should "be able to make observations and carry out simple experiments, as well as be able to analyse and interpret results" and Science studies B that pupils should" be able to plan, carry out and interpret simple experiments and investigations, as well as be able to report orally and in writing" (National Agency for Education 2000, pp 114).

The assessment system in Swedish upper secondary school implies that the teachers are examiners in their own classes. According to the Swedish National Agency for Education, the teacher is presupposed to base their assessment on various forms of assessment, i.e. both oral and written proofs of achievement and on several assessment occasions. The practice among written tests is to have either several tests during a course, or one final test. National tests, centrally administered, are used in Swedish, English, and Mathematics. In e.g. biology and other natural sciences a national item bank is developed which provide test material. Schools are, however, not obliged to use them.

Table 1. The classification model of the lab-work (modified after Millar, Tiberghien & Le Maréchal 2002). This model was also used as questionnaire to students and teachers about intended learning outcome. The question was: *What will this lab-work help the student to achieve?*

| To help students to | | Tick how important<br>1 = not important<br>5 = very important | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Content | a) identify objects and phenomena | | | | | |
| | b) learn a fact (or facts) and concepts | | | | | |
| | c) find patterns and relations. Learn relationships | | | | | |
| | d) learn a theory or a model | | | | | |
| Process | e) learn how to use laboratory instruments | | | | | |
| | f) learn how to carry out a standard procedure | | | | | |
| | g) learn how to plan an investigation | | | | | |
| | h) learn how to process data | | | | | |
| | i) learn how to use data to support a conclusion | | | | | |
| | j) learn how to communicate the results of lab-work | | | | | |

## 2.3- Research setting

During a period of nine months, data for this study were collected from the in-service project mentioned above. Both authors of this study participated in collecting and analysing the data. Laboratory instruction sheets (labsheets) from 12 different exercises were collected for empirical analysis. This was all labwork done during a period of three months. The 12 labsheets contained 25 experimental tasks and covered six different themes. The objectives of the tasks within the collected labsheets were also analysed with respect to the intended learning outcome according to Thibergien et al. (2001). Also, a questionnaire (Table 1, modified after a classification model in Thibergien et al., 2001 and Millar et al., 2002) was used to explore the conception of the learning objectives of the tasks after each labwork session. Both teachers and students from their different classes answered questionnaires about the intended learning outcome of the labwork. The teachers were responsible for handling the questionnaire to the students after each practical work. According to the teachers, the students answered the questionnaire without asking any question. Also, each laboratory instruction was analysed with respect of intended learning outcome independently by the two authors. If differences occurred there was a negotiation until agreement. In the questionnaire, the scale of importance had 5 levels. However, during the analysis the scale was reduced to three levels (1-2 and 4-5 were grouped together).

A description of the skills that make up the basis for the assessment of labwork according to the Swedish standards was developed (Grelsson & Ottander, 2004 and Figure 2 in this paper) by analysing and modifying literature concerning assessment of labwork tasks and theories of assessment processes (Shepard, 2000; Tamir, 1992 a & b; Lindström et al., 1999; Solano-Flores et al., 1999).

Questionnaires about students' view of assessment of laboratory work have been carried out in four classes, one from each teacher in the project. The questionnaire contained both multiple choice and free response questions. The last question of the questionnaire, asked the students to give comments about the prevailing labwork. Informal observation studies, with field notes from the researchers, were done in the four classrooms during the lesson the questionnaire was handed out. The questionnaire was handed out at the end of that lesson. All, but a few students answered the questionnaire. We motivated the students to participate by having a lottery (ticket to cinema) among students who handed in the questionnaire.

The two questionnaires were used both as tools for monitoring practice and for raising questions among the teachers in the project, about the use of labwork and its' assessment in biology and science studies classrooms. During the discussions with teachers and researchers, about the results from the questionnaires, all teachers made reflections upon their own practice.

During the study, i.e. one semester the teachers and the researchers had four discussion seminars about literature concerning practice during experimental exercises and assessment criteria and practise. The teachers kept a reflective log book about their own practise in the light of the outcome of the seminars during the study. The results from the questionnaires and labsheet analysis where presented and discussed with the teachers at the end of the in-service project.

Finally, semi-structured interviews with the four teachers took place three months after the project had ended. The interviews lasted between 45 - 65 minutes, were audio-recorded and repeatedly intercepted. The interview concerned the teachers' assessment practice of the experimental work, goals with labwork, and their reflections on the outcome of the discussions during the project and the results from the different questionnaires.

## 3. Results

All teachers mentioned that the main goals with the labwork were to connect theory to practice, i.e. familiarise the students with scientific objects and phenomena, and stimulate interest and enjoyment. Another goal was to teach laboratory skills and techniques. According to one teacher, labwork was also important to let students confront and challenge their misconceptions and get opportunities to have informal discussions about the theory, model or concept studied. They all said that the informal discussions during labwork are important to consolidate the knowledge.

### 3.1- Assessment of the lab-work

All teachers expressed that labwork is an important part of biology and science study courses. However, two of the teachers had not paid so much attention to the assessment practice of the labwork. The other two had tried to formalise the assessment practice during a period but abandoned it since they thought it was very time consuming.

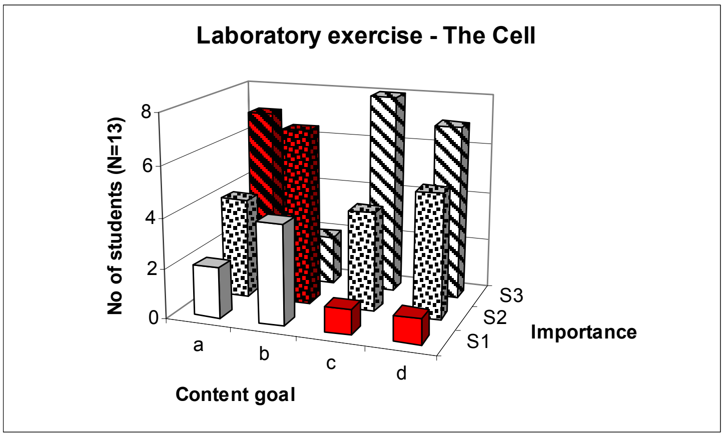
According to the teachers' logbook and the formal interview, the teachers became aware of the restrictions of their present assessment methods of the practical labwork, when realising that only labwork that resulted in a lab-report was assessed. In biology classes the students wrote lab-reports in almost half of the labwork done. Most of the lab-work done in general science classes were only presented orally by the group of students responsible for each labwork or discussed by the teacher in the classroom.

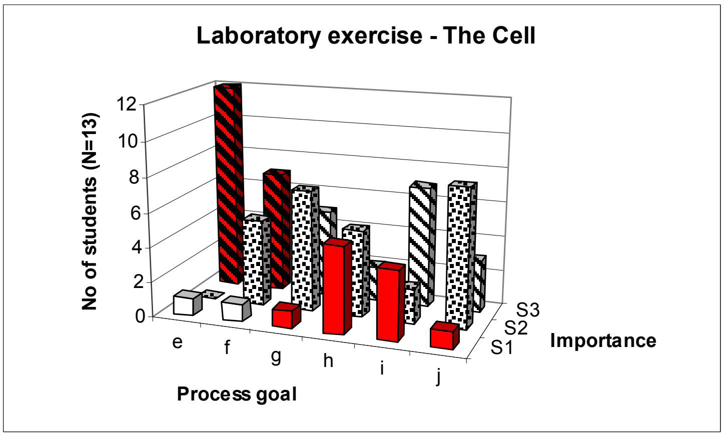
The teacher only comment on the results, and not laboratory skills, when the labwork were presented orally. An agreement with the students' was done about how the lab-report should be written, but no standards or grading criteria for the assessment of labwork were used. Certain headings had been pointed out that had to be covered by the students.

All teachers marked the lab-report with different home-made scales, e.g. OK, OK+ and OK++. Nobody used the grades according to the syllabi. Teachers always give the students possibilities to improve the report. Furthermore, the assessment of the performance was intuitive, not communicated and had little effect on the final grade. To pass the course the student had to participate in the experimental exercise but the performance only matters if the student's results are in between grades.

### 3.2- Analysis of laboratory instruction sheets

The 12 labsheets collected covered six different themes. The labsheets contained between one to six tasks each, the average was two tasks each. The objectives of the labwork tasks within the collected labsheets were analysed by the authors. The main objective as reflected in the lab-manuals provided, were to *help students identify objects and phenomena and become familiar with them*. Only three of the labwork tasks contained exercises where students had to manipulate empirical data. None of the labwork tasks investigated contained data processing, e.g. pooling of data in the class. Students were seldom asked to make generalisations and discuss relevance of the results. Also, students were almost never asked to pose the question to be investigated, formulate a hypothesis to test or plan the experimental procedure.




S1 (plain bar) = Not very important (1 & 2 from the questionnaire pooled)
S2 (dotted bar) = Intermediate
S3 (striped bar) = Very important (4 & 5 pooled)
a) Identify objects and phenomena, b) Learn a fact (or facts) and learn a concept, c) Find patterns and relations. Learn relationship, d) Learn a theory or model,
e) Learn how to use laboratory instrument, f) Learn how to carry out a standard procedure, g) Learn how to plan an investigation, h) Learn how to process data,
i) Learn how to use data to support a conclusion, j) Learn how to communicate the results of lab-work.

Figure 1. The teachers' and the students' classification of learning outcome of a specific experiment. The students' interpretations are summed in piles. The teachers' goals indicated in dark grey.

In the discussion about what is possible to assess during labwork, one question was which of the goals to attain according to the curricula, the labwork tasks covered. Another was which labwork skills that was possible to assess. In the Swedish standards, five assessment criteria concerning 1. planning experiments, 2. carrying out experiments, 3. interpretation of results, 4. evaluation of results and 5. presentation (report or performance), are primarily connected to labwork skills (National Agency for Education 2000). These assessment criteria can be described by different skills (Figure 2) that should be assessed according to the standards (for further details se also Grelsson & Ottander 2004). An analysis of the collected labsheets shows that all skills are not possible to assess regularly (Figure 2). For example, almost none of the tasks in the labsheets give an opportunity for students to develop skills to plan experiments (number one in Figure 2). The skills included in the assessment criteria number 2-5 are represented in most of the labsheets.

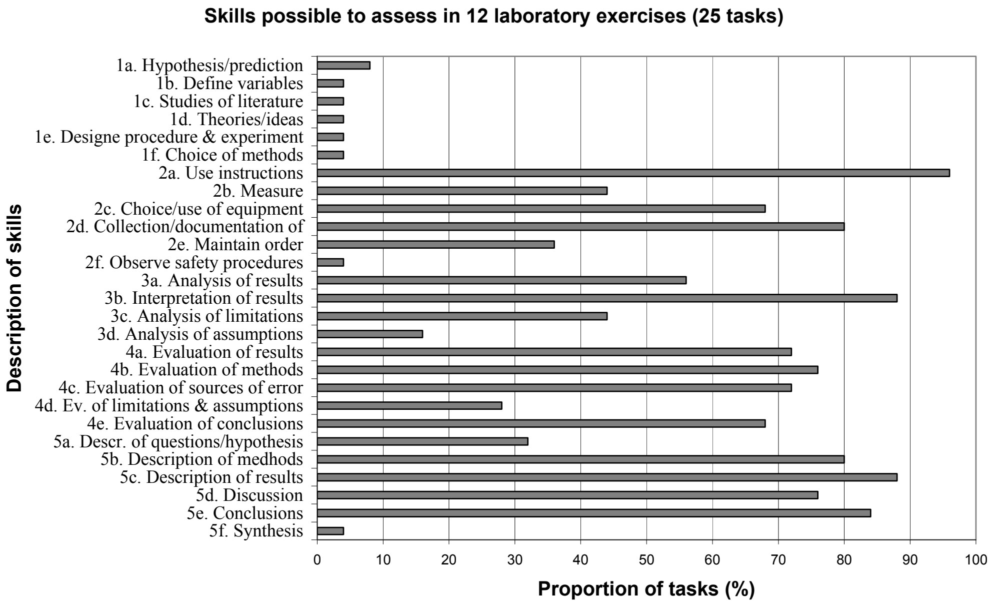



Figure 2. Description of skills in grading criteria: 1. Plan experiments, 2. Carry out experiments, 3.Interpret results, 4. Evaluation, 5. Presentation (report or performance)

When analysing the intended learning outcome of the labwork tasks (Table 1) we found that the agreement between the teachers' and students' interpretation of the goals differs in at least some of the aspects. One example from an exercise where the students studied different cells in the microscope is shown in Figure 1. Obvious differences in interpretation were that many students found "Find patterns and relations" (c) and "Learn a theory or model" (d) as important goals and the teachers' goal were to "Learn how to use laboratory instruments" (e) (Figure 1). Often the students chose several goals as important. The teacher, however, chose fewer goals. This was done more often by females, and especially among the content goals. There were less difference between the teachers and students view of intended learning outcome in Natural science classes. Other examples was seen in three different *recipe-like activities* where more than 2/3 of the students thought that "Planning an investigation" (g) were an important goal. "How to process data" (h) was differently interpreted in some other labwork.

In another labwork, which also was observed by the authors, the teachers marked the intended learning outcome as “Learn how to use laboratory instructions”. However, all manuals to the equipment were removed. When we discussed that labwork session during the interview later, the teacher said that; “I never bring the manuals to the instruments since the student never use them”.

### 3.3- Students view of assessment of laboratory work

The students’ views on what is important during the labwork were investigated by questionnaires in four classes. Most students in biology classes found it important to understand the theoretical knowledge expressed in the practical labwork (Figure 3). A higher percent among the students in the biology classes were concerned about “to understand the processes” during the labwork and make connections to theory, than among the science studies classes (Figure 3). Some students’ view of labwork, as indicated in the open-ended final question in the questionnaire, was that it is important as a help to understand theory. It is also a break from ordinary lessons that students enjoy. No comments gave a negative view of the labwork.

Four questions in the students’ questionnaire concerned their views about how the teachers assess their labwork achievement. The students’ views on assessment practice of labwork skills showed that half of the students believe that activity/commitment is assessed. Some mention ability to co-operate and a few mention ‘the result you get’. 44% of the students mention that assessment of the lab-reports concern ‘how clear and precise the lab-report is’. One third of the students mentioned ‘if you can demonstrate understanding’. When students are asked to describe how they want lab-work to be assessed, some express satisfaction with assessment methods used. However, more than 20 % want student activity and ‘how you work’ to be more valued. Only two out of 68 students say that they do not want them to be assessed at all.

Many of the students thought that the practical skills and laboratory reports have little or no importance in the grading process. Students believe that lab-work is of little consequence for final grade. Some students even say that they “do not know how or if it is assessed”.

### 3.4- Changes in teachers’ point of view – professional development?

Both in the beginning of the in-service professional development project and during the interviews, the teachers expressed that the labwork had three main goals; i.e. confirm theory, give practical skills and stimulate interest. The process of scientific inquiry was not mentioned, but is important according to the goals in the syllabi (National Agency for education 2000). Questions about how to increase the level of scientific inquiry in the experimental work, was raised several times during seminars and interviews by the authors. All teachers realized that it was incompletely covered. However, even if they have intentions to cover this, they think there are too much content to cover in the courses, and lack of time to fulfil this goal. All teachers mentioned in the final interview, that they will try to involve the students in the planning of the labwork. Pre-lab discussions were one of the suggestions from Teacher 3.

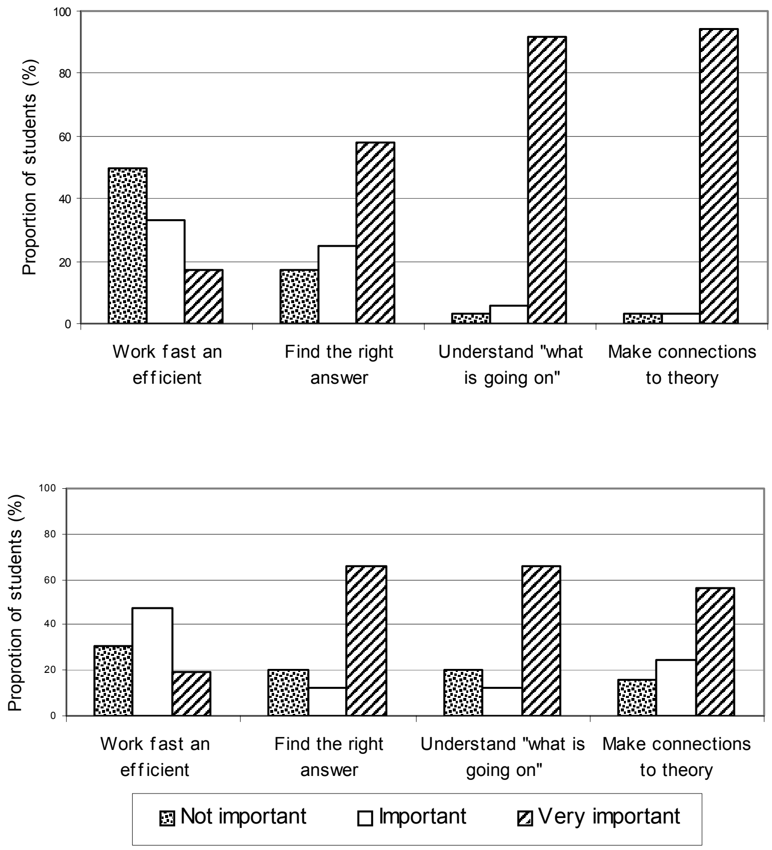



Figure 3. What is important during lab-work? Students' views (Upper: biology classes N=36, lower: science studies classes N=30).

Teachers were interested in practicing a transparent assessment model for the students and with potential to use formatively. However, two of the teachers expressed apprehension that the students could experience the learning situation around the lab work more stressful if they were aware of that it was an assessment situation. Furthermore, the two teachers thought it would inhibit the discussions during the experimental exercises. All teachers emphasized that the laboratory work has important social goals equally important as the scientific goals and thus were not willing to sacrifice these for assessment goals of students' performance. Teacher 3 expressed this as following: "*I find it important to use the opportunity to get to know the students, to show that I care about them.*"

All teachers were much more active in the discussions during the in-service project when results from questionnaires and observations were presented compared to when literature where discussed. All teachers' epistemological belief was that labwork prepare students with labwork skills and techniques. The classroom observations, informal discussion and labsheet analyse, however, show that Teacher 4 not gave the opportunity to practice that as much as he thought (3.2). One example was in a lab were all instruction manuals for the equipment were missing. Another example concerned using the microscope. The students were never told that they were supposed to learn how to use the microscope, and teacher no 4 said that he continued to help them find what to see over and over again.

In the formal interviews three months after the in-service project ended, all teachers mentioned the importance of making the intended learning outcome of different laboratory exercises more apparent to the students. How they want to achieve this differ:

> Teacher 1 - will mainly formalise the assessment. Want clear assessment criteria (standards) to get more justice between students and classes.
>
> Teacher 2 - will refine the instructions in cooperation with teachers at the school. Do not want assessment of hands-on skills – believes that it will make the laboratory exercises more stressful for students.
>
> Teacher 3 - will use more pre-lab discussions about goal and strategies in the science studies classroom. This decision was based on the results from the two questionnaires.
>
> Teacher 4 - was reminded of the importance of lab-work and will consider the different laboratory exercises more thoroughly.

## 4. Discussion and Conclusions

Both students and teachers stressed that labwork is important in science education, especially for understanding theory (Jenkins, 1999) and stimulate interest (Lindahl, 2003).

Even though the process of scientific inquiry is important according to the goals in the curricula (National Agency for education 2000), and also stated as important outcome of labwork (e.g. Lazarowitz & Tamir 1994), the teachers in this study did not mention this as important goals. According to the teacher interviews, the main goal with labwork was to connect theory to practice, stimulate interest and enjoyment and practice laboratory skills and techniques. Students in this study very seldom were given the opportunity to plan experiments and make predictions (Figure 2). The main intended learning outcome, as reflected in the lab-manuals provided were to help students identify objects and phenomena and become familiar with them (Figure 1). Similar results are also found in other European countries (Tiberghien et al., 2001; Coquidé, 2003). According to Kang and Wallace (2005) teachers with naive epistemological beliefs are likely to pursue delivering information as primary instructional goal. Some of the labwork in the category *identify objects and phenomena* were presented as *delivering of information*. Teacher 3 stressed that labwork should give students opportunities to have informal discussions about the theory, model or concept studied. These informal discussions are very important in science education (Sutton, 1998). A more formal assessment of labwork would inhibit the discussions during the experimental exercises and be of disadvantage for the students, according to teachers (no 2 and 3). The teachers also pointed out informal discussions of more social character, between teacher and students during labwork, as important.

This study shows that labwork skills neither are assessed on a regular basis nor tested on special occasions in the two schools investigated. The analysis of the labsheet tasks showed that the students are not given more than occasional opportunities to practise their ability to plan experiments (and field studies), although it is a goal to attain according to the syllabus. Most of the labsheets included clear instructions of both the methods and procedures. This means that planning experiments hardly is practised and assessed. The criteria concerning carrying out experiments (i.e. practical skills), interpretation, evaluation and presentation of results (Figure 2) are all satisfactorily represented, if not in all tasks but many enough to give basic data sufficient for a reliable assessment. The results from both student questionnaire, and teacher interview, show that the teacher basically assesses how the students can present their labwork in a lab-report. The students always have opportunity to improve the lab-report, thus the assessments were mainly formative.

However, an assessment of a lab-report does not cover students' skills in carrying out an experiment. This assessment practise might be enough for student counselling or formative assessment, but should not be recommended as the basis of grading. An experienced teacher will probably do a correct assessment but it is important to verbalize what is important with labwork, both to give the students possibilities to develop special qualities and to make the assessment criteria more transparent. Since assessment of a lab-report does not include students' practical skills, and according to the teachers, practical skills never are communicated with the students, only the criteria concerning interpretation, evaluation and presentation of results are included satisfactorily in the assessment. The results also show that most of the labwork at upper secondary school do not include challenges which reach higher levels of knowledge. The student performance and result on lab-report only mattered if the student's grade from written exams were in between grades. All teachers wanted an assessment model transparent for the students and with potential to use formatively, since it would influence how and what students learn (Boud, 1995; Marton & Booth, 2000). Still, two of the teachers were not convinced that it would be beneficial since the more stressful labwork situation would take away the enjoyment.

The different interpretations of the intended learning outcome of the labwork, between teachers and students (Figure 1), can be explained in several ways. One is that the instructions from the teachers and the labsheets are not focused on the goals, but on what the students are expected to do. But it can also be explained by the fact that the scientific language is not familiar to the students. For a student, "patterns and relations" can be viewed more literal and be of importance when using a microscope to compare different cell types. However, to decide which of the explanation models are the most plausible, student interviews would have been required.

The project has made it possible for practitioners and researchers to share their knowledge in a community of learners. The empirical studies made it possible for the participants to reflect over their experimental practise. It was important for teachers to investigate their practise, since these results from students view influence the teachers more than the literature. All teachers realized, through the empirical studies, the importance of making the intended learning outcome of different laboratory exercises more apparent to the students. One recommendation revealed from this study is that goals, instructions and assessment criteria of experimental exercises must be treated as a unit, i.e. planned in coherence with each other. It is also important that the goals are apparent to the students, and the laboratory manuals are formulated so that the goals are communicated with the students.

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# Section 5

# Developing Attitudes and Opinions: Interest and Motivation for Biology

# IS PUPILS' INTEREST IN BIOLOGY RELATED TO THEIR OUT-OF-SCHOOL EXPERIENCES?

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## Abstract

Interests in biology and out-of-school experiences of Finnish primary school pupils (n=3626, median age 15) were surveyed in spring 2003 using the international ROSE questionnaire. Likert-scaled items were categorized with explorative factor analysis. The scores of eight interest context factors and seven out-of-school experience factors were studied. More boys than girls were interested in basic processes in biology, whilst more girls than boys found human biology and health education interesting. Nature experiences were the most important factor correlating with interest contexts in biology. Experiences in science and technology, such as science kits and constructing models had the highest correlation with the interest in basic processes in biology, such as ecology, cell biology and genetics. Experiences of caring farm animals correlated with the interest in applied biology, such as agriculture. Experiences linked to design and technology or information technology were least important factors to correlate with interest in biology. Thus, to enhance pupils' interest in biology and the living environment, it is important to put more emphasis on situational outdoor education and laboratory work.

## 1. Introduction

Many studies have shown that interest-triggered learning activity leads to higher degree of deep-level learning (Krapp, 2002). Interest is a relationship between an individual and an object. Most researchers differentiate between individual and situational interests (Krapp et al., 1992). Individual interest is understood to develop gradually and affect one's knowledge and values over time, while situational interest appears suddenly as a response to something in the environment and is more emotional in nature (Hidi, 1990). Situational interest is thought to have only short-term impact, whereas individual interest is believed to be more stable.

The general view of school education is that pupils' knowledge on a school subject is acquired in the classroom within varying educational settings constructed by the teachers. Very little importance is ascribed to children's out-of-school experiences. Informal learning may occur at home, in everyday situations like interaction with friends, watching TV, reading books or magazines, in various hobbies, junior organizations and in institutions like museums and zoos. Out-of-school activities and learning environments may influence children's interest in different school subjects.

Many researches in science education have revealed that pupils are usually more interested in biology than other science subjects, such as chemistry and physics (Fairbrother, 2000; Osborne, 2003). Gender is an important factor relating pupils' interests and attitudes towards science, boys being in average more interested in physics and girls in biology. In addition, according to the evaluation of The National Board of Education in Finland on comprehensive schools, the grades of the girls in biology and geography were statistically significantly higher than those of the boys, but the reverse was found in physics (Rajakorpi, 2000). In spite of numerous studies concerning gender aspects in science education, the meaning of gender is rarely explicated. In this research, we engage in cultural construction interpretation of gender. This means that neither girls nor boys are homogenous groups, girls (or boys) do not share essential characteristic. For instance, possible differences between boys and girls interests cannot be explained only by biological difference, but largely by expression of cultural gender roles (Gilbert, 2001; Juuti et al., 2004).

In this paper, the relation between pupils' interests in different contexts of biology and their out-of-school experiences are studied. We asked the questions:
(1) Are there any gender differences in the interest and out-of-school activities, and
(2) Is pupils' interest in biology correlated with the out-of-school experiences?

## 2. Material and methods

The study was carried out in connection with an international ROSE project (Schreiner & Sjöberg, 2004). The original English ROSE questionnaire was translated to Finnish. Seventy-five primary schools were selected by weighted random sampling. The sample included Finnish primary schools that had at least 20 students at grades 7 to 9. The questionnaire was sent to schools in March 2003. The median age of the pupils was 15 years. Twenty-six reminders to 35% of the selected schools were sent in May. Totally 3666 pupils answered the survey, in 3626 of which the gender was indicated. After returning the questionnaire, coding for SPSS files was done by automatic scanning of the returned questionnaires.

The questionnaire contains 108 statements for pupils' interests in science education and 61 statements on their out-of-school activities. Eight national questions concerning basic biological processes were included at the end of the ROSE questionnaire. For each statement the pupils were asked to indicate their response by ticking the appropriate box below the topics: *"What I want to learn about? How interested are you in learning about the following?"* and "*My out-of-school experiences. How often have you done this outside school?"* The interests were studied with the scale "not interested" to "interested" and out-of-school activities with the scale "never" to "often". The two categories in the middle of the scale were untitled. There was no neutral middle point or the 'do not know' category. However, in the introduction to each question, it was remarked that the pupils may refrain from ticking any boxes if they do not know what to answer.

To find out pupils' interest in biology and their main out-of-school experiences, appropriate items were chosen for the further multivariate analysis. The items' selection was carried out using stepwise explorative factor analysis (EFA), in which most insignificant items were gradually excluded to find out the best fit factor model. The 38 interest items dealt with pupils' interests in different contents of general biology (ecology, zoology, genetics, evolution) or biology-related contents (applied biology, human biology/health education). The 32 out-of-school experience items dealt with various science or technology related activities.

In the EFA analysis, maximum likelihood was used as the extraction method, rotation being Promax (kappa =4) with Kaiser Normalization. The calculated Kaiser-Meyer-Olkin Measure of sampling adequacy and in the Bartlett's test of sphericity for the factor analysis showed that the data were adequate for EFA analysis. For interest context the KMO of Sampling Adequacy was 0.972 and in the Bartlett's Test the approximate Chi-Square was 79312 (df =1035, p=0.000). For the out-of-school experiences the corresponding values were for KMO 0.897 and for the Bartlett's Test 48601 (df =496, p=0.000).

Boys' and girls' factor scores were compared with the independent-samples t-test. The power of the statistical difference was analyzed by calculating the effect size measure (*d*) for the groups (Cohen, 1988), because it is independent of sample size. The measure is calculated as the difference between two means, divided by the standard deviation of either group. The two-way Pearson's correlation analysis was used to find out if there were any relations between pupils' interest context factors and their out-of-school experience factors.

## 3. Results

Eight factors describing pupils' main interest contexts in biology explained 53% of the extraction sums of squared loadings (Table 1, Table 2). Seven factors that described different out-of-school activities explained 52 % of the extraction sums of squared loadings (Table 3, Table 4). The number of items in interest context factors varied between 5 and 8 and in experience factors between 2 and 8. The reliability index of Chronbach's $\alpha$ varied between 0.78 and 0.90 for the interest context factors (Table 2) and between 0.77 and 0.89 (Table 4) for the out-of-school experience factors.

Table 1. Loadings of interest factors (F1-F8) reduced by the EFA from pupils' interest items (Loadings < 0.3 are not included)

| Interest factors | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 |
|---|---|---|---|---|---|---|---|---|
| Items | | | | | | | | |
| Factors determining species' distribution on land and in the water. | .83 | | | | | | | |
| What chromosomes and genes are and how they function. | .81 | | | | | | | |
| How microscopically small organisms look like. | .76 | | | | | | | |
| How oxygen is recycling. | .76 | | | | | | | |
| How the cells of animals and plants look like and how they function. | .73 | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| How energy is transmitted to humans through the food web. | .68 | | | | | | | |
| How species' individuals communicate with each other. | .62 | | | | | | | .35 |
| What we know about HIV/AIDS and how to control it. | | .78 | | | | | | |
| Sexually transmitted diseases and how to be protected against them. | | .77 | | | | | | |
| How different narcotics might affect the body. | | .72 | | | | | | |
| How alcohol and tobacco might affect the body. | | .71 | | | | | | |
| Cancer, what we know and how we can treat it. | | .63 | | | | | | |
| How to control epidemics and diseases. | | .54 | | | | | | .32 |
| The ability of lotions and creams to keep the skin young. | | | .93 | | | | | |
| Plastic surgery and cosmetic surgery. | | | .78 | | | | | |
| How radiation from solariums and the sun might affect the skin. | | | .76 | | | | | |
| Eating disorders like anorexia or bulimia. | | | .73 | | | | | |
| What to eat to keep healthy and fit. | | | .52 | | | | | |
| How to exercise to keep the body fit and strong. | | | .50 | | | | | |
| Plants in my area. | | | | .84 | | | | |
| Animals in my area. | | | | .73 | | | | |
| How to improve the harvest in gardens and farms. | | | | .72 | | | | |
| Benefits and possible hazards of modern methods of farming. | | | | .69 | | | | |
| Organic and ecological farming without use of pesticides and artificial fertilizers. | | | | .64 | | | | |
| How different sorts of food are produced, conserved and stored. | | | | .50 | | | | |
| How plants grow and reproduce. | | | | .38 | | | | |
| Symmetries and patterns in leaves and flowers. | | | | .37 | | | | |
| Dinosaurs, how they lived and why they died out. | | | | | .73 | | | |
| Animals in other parts of the world. | | | | | .72 | | | |
| Brutal, dangerous and threatening animals. | | | | | .62 | | | |
| How animals use colours to hide, attract or scare. | | | | | .51 | | | |
| The possibility of life outside earth. | | | | | .41 | | | |
| Deadly poisons and what they do to the human body. | | | | | | .73 | | |
| Biological and chemical weapons and what they do to the human body. | | | | | | .72 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| The effect of strong electric shocks and lightning on the human body. | | | | | | .69 | | |
| Epidemics and diseases causing large losses of life | | | | | | .48 | | |
| Poisonous plants in my area. | | | | | | .47 | | |
| How radioactivity affects the human body. | | | | | | .31 | | |
| Sex and reproduction. | | | | | | | .76 | |
| Birth control and contraception. | | | | | | | .71 | |
| How babies grow and mature. | | | | | | | .43 | |
| Heredity, and how genes influence how we develop. | | | | | | | .38 | .58 |
| How the human body is built and functions. | | | | | | | .41 | .51 |
| The origin and evolution of life on earth. | | | | | .40 | | | .47 |
| How human being is developed in evolution. | .40 | | | | | | | .44 |
| How gene technology can prevent diseases. | | | | | | | | .33 |

Table 2. Factors (F1-F8) interpreted as interest contexts in general biology and human biology / health education, percentage of variance explained by extraction sum of squared loadings and Chronbach's α.

| Interest context factors | No. of items | % of variance | Chron-bach's α |
|---|---|---|---|
| General biology | | | |
| F1: Basic processes in biology | 8 | 24.4 | 0.90 |
| F4: Applied biology | 8 | 4.2 | 0.85 |
| F5: Zoology | 6 | 2.9 | 0.78 |
| F8: Genetics and evolution | 7 | 1.6 | 0.80 |
| Human biology/health education | | | |
| F2:Common health and illness | 6 | 10.3 | 0.89 |
| F3: Personal outlooks and fitness | 6 | 4.9 | 0.86 |
| F6: Human body in extreme conditions | 6 | 2.2 | 0.81 |
| F7: Sex and reproduction | 5 | 2.1 | 0.83 |

Each factor was named according to the loaded items, emphasising the highest loadings and contents common for factor items. Interest contexts factors were categorised to be included in general biology (factors 1, 4, 5, 8) and in human biology/health education (factors 2, 3, 6, 7) (Table 1, Table 2). The out-of-school experiences context factors were named according to the activities they described (Table 3, Table 4).

Table 3. Loadings of experience factors (F1-F7) reduced by the EFA on pupils' out-of-school experience items. The loadings <0.3 are not included. Interest factors reduced by the EFA on pupils interest in contents of biology.

| Experience factors | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Items | | | | | | | |
| Used a science kit (like for chemistry, optics or electricity). | .81 | | | | | | |
| Made a model such as toy plane or boat etc. | .79 | | | | | | |
| Used a windmill, watermill, waterwheel, etc. | .76 | | | | | | |
| Used a water pump or siphon. | .64 | | | | | | |
| Made a bow and arrow, slingshot, catapult or boomerang. | .59 | | | | | | |
| Used an air gun or rifle. | .54 | | | | | | |
| Mended a bicycle tube. | .47 | | | | .42 | | |
| Watched nature programs on TV or in a cinema. | | .76 | | | | | |
| Collected edible berries, fruits, mushrooms or plants. | | .68 | | | | | |
| Read about nature or science in books or magazines. | | .62 | | | | | |
| Put up a tent or shelter. | | .49 | | | | | |
| Planted seeds and watched them grow. | | .49 | | | | | |
| Prepared food over a campfire, open fire or stove burner. | | .41 | | | | | |
| Made a fire from charcoal or wood. | | .39 | | | | | |
| Sent or received e-mail. | | | .75 | | | | |
| Downloaded music from the internet. | | | .67 | | | | |
| Used a word processor on the computer. | | | .63 | | | | |
| Played computer games. | | | .51 | | | | |
| Searched the internet for information. | | | .47 | | | .38 | |
| Milked animals like cows, sheep or goats. | | | | .83 | | | |
| Watched (not on TV) an animal being born. | | | | .68 | | | |
| Made dairy products like yoghurt, butter, cheese or ghee. | | | | .64 | | | |
| Cared for animals on a farm. | | | | .64 | | | |
| Made compost of grass, leaves or garbage | | | | .33 | | | |

| | | | | |
|---|---|---|---|---|
| Used a crowbar (jimmy). | | .78 | | |
| Used a wheelbarrow. | | .66 | | |
| Used tools like a saw, screwdriver or hammer. | | .55 | | |
| Used a rope and pulley for lifting heavy things. | .40 | .49 | | |
| Sent or received an SMS (text message on mobile phone). | | | .96 | |
| Used a mobile phone. | | | .88 | |
| Cooked a meal. | | | | .80 |
| Baked bread, pastry, cake, etc. | | | | .74 |

Table 4. Factors interpreted as experience context factors on pupils out-of-school experiences, percentage of variance explained by extraction sum of squared loadings and Chronbach's α.

| Experience context factors | No. of items | % of variance | Chronbach's α |
|---|---|---|---|
| Science and technology | 8 | 15.9 | 0.88 |
| Nature | 7 | 18.0 | 0.77 |
| Computer | 5 | 7.9 | 0.77 |
| Farm animals | 5 | 2.8 | 0.77 |
| Design and technology | 5 | 3.0 | 0.84 |
| Mobile phone | 3 | 2.4 | 0.89 |
| Home economy | 2 | 2.0 | 0.82 |

The gender difference was statistically significant ($p<0.001$, two-tailed t-test), when calculated from the scores of different interest context factors. However, the effect size of the gender difference was 'large' only in the interest contexts of 'b*asic processes in biology'* ($d = 0.95$; $M_{boys} > M_{girls}$) and '*personal outlooks and fitness*' ($d = 1.08$; $M_{girls} > M_{boys}$). The effect size of the gender difference was 'medium' ($d = 0.59$; $M_{girls} > M_{boys}$) in the interest context of '*common health and illness'.* Girls liked more than boys '*applied biology*', '*zoology*' and '*genetics and evolution*', but in these cases the effect size of the difference was 'small' ($d < 0.5$). Boys were more interested in '*human body in extreme conditions*', but the effect size of this difference was low ($d = 0.18$).

As for the out-of-school experiences, the effect size measure did not indicate statistical gender difference at the 0.001 significance level for the experience contexts of '*computer'* use and caring of '*farm animals*'. The power of gender difference was 'large' in the context factors of '*science and technology'* ($d = 1.37$; $M_{boys} > M_{girls}$) and '*home economy*'

(1.25; d = 0.59; $M_{girls} > M_{boys}$) and medium size (d = 0.5-0.8) in the other factors. Girls had more '*nature*' experiences, but experiences in '*design and technology'* were more favored in boys group. Because of large skewness (-2.1) and kurtosis (3,9) of the score distribution, the experience factor of '*mobile phone*' was not included to the analysis.

Out-of-school '*nature'* experience was the most important factor correlating with the interest in biology, especially with '*applied biology'* and '*zoology'* (Table 5). Experience in caring '*farm animals'* correlated with the interest in '*applied biology*' too. Surprisingly, experiences in '*science and technology*' related with the interest in '*basic processes in biology*', and in this case, the coefficient was at it highest ($r$ = 0.51), thus explaining 26% of the variance of either factor. Experience with '*computer*' had the lowest correlation ($r$ < 0.2) with the interest contexts.

Table 5. Pearson correlation coefficients between interest context factors and out-of-school experience factors

| Factors | Basic processes in biology | Com-mon health and illness | Personal outlooks and fitness | Applied biology | Zoo-logy | Human body in extreme conditi-ons | Sex and repro-duction | Gene-tics and evolu-tion |
|---|---|---|---|---|---|---|---|---|
| Science and techno-logy | 0.51** | -0.12** | -0.19** | 0.18** | 0.04* | 0.19** | -0.04* | -0.04* |
| Nature | 0.12** | 0.28** | 0.30** | 0.42** | 0.40** | 0.27** | 0.19** | 0.34** |
| Compu-ters | NS | 0.13** | 0.06** | NS | 0.15** | 0.18** | 0.09** | 0.11** |
| Farm animals | 0.18** | 0.04** | 0.15** | 0.38** | 0.11** | 0.06** | 0.10** | 0.06** |
| Design and techno-logy | 0.22** | NS | -0.10** | 0.10** | 0.08** | 0.17** | 0.05** | -0.06** |
| Home economy | -0.13** | 0.30** | 0.38** | 0.23** | 0.23** | 0.13** | 0.23** | 0.27** |

*Note. ** p < 0.01 (2-tailed) * p < 0.05 (2-tailed)*

## 4. Discussion

### 4.1- Gender differences

The results indicated that in some contexts, boys and girls had different interests in biology and that they had different out-of-school experiences. Girls were clearly more interested in the contexts of human biology and health education, especially those concerning factors affecting personal outlooks and fitness, such as exercise, healthy eating or eating disorders. Boys were more interested in basic processes in biology such as ecology and cell biology. However, the gender difference in the interest contexts of applied biology, zoology, sexuality and genetics and evolution was only small.

The finding that girls are more interest than boys in human biology is in accordance with other studies (Dawson, 2000). However, from the same data as in this study, Juuti et al. (2004) found that girls and boys preferred physics in human-related context alike. Girls' interest in the context of health education and personal outlooks and fitness may be partially explained by the findings that many adolescent girls worry their body image (Vereecken et al., 2004). For instance, in an international comparative study, even 43% of Finnish girls aged 15 years have been found to be dissatisfied with their weight, for boys the value being 20% (Mulvihill et al., 2004).

Boys liked more than girls the context of basic processes in biology. The result is surprising, because generally biology is found to be favoured more by girls than by boys (Dawson, 2000; Rajakorpi, 2001). From the same survey as in this study, Juuti et al. (2004) suggest that in studying physics, boys liked to know how technical applications work and girls to what purpose the technical applications can be used. According to Hoffmann (2002), cultural gender roles affect pupils' self-esteem, motivation and interest to study science subjects, which may influence their interest to study different topics of biology, too.

Boys and girls had partially different out-of-school experiences. Boys had clearly more experiences with science kits and constructing models. Girls were more occupied with domestic work such as cooking and baking. There was no clear gender difference in the prevalence of computer use as such, but girls used computers more for e-mailing, while boys used more time playing computer games. In an international comparative study, 21% of boys and 3% of girls aged 15 years have been found to spend daily more than three hours playing computer games during weekdays in Finland (Todd & Currie, 2004).

### 4.2- Relation between interest contexts and out-of-school experiences

The most important out-of-school factor correlating with the different interest contexts was pupils' general interests and activities in and about the living nature. This appears in many ways: reading books or magazines on nature; or watching nature programs on TV or cinema; or hiking, camping, gardening, collecting edible berries in the nature. Experiences of caring farm animals related to the interest in applied biology, such as interest in local plants and animals, modern methods of agriculture and farming, and the use of pesticides and artificial fertilisers and food production. Pupils' interests (or non-interests) in different contexts of biology may thus be an expression of individual longer-lasting interest (Krapp et al., 1992; Krapp, 2003) in nature-related contexts.

Experience to use information technology, such as playing computer games and e-mailing, did not clearly relate to the interest in varying contexts of biology. If nature activities are important in generating interest in biology, hobbies around information technology may have taken time from them. Even if computer-aided learning has been found to be useful in learning biology (Kroβ, 1998; Nerdel et al., 2003), keen free-time hobbies around information technology may estrange pupils from real life experiences. If pupils free-time activities and experiences in living nature are limited, organising of experiential out-door learning environments would be especially important to evoke pupils' situational interests and motivation to learn more for instance on ecology in the school, as shown by Bogner (2003).

According to our results, girls had more out-of-school nature activities than boys did. From the same sample Uitto et al. (2004) found that on average, girls had more naturocentric attitudes towards environmental values and positive attitudes towards environmental responsibility than boys, who had owned more anthropocentric attitudes. Although factors enhancing positive environmental attitudes are multiple, positive nature experiences play an important role in the development of environmental responsibility. Knowledge on ecology is important, but cannot be the only factor to predict the development of environmental responsibility (Hungerford & Folk, 1991). Thus, interest and activities in and about living nature would predict not only interest in biology, especially in ecology, but also a positive attitude towards environmental responsibility.

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# MODIFYING STUDENTS' AESTHETIC APPRAISAL OF "CREEPY CRAWLIES" THROUGH CHANGE OF PERSPECTIVE

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## Abstract

Some animals are not liked by humans because they look ugly or scary rather than being really dangerous. Such an emotional rejection might hinder people from developing an interest in protecting these species and their habitats. We analysed the aesthetic decision of pupils about such "less attractive animals" and tried to modify their opinion by presenting the same animals in another perspective. The study is based on the model of Retzlaff-Fürst (2000) that, at a detailed perspective, the aesthetic decision is based on the form of the animals, while content related factors become less important ("model of form and content"). The test animals were four living "creepy crawlies": *Porcellio scaber* (Woodlouse), *Lithobius forficatus* (Centipedes), *Arion ater* (Black slug) and *Tenebrio spec.* (Earthworm). The results confirm that pupils' aesthetic decision about living organisms is not consistent, but changes with the perspective animals are looked at. The aesthetic decision was more positive at a detailed perspective (watching the animal under a stereo microscope) than at a normal perspective (looking at it with the naked eye). Finally, we discuss some teaching implications of our results in regard with developing pupils' aesthetic decisions during their biology lessons.

## 1. Introduction

"Creepy crawlies" such as woodlouse, centipedes or slugs have important roles in ecosystems. However, school pupil characterise them often as ugly. Such emotional rejection of organisms might hinder further interest. A study of Lude (2000) shows that a person's voluntary protection of the environment is well correlated with their affection for particular species. Beauty or ugliness of plants and animals has an emotional effect on pupils. This can result in attention and care or in rejection. Those, which look "ugly", are often neglected, while "nice" ones might cause attention and care. It should be possible to increase pupil's interest in "creepy crawlies" and in environmental activities by turning their aesthetic decision from a rather negative into a positive one (Figure 1).

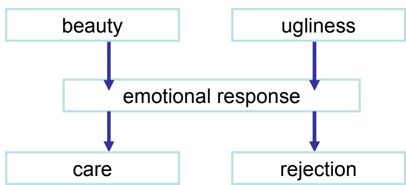


Figure 1. Emotional response

This study will show how pupil's study of "creepy crawlies" during school biology lessons can change their emotional view.

## 2. Theoretical background

Traditionally, "aesthetics" has referred to, and still refers to, the philosophy of art and of beauty. Aesthetic judgement was the focus in the seventeenth and eighteens century. Well known representatives like Kant and Hume asked: "How do we make judgements about the aesthetic qualities of an object or event. Kant considered the form of an object as its main aesthetic characteristic (Kant, 1993). In the following centuries aestheticians began to focus on the psychology of aesthetic experience. A better definition in this sense is: "aesthetics is the philosophical exploration of the sensuous aspects of experiences". Fenner (2003) said: "Aesthetics is about the sensuous aspects of our experiences." In this context, he submitted an attempt to analyze the complexity we normally find in aesthetic experiences:

a. *Formal Analysis:* the basic objective properties of lines, colours, proportions, contrasts and so forth; that's what immediately hits our eyes, ears or noses.

b. *Associations:* recollective, emotional and cognitive.

c. *Contexts:* social, moral und taste contexts.

d. *External Factors:* so called "secondary aspects" like informational factors and subjective factors (Fenner, 2000; Fenner, 2003).

Scientists at the University of Rostock have studied the relation between environmental education and bio aesthetic since 1995. According to different attempts to analyze aesthetic experiences (Rensch, 1973; Wilson, 1986; Fenner, 2003), they developed a model to analyse and modify the aesthetic view of pupil and tested the abilities of this model. The model, named "The model of form and content" (Retzlaff-Fuerst, 2001) can by summarised as follows:

| aesthetic decision = aesthetic assessment + aesthetic argumentation |
|---|

The aesthetic assessment covers the range from very nice over nice-not so nice to ugly. The aesthetic argumentation is based on aspects of form like colour, shape or symmetry. Nevertheless, this is often not sufficient to explain the subjective feelings about the beauty or ugliness of woodlouse for instance. Those reasons refer to the content. They can be divided in propositions, images, and episodes und intellectual skills. The present study is based on this model. It is presented in Figure 2.

| Aesthetic decision | | |
|---|---|---|
| Aesthetic assesment | Very nice – nice – not so nice – ugly | |
| Aesthetic argumentation | Form<br><br>(e.g. colour, symmetrie, shape) | Content<br><br>(propositions, images, episodes, intellectual skills*)<br><br>* according to the theory of learning (White/Gunstone, 1992) |

Figure 2. "The model of form and content" (Retzlaff-Fuerst 2000)

The aim of the study is to record the aesthetic view of pupils when looking at certain living animals in different perspectives. Opinions will be analysed and finally, suggestions will be made of how the aesthetic perception of an object/animal can be changed.

## 3. Material and Methods

In the very first study, children from year 4 of a primary school confirmed the following assumption: The aesthetic decision of pupil about pictured animals (*Epicrates chenchria chenchria, Agyope bruennich*) is not consistent, but changes with the perspective of view. Details (e.g. the skin of a snake) get more positive responses than pictures of the complete animal (Retzlaff-Fuerst & Horn, 2002).

Based on the first study, where photographs of animals were presented, the aesthetic decision of pupils from secondary school (year 16-17) about *living animals* was analysed in the second study, which is presented in this paper.

The main question in the study was:
Which effect has the observation of living animals in magnified view and normal perspective on the aesthetic decision about those animals?

The working hypothesis was:
Pupils view living animals in different perspectives and make their aesthetic decision. Magnification alters both the aesthetic assessment and the aesthetic argumentation.

The test animals were living "creepy crawlies". Humans do not like some "creepy crawlies" because they look ugly or scary rather than being really dangerous. Such judgements do often not include considerations about the way of living and ecological function of those species. Actions resulting from those judgements could have fatal consequences for ecosystems. Wilson (1995, p.171) considers insects and land-living arthropods as so important that their extinction from our planet would shortly be followed by an extinction of mankind.

Four "creepy crawlies" were presented to 80 pupils from secondary school (year 16-17):

- *Porcellio scaber* (Woodlouse)
- *Lithobius forficatus* (Centipedes)
- *Arion ater* (Black slug)
- *Lumbricus terrestris* (Eartworm).

The design of the study is characterised by a quantitative and a qualitative analysis.

1. Quantitative study: Questionnaires for acquisition of aesthetic assessment and briefly aesthetic argumentations and interviews for different acquisition of aesthetic argumentations. First the pupils had to assess the aesthetic of the animals in a questionnaire and briefly to explain their decision. The pupils were asked to observe each animal under a stereomicroscope (magnified perspective) and in their normal perspective. For the woodlouse the magnified perspective was e.g. magnified dorsal segments of the carapace and the normal perspective was e.g. the whole animal sitting in a petri dish. Questionnaires were evaluated statistically (t-test).
2. Qualitative study: In addition, some of the pupils were interviewed for more detailed explanations of their aesthetic decision.

## 4. Results

### 4.1- Questionnaires

The evaluation of the questionnaire gave the following results: The pupils changed their aesthetic decision according to the perspective the animals were observed at. The decision was more positive for the detailed perspective than for the normal perspective for all four animals. For the black slug, the evaluation of the questionnaire gave the following results, presented in Figure 3.

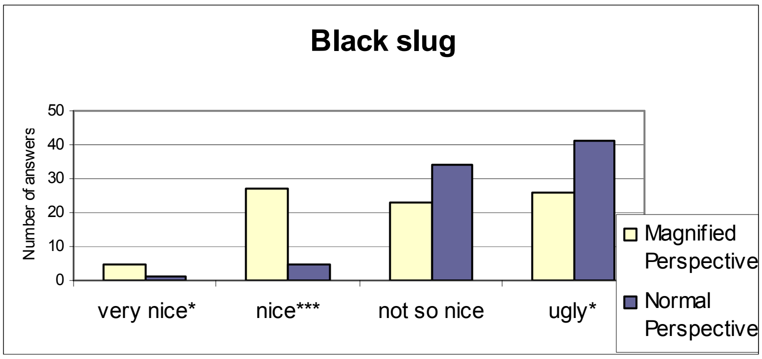


Figure 3. Results of the questionnaire "black slug"

Stars indicate significant differences between magnified and normal perspective. For instance, at normal perspective only 5 pupils thought the slug to be "nice", but 27 at magnified perspective. This difference was highly significant. In opposite, more than 40 pupils assessed slugs to be "ugly" at normal perspective, but only 26 thought so at magnified perspective.


Figure 4. Results of the questionnaire "woodlouse"

For the woodlouse, the evaluation of the questionnaire gave the following results, presented in Figure 4. At normal perspective only 4 pupils assessed the slug to be "nice", but 26 at magnified perspective. This difference was highly significant. In opposite, more than 30 pupils assessed slugs to be "ugly" at normal perspective, but only 18 thought so at magnified perspective.

4.2- Interviews

Aim of the interviews was to better understand pupil's aesthetic argumentation. The results of the interviews are still to be evaluated, but a few examples are given.

We used the program ATLAS/ti to analyse the results of the interview. The program enables a stepwise reduction of the material according to certain propositions. It has the opportunity to summarise the material and to make networks with connections. On fig.5 you can see one of the *original* networks (in German). Pupils' argumentation was summarised within propositions like reproduction, habitat, biology and ecological importance. This network shows only a small part of the arguments.

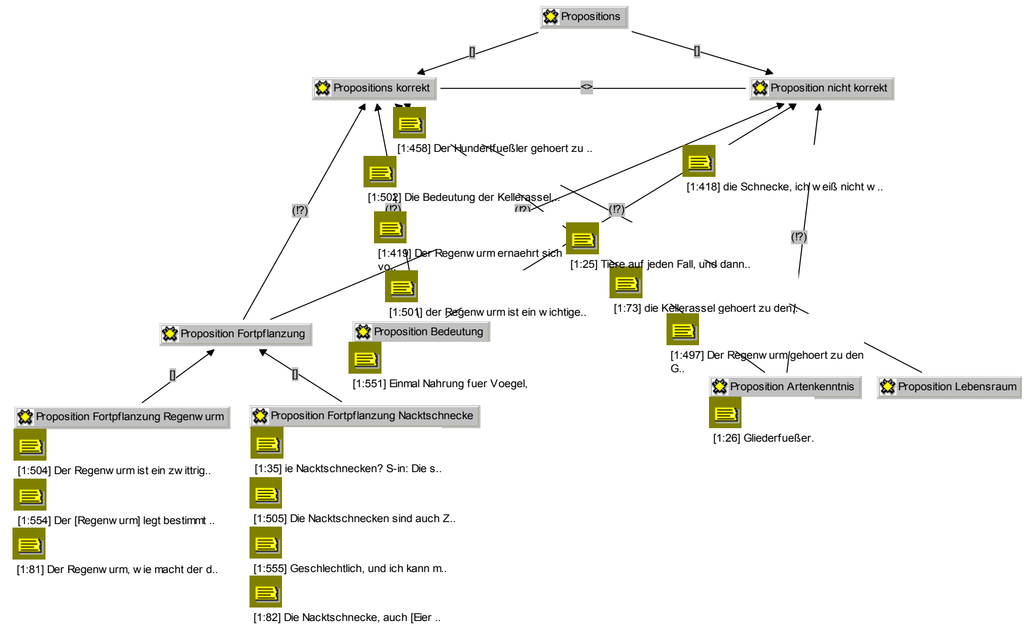


Figure 5. Original network "propositions" from ATLAS/ti

The following network (Figure 6) represents the simplification of the original network. The propositions were declared as correct or not correct. The features imply three areas: reproduction, importance and knowledge about species biology. Most statements of the reproduction referred to the earthworm and the black slug.

1. *Correct statements of reproduction*. Students said:
- "The earthworm, I don't know how it reproduces, does it lay eggs? It divides itself, but it grows together again, or it lives on at least, that is what I know. I believe it lays eggs as well."
- "The earthworm is a hermaphrodite; the earthworms come together, exchanges seeds or so and then create little capsules, where the little ones hatch of."
- "The earthworm lays eggs probably."
- "The slugs are hermaphrodites as well; I think snails in general are hermaphrodites, isn't it so?"

2. *Not correct statement of reproduction*. Students said:
- "The slugs, have a sexual reproduction, I don't believe that it lays eggs.

3. *Correct statements of importance*. Students said:
- "The (ecological) importance of the woodlouse? I would think it plays an important role within the decomposition of remnant plants and it is as well a destruent, as the earthworm."
- "The earthworm eats components of soil and digests these components so to say, and it excretes them again and due to that it creates humus. So it produces fertile soil and it contributes to the loosening up of the soil, too."

4. Not correct statement of importance. Students said:
- "The slug, I don't know what it does for the soil, it crawls there and it has its habitat there and about any importance I'm not sure, maybe in means of transport. Something sticks to its slimy skin and this will be laid at another place."

5. *Correct statements of knowledge about species biology*. Students said:
- "The woodlouse belongs to the animals, and then I would say to the annelid, to the arthropods and especially to the animals of crustaceans."
- "The earthworm belongs to the annelids."
- "The centipede belongs to the group of annelids, to the group of arthropods and to the myriapods."

The pupils formulated the statements of the knowledge about species biology with the help of a genealogical tree (application).

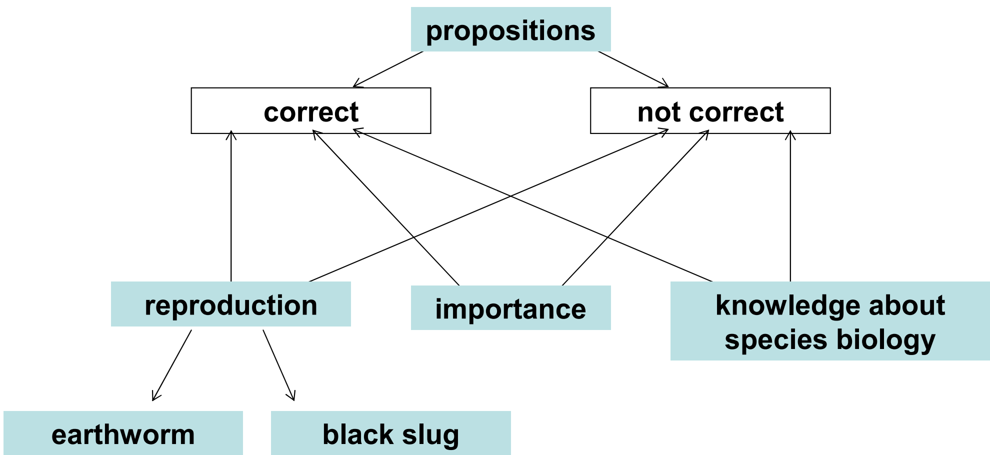


Figure 6. Simplification of original network "propositions"

Another network (see Figure 7) analyses *all* answers by *one* student referring to the woodlouse. Figure 7 represents the simplification of the original network.

First, the pupil explained her aesthetic assessment about the dorsal segments of the carapace of the woodlouse and the whole animal. The arguments for the *magnified perspective* relate to the form and show why the aesthetic assessment of the magnified perspective was more positive than that of the normal perspective.

Second, the pupil explained why looking at the whole woodlouse did not put her off. The argument from the *normal perspective* relates to the content – it is an image and to the form (little legs). The argument shows how important it is to have positive experiences with animals to be able to assess them positively.

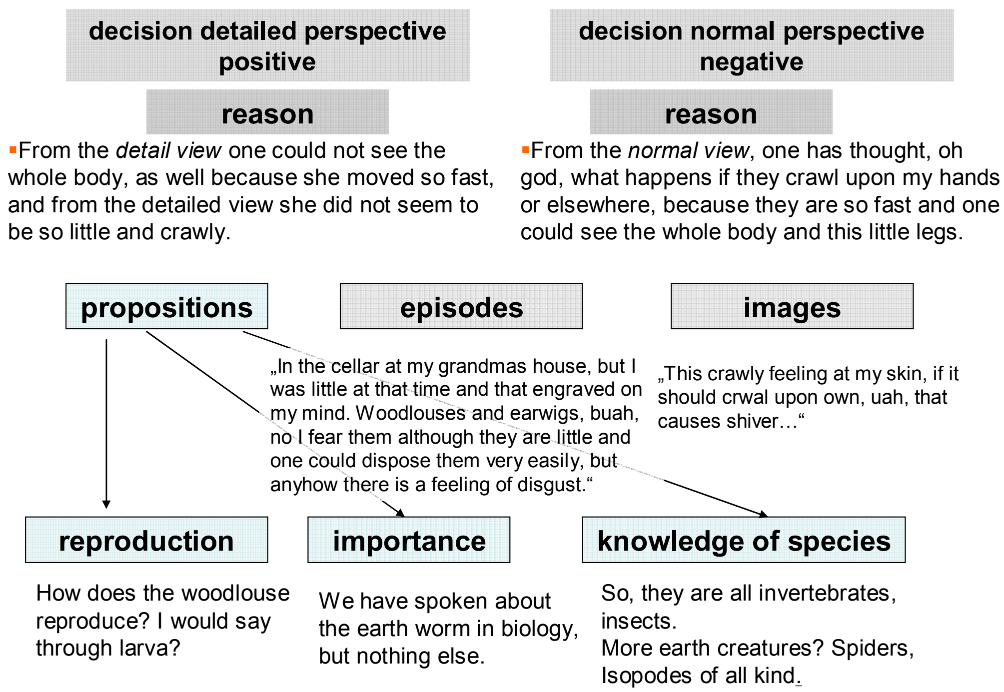


Figure 7. Simplification of original network "woodlouse"

The following answers were declared as propositions. Referring to the reproduction she didn't know a correct answer. She didn't know anything referring to the significance and just a little referring to the knowledge about species biology. The episode represents statements, the student made about her experiences. Her images were documented as well.

In Figure 8, there are further aesthetic assessments and arguments given, arranged according to the "Model of form and content" (Retzlaff-Fuerst, 2001).

| Aesthetic Argumentation: Form | Aesthetic Assessment | | | |
|---|---|---|---|---|
| | Magnified Perspective | | Normal Perspective | |
| | positive | negative | positive | negative |
| | „[…] didn't appear so small and crawly […]“ | | | „[…] and as it started to crawl and try to escape […]“ |
| | „[…] black underground and twinkling effects […]“ | | | „[…] big and slimy […]“ |
| | „[…]have I really seen only the structure of the body […]“ | „[…] it is simply a black animal […]“ | „ […] doesn't have so many crawl legs and antennae […] “ | „[…] and when you see its legs moving and it is crawling away […]“ |
| | „[…]only the structure of the body was to be seen […]“ | | | |
| **Aesthetic Argumentation: Content** | **Aesthetic Assessment** | | | |
| | Magnified Perspective | | Normal Perspective | |
| | positive | negative | positive | negative |
| Propositions | „[…] if we didn't know that it is a naked snake, we couldn't say, what it is […]“ | | „ […] because I have a garden where many of them live […] “ | |
| Images | „[…] almost like a discoball […]“ | | „[…] looked like a meatball: I like eating and so I felt hungry […]“ | „[…] one thought, oh god, what happens if they crawl upon my hands or elsewhere […]“ |
| Episodes | | | | „[…] it looked robust and then the antennae and legs… all in all it looks a bit like a spider or alien […]“ |
| | | | „[…] I used to take it in my hands and play with it […]“ | „[…] crawling and they are so small and remind me of our camping when they crawled under my night skirt and this are bad memories which left their marks on me […]“ |

Figure 8. Aesthetic assessment and aesthetic argumentation

### 4.3- First summary of interviews

The interviews revealed clearly why pupils do not like creepy crawlies. Some of the aspects are related to their form others to their content.

Formal-aesthetic aspects:
- Many legs,
- Fast movements,
- Chitin corpus and
- Grey and black colour.

Content-aesthetic aspects:
- Associations with the animals with mud, slime and "alien",
- Bad experiences and
- Inadequate knowledge on the ecological significance.

Another observed fact is that students who have a wider knowledge have lesser prejudices. They differenced much more their aesthetic assessment and show more interests in the features of the animals. But one cans not due a line between correct knowledge and positive attitude towards the animals.

## 5. Teaching Implications

From the research results one could draw the following implications for teaching biology:

- Select species carefully:
  - Pupils don't like incomplete animals or animals with missing extremities
  - Select well-coloured species (red ladybird, striped potato beetle, green grasshopper).
- Present animals in magnified perspective and discuss:
  - The details which become obvious only in the magnified and not in the normal perspective, as well as
  - Pupils' individual experiences with the selected species.

Positive and negative experiences are important for the decision to actively help protecting the environment. Negative experiences with "creepy crawlies" should not be avoided. Rather it is important to accept the existence of those negative experiences and use biology lessons to put them into proportion. One option would be to observe the animals in different perspectives as has been demonstrated in the present paper.

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# THE IMPACT OF A DEBATE ON GENETIC ENGINEERING APPLICATIONS IN MEDICINE ON THE OPINIONS OF TUNISIAN STUDENTS MAJORING IN EXPERIMENTAL SCIENCES IN THEIR FINAL YEAR OF HIGH SCHOOL

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**Abstract**
The research reported in this article draws on the field of Science-Technology-Society. We adopted a socio-constructivist framework of cognition, this theory focused on the exchanges between peers to get better performances, to improve the learning knowledge and the pupils' argumentation. It is a qualitative study where the main objective is to evaluate how a debate, on medical applications of genetic engineering, influences the opinions and debating skills of Tunisian students majoring in experimental science, in their final year of high school. We examined the students' discussions to elicit their opinions towards genetic engineering applications and the ideas, knowledge, and arguments supporting their decision-making.

## 1. Introduction

Genetic engineering is a "*frontier science*" *which* has evolved very quickly over the last few years. It opens new perspectives in various fields such as the environment, agriculture and public health and covers a wide range of applications, some of which are controversial. Genetic engineering has various repercussions, positive or negative, predictable or unpredictable, controllable or uncontrollable (Simonneaux, 1999). These are given a great deal of media coverage and thus add to social anxiety. They are part of the controversial issues referred to by Legardez (2001) since they raise questions for research, society and teaching. The "*stakeholders in the teaching situation, students and teachers, cannot escape them as they are a "burning" issue in their social and media environment*" (Legardez & Alpe, 2001). This places genetic engineering at the crossroads of science - technology - society and means that all citizens must come to terms with it in their lives. This means that new teaching strategies are required to improve knowledge and prepare students to be mature citizens, capable of developing arguments and making informed decisions.

This paper reports on the use of a didactical strategy to generate debate about two specific applications of genetic engineering amongst Tunisian high school students. Our research questions were the following: "Do the opinions of the Tunisian students depend on a specific situation, in other words, on the genetic engineering application in question?"; "In which way do the opinions of these students change following a debate on genetic engineering in medical applications?"; "How does the notion of risk influence their opinions?".

The importance of exchanges and discussions amongst students to help them develop knowledge is not a new idea. It appeared in the cognitive and socio-cognitive theories. Indeed, the successors of Piaget, called collectively "The School of Geneva or The New Piagetians", developed a model of constructivist and interactionnist learning based on the concept of socio-cognitive conflict, which integrates strongly the social component. This socio-cognitive conflict would establish according to Schubauer (1983): "*A sort of imbalance momentary and structuring at the individual's.*" In the same prospect, Doise and Mugny (1981) underline that "*students who interact socially achieve higher performances*". There are several conditions for this. First, in debate, there is no "*right answer*", which means that the various points of view and therefore all participants have an equal status. Then, the situation leads the discussion away from each of the participant's representations: during discussion, each student's conception may be brought into question. Finally, the debate has a socio-emotional dimension which favours the development of knowledge.

Classroom debate has also been shown to improve conceptual understanding, to favour the understanding of the epistemology of science, to develop the competence of investigation and to improve decision-making on socio-scientific issues (Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Jiménez- Aleixandre et al., 2001; Simonneaux, 2000, 2001, 2003).

## 2. Methodology

### 2.1- The debate

The debate was a contextualised didactical strategy intended to support the development of the students' knowledge and opinions and improve the quality of their arguments. The students were presented with a scientific dilemma and expected to make a decision and give arguments justifying their positions. The argument, in this context, was a means of sharing each others opinion or point of view. It means *to propose an opinion to others by giving good reasons for adhering to it.*

When choosing the debating topics, we based our decision on the four dimensions defined by Dolz & Schneuwly (1998): the psychological, cognitive, social and didactical dimensions. While restricting ourselves to the Tunisian context, we decided to lead the debate using two medical applications, which are dealt with in the teaching manual - antenatal diagnosis and production of insulin. This enabled us to develop a tool, which could be used in the Tunisian classroom to see whether students expressed different opinions according to the applications. Our goal was to see if the students would reach the same opinion for both applications or rather different opinions. What would be the knowledge and the arguments they used to support their decision-making?

Scenarios relating to each of the two contexts were developed and presented to the students within a single debate about genetic engineering. The first sequence began with a presentation of the illness of diabetes, which is very common in Tunisia. The students were called to debate on the origins of this illness and its symptoms, on the methods of treatment and the possible repercussions of using insulin synthesized from the pork pancreas on the human body. The facilitator raised then the possibility of treating diabetics with the insulin produced by genetic engineering. Students were called upon to present their opinions, to explain their point of view and to offer arguments.

In the second sequence, the participants were asked to read one document on the subject of cystic fibrosis. This document was followed by a short paragraph introducing the case of a couple which were exposed to the cystic fibrosis illness and debates on the antenatal diagnosis, on the advantages and the risks of this intervention for the mother and the fetus.

After reading the document, the students were asked to debate the illness, its origins, its methods of treatment and they were asked to give their opinions and to advance arguments to help this couple to make an informed decision.
At the end of each sequence of debate, we asked the students to voice their opinion for or against the application, which we just discussed. The focus of this vote was to relieve the students' opinions and to identify what was the impact of the debate on their opinions and in what way they changed.

Due to the fact that the students were in their final year, co-operation was difficult on behalf of the teachers as well as the students. We were satisfied with this qualitative study that such a small group of students (nine) were co-operative and willing to take part in the debate. They were between 18 and 19 years old, as well as all of them having an average grade in science and they all belonged to the same social class.

The facilitator was the researcher. The debate took place in the classroom but out of school time. It lasted 1hour and 45 minutes; it was video- recorded and then transcribed.

### 2.2- Analysis

Data collected from the debate have been analysed according to a qualitative procedure (macro- and microanalysis).

The macro analysis of the debate consists of an analysis of the opinions of the students, during and at the end of the debate (at the time of the vote) to show if/how their opinions changed through the process of debate. To record the opinions advanced by the pupils during the debate, we codified their arguments in arguments for or against each of the applications of genetic engineering.

We consider that decision-making is not only a product but also a whole process, which it is advisable to analyse. This would allow us to see how the students establish their points of view towards the proposed subjects. What are the statements, which they made before proposing their points of view? What are their arguments and which are the mobilized knowledge? We also wanted to verify if the concept of risk is central in the decision-making of the students and if it could influence the opinions of the students in one way or another.

In the microanalysis, we used a detailed assessment of some argumentative sequences to identify some models of decision-making, notably those which seemed the most relevant to us. We were inspired by the work of Kolstoe (2001) who successfully identified several models of decision-making from conversations with the teenagers about the subterranean installation of high tension electric lines to avoid the risks of leukaemia affecting children living close by.

We took into account all the types of information supplied by the students, which are scientific or of other knowledge. We identified three models of decision-making, characterised according to the importance which students agreed upon as to the notion of risk:

- The uncertain model
- The model of minimized risk
- The model of maximized risk

These models have the following essential characteristics:

A. The students belonging to the uncertain model are those that did not make any decision. Till the end of the debate these pupils were unable to decide. The uncertainty and the risk seem to be an insurmountable obstacle for them. Knowledge of the risk as well as its importance is necessary before making a decision.

B. In the second model, the risk exists but it is negligible compared to the advantages of the applications of the genetic engineering. For this group the notion of risk is not a decisive criterion. In spite of the risk, they opt for the applications suggested. It is the model of minimized risk.

C. The last model gathers the pupils for whom the notion of risk is the determining factor in decision-making. For these pupils as long as the risk exists, they are against this application, their opinion is negative. It is the model of maximized risk.

## 3. Findings

### 3.1- Analysis of the opinions

The macro analysis of the opinions of the students towards both applications of the genetic engineering is summarised in Table 1.

Table 1. Variation of the students' opinions according to the applications treated during the debate

| *Pupils* | *Opinions* | |
|---|---|---|
| | *Production of insulin* | *Antenatal diagnosis* |
| *E1* | *Yes* | *No* |
| *E2* | *Yes* | *Rather not* |
| *E3* | *Doesn't know* | *Yes* |
| *E4* | *Yes* | *Yes* |
| *E5* | *Yes* | *Doesn't present an opinion clarifies* |
| *E6* | *Yes* | *No* |
| *E7* | *No* | *Yes* |
| *E8* | *No* | *Yes* |
| *E9* | *No* | *Yes* |

We observed that most of the students were in favour of genetic engineering applications and especially at the beginning of the debate. Their arguments revealed that they found it fantastic, incredible and fascinating: "*genetic engineering is always incredible,* E7; *I have complete faith in genetic engineering",* E2. However, we observed that they did not always have the same opinions concerning the two genetic engineering applications.

Concerning the production of insulin by genetic engineering, which was discussed during the first part of the debate, five students were in favour of this application on medical grounds: *"Its structure is identical to that produced by people; this means there is no risk of rejection",* E4; *"its structure is similar to human insulin*", E7. Student E6 gave a more scientific argument by raising the question of immunology: *"Insulin produced by genetic engineering is more efficient… in that there is more compatibility between the donor and the receiver*". Surprisingly, this student changed his opinion during the debate in agreeing with another participant who raised the risks, which might be incurred with this insulin: "*You're right; the other insulin (…) is artificial.*" This might be explained by the fact that the student was neither convinced nor sure of his opinion and as soon as he heard an opposing argument, he changed his opinion and gave contradictory arguments. Others expressed ideas which related more to the advantages of this production technique: "*It would enable us to get more insulin quicker*", E4; "*We'll be able to cure diabetics"*, E1.

Some students were not in favour of producing insulin by genetic engineering even though this application is less controversial. Their arguments concern the artificial nature of insulin produced by genetic engineering: "*In my opinion, natural insulin is better*", E8; "*the other insulin, in other words, the one produced by genetic engineering is artificial*", or again the fear of possible risk: "*I have no idea of what genetic engineering may lead to, the risks are unknown and we do not yet know the consequences… I would not take such a risk",* E8.

Other students remained unsure until the end of the debate. They were neither in favour of nor against the production of insulin by genetic engineering. Their arguments were of the type: "*I would ask my chemist for advice*", E2; "*I don't know, I have nothing to say*", E1; "*I have no answers… both types of insulin involve risks. We might ask the opinion of a doctor who would advise us on the most efficient one*", E3. We may note in the light of these arguments, that for these students, the fact that they did not know anything about the consequences of these applications, is a sufficient reason for refusing them. However, we note that the students E1 and E2, even though they expressed doubts, finally came out in favour of the application at the end of the debate. Student E3 is the only one who was not able to make up his mind.

During the second part of the debate, we dealt with the issue of prenatal diagnosis. Students were asked to give their opinion on prenatal diagnosis and then on whether the fetus should be allowed to survive if an illness was detected or whether the mother should abort. Students had different opinions on both diagnosis and abortion.

With respect to the prenatal diagnosis, three students had a negative opinion on this application. They justified their opinions by referring to the risks that this technique might involve and to the reliability of the result: "*It's possible that the doctor might say that the child is sick and that after the birth, we realise that she is in fact healthy*", E5; "*The result is not reliable and furthermore it's painful for the woman*", E1. *Whether the risk is great or not, there is always a risk",* E1; "*And if the child is healthy and the mother has a miscarriage following diagnosis, this is another problem…. not only will the mother be exposed to physical pain but also moral stress and she might loose her child"*, E3. "As for student E2, he laid down certain conditions for accepting to change his mind: *"It depends on the seriousness of the illness. We have to be sure of the percentage of miscarriages*".

Students E3, E4 and E7 had very strong opinions on prenatal diagnosis. They advise parents to accept the diagnosis and to choose abortion if an illness were detected. Their arguments were: "*If the parents have the diagnosis done, this means that they are not only thinking of their child, but also of their children",* E3; "*Have the diagnosis done and if the child is ill, then it's better to abort in order to avoid its suffering",* E4; "*The diagnosis is important because it enables a couple to know the state of health of their child (…). It's better to have an abortion than to keep a child which is threatened by illness",* E7.

For student E8, the two decisions are not obvious. He was in favour of prenatal diagnosis but against abortion, no matter what the state of health of the embryo. His argument was that "*we should start treating pulmonary symptoms by genetic therapy in the meantime. Perhaps one day, we will be able to cure completely this illness".* The same student changed his opinion during the debate. As far as he was concerned, if the mother has no intention of aborting if an embryo is ill, then there is no point in having the diagnosis made.

Student E5 could not make up his mind on prenatal diagnosis, but claimed that he was against abortion. Student E1, even though he was against the diagnosis, was in favour of abortion in certain cases in which illness was detected and if such illness was fatal.

### 3.2- Changes in opinion

More detailed analysis enabled us to evaluate students' opinions after the debate and to compare them with those offered during the debate (Figure 1, Figure 2).

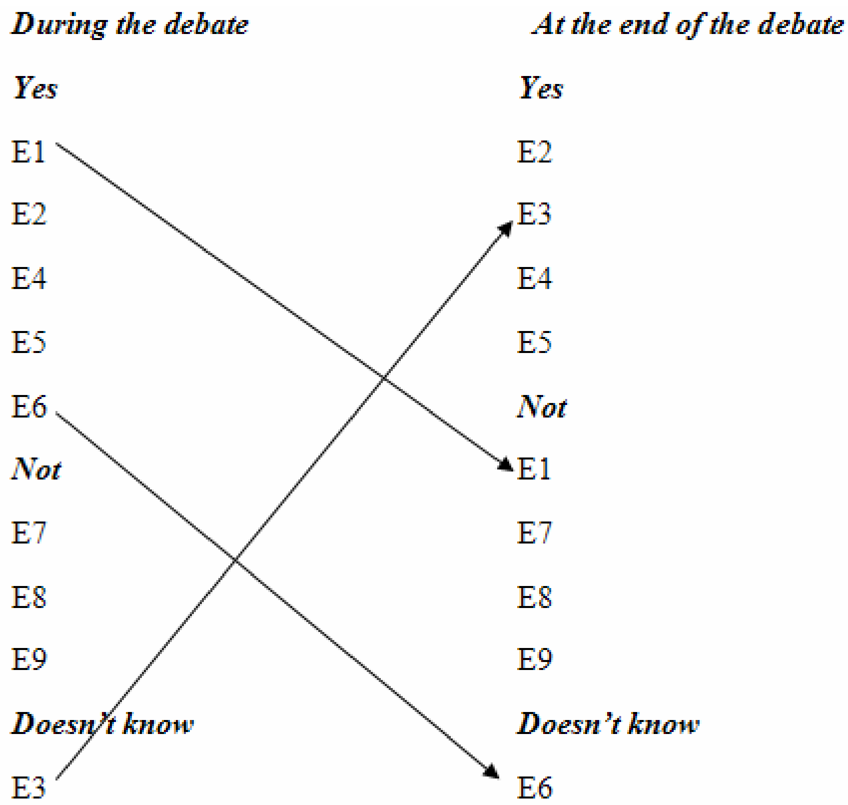


Figure 1. Positions of the students to the production of insulin

Concerning the production of insulin, most students maintained their initial opinions. Moreover, we observed that during the debate, most students were in favour of this application. Strangely enough, following the debate, we noticed that some students given up their positions: E1 was moving towards a negative position concerning the production of insulin by genetic engineering. His argument was based on the risk that this hormone might cause: "*I would accept insulin synthesised from a pig's pancreas because there is no risk involved".* On the other hand, student E6, who was in favour of this application during the debate, hesitated clearly afterwards. His arguments were that: *"The two insulin have the same effects and we don't know their disadvantages."* Student E3's opinion changed from a position of uncertainty and hesitation during the debate towards a stronger position in favour of the production of insulin by genetic engineering. His argument was based on scientific knowledge: "*It is closer to that of man and there is less risk involved".*

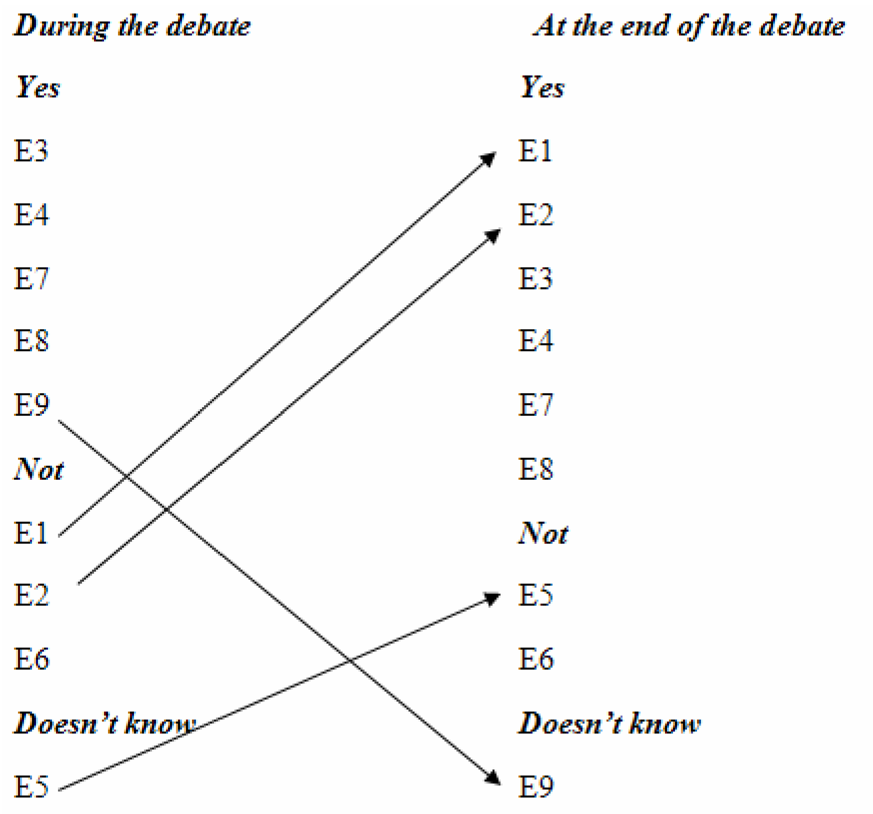


Figure 2. Positions of students to the antenatal diagnosis

Concerning the prenatal diagnosis, we observed that students were mostly in favour of this application following the debate. The opinions of students E1 and E2 changed from a negative position during the debate towards a position in favour of the application after the debate. Student E5, who hesitated throughout the debate, finally made a decision by expressing a negative opinion concerning prenatal diagnosis. His argument was based on the risk that this technique might involve and the fact that he would not accept the idea of aborting the fetus in the event of an illness being detected. On the contrary, student E9, who had a positive opinion towards the diagnosis during the debate, clearly hesitated after the debate. Finally, we can say that the change of opinion favours the antenatal diagnosis (Figure 2) that is supported by the nature of this application.

### 3.3- Decision-making models

The models identified accurately demonstrate that the concept of risk is central in the students' decision-making and according to their perception, the enormity of the risk. They decided for or against the application of genetic engineering despite the advantages it could have. We are now going to present, in more detail, the various students' perception of risk, their arguments and their interrelation.

### 3.3.1- The uncertain model

To illustrate the uncertain model, we chose the case of Dhafer (E3) about the production of the insulin by genetic engineering.

For E3, the fact that the risks are not yet known is an important thing:

***E2:*** *According to me, since it is produced by genetic engineering I give confidence to the genius.*

***E3:*** *Me, I don't know, I don't have an answer.*

We perceived in this answer a total distance of the speaker. It shows that this student is not convinced at all by what is presented by his peers and he is unable, on this level, to make a decision.

***Professor:*** *You had said to me, a few moments ago, that your mom is diabetic; which insulin do you advise her?*

***E3:*** *Yes. But both are risky, traditional insulin as well as the insulin produced by genetic engineering.*

The fact that E3 quoted both types of insulin shows that he is hesitant and that he does not manage to make a decision. He thinks that on the one hand the insulin extracted from the pancreas of an ox presents a risk because of the immunological problems, which it can provoke. On the other hand, he it is still unaware of the risks that the insulin produced by genetic engineering can generate. This is the source of the doubt and the difficulty in choosing one or the other: ***E3***: *We can ask all the same for the opinion of the doctor on that which is most effective one.*

According to the comments of E3, the efficiency is related to that which presents less risk. It seems difficult for him to make a personal and autonomous decision. He leaves the choice to the doctor. At the time of the vote and after some hesitation, he proposed an intermediate decision as a refuge: ***E3:*** *I can tell her to begin by taking the insulin extracted from the ox and if she would have problems, she will change insulin.*

We notice that at the end of the debate, this student still doesn't succeed in making a firm decision in favour or against the insulin produced by genetic engineering. The decision, which he took, is temporary. It was just for taking a position in the debate.

Let us indicate finally that all the arguments proposed by this category of students are personal views based on common sense or which are even in certain cases unjustified. The fact that the risks are, neither defined nor exactly considered leaves them indecisive and unable to decide. The knowledge of the risks relative to the production of the insulin by genetic engineering turns out indispensable, for the students, before making any decision.

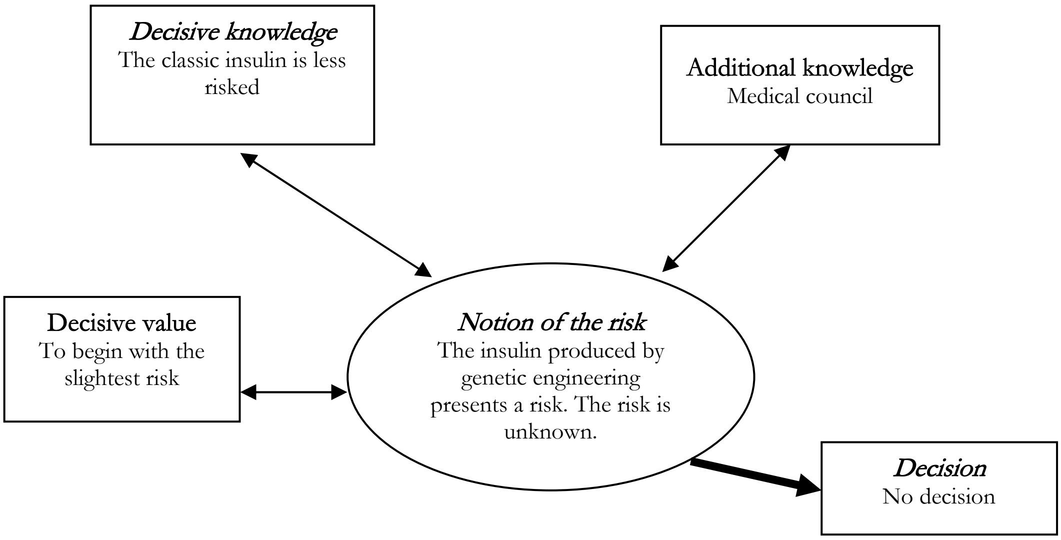


Figure 3. The uncertain model (Inspired by Kolstoe, 2001)

### 3.3.2- The model of minimized risk

We chose to take the case of Malek (E4) about the antenatal diagnosis to illustrate the model of the minimized risk. This pupil evokes the concept of risk in her comments but that does not prevent her from being in favour of this application. The risk exists but it is not decisive. Before making her decision, E4 wanted first of all to know the lifespan of the patient. She hustles another student who has already advanced an opinion against the diagnosis.

***E4:*** *Wait! You burn the stages. It is necessary to know at first if the sick child will live a long time or not?*

For E4, the knowledge of the lifespan of the child reaches cystic fibrosis is necessary to make a decision.

*E4: I advise the parents to go to see several gynaecologists and to make all the types of diagnoses as that they will be sure reliability of the result. Even if reliability is not to 100%, the result is closer to reality.*

We see here an exaggerated position. E4 advises the parents to go to see several gynaecologists to be surest possible result. She declares that she is for abortion in case of the disease of the fetus.

***E4:*** *It is necessary to make the diagnosis and if the child is sick, to have a miscarriage and not make it suffer.*

Then, she takes back her arguments to evoke the limits of this technique, to know the unreliability of the result and its consequences. She also quotes the moral suffering of the mother in order to make her decision.

***E4:*** *The first thing for which it is necessary to think about is that the mother will have a guilty feeling towards the child. She's going to suffer morally or if she will have the child, he will suffer during his whole life; or because it fell through if she knows thereafter that her baby was healthy.*

***E4:*** *Let us suppose that the mom had an abortion following the diagnosis, which shows that the child is sick whereas it is actually not it. How can you know? More so, one will be in a similar situation for any further pregnancies.*

This is an argument on the limits of science. E4 notices that the same difficulty will arise for the parents with each pregnancy. She proposes a solution: ***E4:*** *In this case, and if the problem will be repeated each time, the best solution would be adoption.*

For the students belonging to this model the concept of risk does not seem to be problematic. They recognize that the risk exists, it is a fact that they manage to define; but that by no means prevents them from choosing the applications of the genetic engineering. They believe in the progress of science despite some of the limits.

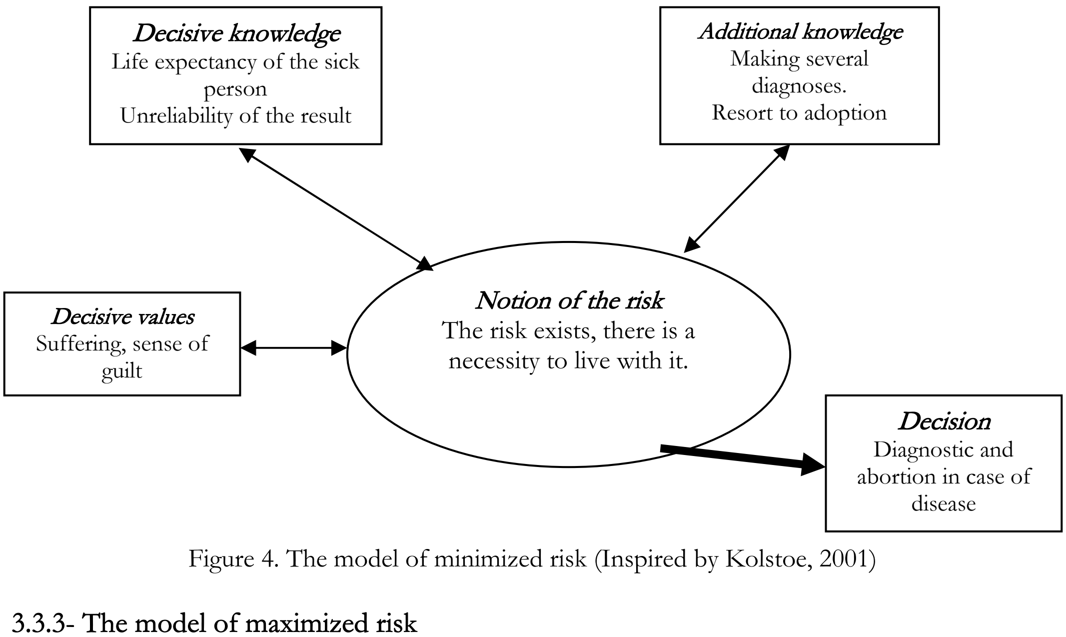


Figure 4. The model of minimized risk (Inspired by Kolstoe, 2001)

### 3.3.3- The model of maximized risk

To illustrate the model at maximized risk we chose to present the case of Ahmed (E1). This student positions against the antenatal diagnosis. He advances his decision from the beginning of the debate:

***E1*** *I am not for. The result is not reliable and then, it is painful. The poor woman is going to suffer.*

E1 justifies his opinion by evoking the limits of the technique of the diagnosis: the reliability of the result and the pain to which the woman will be exposed. We also appreciate the presence of his emotions.

***E1:*** *Significant or not, there is always a risk and then it costs much more.*

The second argument which he considers, on the one hand, the diagnosis' risk i.e. the risk of miscarriage and, on the other hand, the cost of this intervention, which leads him to take this decision in spite of the advantages which the diagnosis could have about which his peers, spoke. However, in the event of disease of the fetus, E1 is for the abortion.

*E1: If he will die one day, it is better* ***to kill him*** *now that he* ***is not yet conscious.***

E1 thinks that aborting the fetus is better than to let him die by the disease. However, we see according to this argument that there is always the presence of emotion in the comments of this student. The choice of the terms employed shows it very well; E1 uses the verb *to kill* instead of saying to abort. Abortion is, for this student a crime. He also says: *he is not yet conscious* to show at which point it is difficult to lose a child or of living threatened of death.

Thereafter, E1 pressures one of his peers, which is for the diagnosis but not for the abortion.

*E1: If you don't intend to abort, why make the diagnosis? How will it help?*
From there, one can deduce that for E1 the fact of agreeing to make the diagnosis led inevitably to the acceptance to abort if the fetus is sick. In the students' comments, we also find recommendations such as:

*E1: Moreover, I think that the couple must take its precautions in advance*
*E1: ... The couple should not marry any more for love but according to its genetic chart*
For E1, if the couple had taken its precautions in advance, it would not be in a similar situation.

To conclude, we can say that students belonging to the model of the maximized risk evoke scientific information in connection with the concept of risk to justify their standpoint. They insist on the unreliability of the result of the diagnosis and on the risk of miscarriage, which this technique could cause. Besides the scientific notions, personal, emotional appreciations and common sense are also at the base of the decision taken by this group of students.

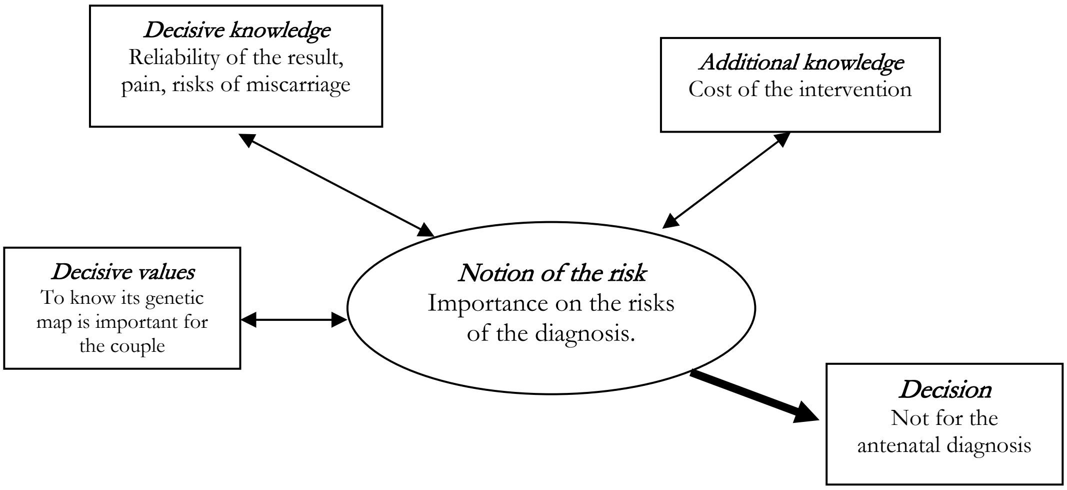


Figure 5. The model of the maximized risk (Inspired by Kolstoe, 2001)

## 4. Discussion

In the light of this analysis, we can say that following is a debate concerning the medical applications of the genetic engineering; and that these Tunisian students presented their opinions in favour of these applications. However, we perceive that they don't have the same opinions towards the two applications treated during the debate. Regarding the antenatal research on a hereditary illness, the students almost all gave evidence that this technique was indispensable. It appears that this problem worries them profoundly. We note that with regards to abortion, the students seemed slightly hostile to this solution. They seem to be influenced by the consequences conveyed by the Tunisian society, which is an Arab-Muslim one. This confirms the idea that the opinions differ according to the context and the applications considered.

Concerning the evolution of the opinions, different results were obtained according to the researches. Almost in all the researches, which appealed to the debate, the knowledge, the opinions and the argumentation don't evolve in the same way. We can quote Simonneaux (1995, 2000a, 2000b) who showed that the students of agricultural establishments could easily acquire new knowledge on the biotechnologies of the bovine reproduction, to change opinions. P. Abou Tayeh and Clément (1999) also showed that the opinions evolve more with difficulty than the knowledge. It is that in some studies only that there were evolutions in the opinions (Simonneaux, 2000, 2001). In this study, we observe that there is a resistance in the opinions of some students. That is explained by the fact that attitudes and opinions are connected on the social representations; they are indexed in the socio cultural repository of the students and are not modified easily. For that purpose, we think that this resistance is completely normal.

According to the models of decision-making identified, scientific knowledge seems to play a significant role in the decision-makings although they are not always at the base of those models. This consolidates the results of Kolstoe (2001).

Moreover, we note that in these models the concept of risk, characterizing the applications of the genetic engineering, is evident during the debate. The students' arguments are focused on the notion of risk. Their approach when making a decision or to express an opinion are connected with the uncertain risks regarding the applications of the genetic engineering. This is not surprising because this idea of the uncertainty is central in a controversial scientific knowledge or "*frontier science*" as we indicated above.

In order to assist the students in overcoming this obstacle and be able to make decisions with knowledge of all the facts, we think that scientific education should emphasize the concept of risk, in both scientific and social contexts. For instance, starting from concrete situations inspired by the reality, by the current life and by the every day life of the student. At this point we support the thesis of Kolstoe (2001), which considers that it is important to reward the students with attitudes towards the concept of risk, to promote in the student a thoughtful and cautious use of the risk.

We think that the learning of the argued decision-making also raises numerous questions, notably those connected to the contribution of the other disciplines as far as the learning of the argumentation is not only connected to the teaching of the sciences. This one can occur in the course of sciences as in the course of philosophy, of French, Arabic or still in society in the everyday life of the individual. This approach rises from the nature of the knowledge of genetic engineering, which covers a range of chapters to which it is strictly connected. For that purpose, we suppose that the participation of the students in health clubs as well as the realization of projects which allow to combine the knowledge acquisition on debates and discussions between peers, would favour a restricted space where the confrontation of opposing arguments and the contribution of proofs allow the students to confide, to question its ideas, to exchange them and to enrich them and promote an autonomous and justified making-decision.

This engineering raises debates and uncertainties because the individual is today confronted with the social involvements of this technique. That is why; the social representations of the students about this knowledge are marked by the values associated to it (Simonneaux, 2000). Our results support this idea. Concerning the antenatal research on a hereditary illness, the students almost all gave evidence that this technique was indispensable. It appears that this problem worries them profoundly. We note that with regards to abortion, the students were slightly hostile to this solution. It suggests that they are influenced by the consequent system conveyed by the Tunisian society, which is an Arab-Muslim one. We think that semi-directed interviews with the students could enlighten their decision-making.

## 5. Conclusion

In the light of this analysis, we can conclude that the implementation of a debate on genetic engineering as a socio-scientific issue can lead the students to establish an opinion and justify their own point of view. It permits an evolution in the opinions of the students (not necessarily of the refusal to adhesion) and allows as deducing that the students' opinions differ according to the context and applications.

Our analysis of the models of decision-making permits us to postulate that the concept of risk is fundamental in this process. It influences the opinions and the attitudes of the students.

We believe that the science classroom is the most appropriate place to think about socioscientific issues. By placing at the disposal of the students, suitable information and by having them take part in activities enabling them to express opinions and discuss, it would be possible to encourage young people at the end of their high school, the capacity to deal with scientific questions of a broad social interest.

However, we consider that the teacher is a strong link in the process of teaching/ learning. He establishes the interrelation between the programs and the students. Consequently, we think that the teachers' opinions and their representations about sciences could influence, consciously or not, their teaching. The opinions and the conceptions, which they convey could guide their choices concerning the examples considered relevant to teach, the arguments presented to motivate students and the strategies of their teaching. That would influence the internal didactical transposition of the knowledge. In fact, we suggest completing this research by studying the impact of the conceptions and the value system of the teachers towards the genetic engineering on their teaching practices and on the opinions of their students.

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# SECTION 6

# ENVIRONMENTAL AND HEALTH EDUCATION

# EVALUATION OF EXTRA-CURRICULAR SUSTAINABLE DEVELOPMENT EDUCATION IN SCHLESWIG-HOLSTEIN, GERMANY

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## Abstract

The paper reports on a study investigating extra-curricular sustainable development education (SDE) in Schleswig-Holstein, Germany. Firstly, a questionnaire study was conducted with SDE-institutions (n = 71). Secondly, we carried out semi-structured interviews with key multipliers of twenty organizations. We applied the grounded theory to investigate the multipliers´ concepts on sustainable development (SD) and SDE. The educational programmes were analysed by employing core competence areas of scientific literacy (SL). The frame for analyses is a synthesis of SL with central features of SD: basic need orientation, justice, retinity, and understanding of SD as a regulative idea of the discourse on environment and development. The multipliers classified the SD concept as too abstract and too theoretic. 50% of the interviewees did not recognize that SD confronts us with new challenges. Particularly, multipliers with forestry, biology and religious backgrounds equated SD with their traditional concepts. An understanding of SD as a regulative idea was very rare. The multipliers had not identified the development of ethical competences as one crucial SDE-aspect. Implicit ethical components of the own interventions are often not recognized. Deficits regarding the reception of pedagogically valid concepts of SD, and the promotion of ethical competences have been detected.

## 1. Introduction

For several years, environmental education (EE) has been facing the challenge to move towards a "sustainable development education" (SDE). In the article the term SDE is used synonymous with "education for sustainable development" (ESD, EfSD, EfS), a term also used in official documents (e.g. UNESCO 2003a, b).

We investigated important representatives from institutions promoting extra-curricular SDE (key multipliers) – among these, institutions of environmental education and global learning (GL) – in Schleswig-Holstein (Germany) from April 2001 to February 2002. The study aimed at describing extra-curricular sustainable development educationE, analysing the deficits and making recommen-dations for SDE. The investigation was funded by the ministry of environment, nature and forestry (MUNF) of Schleswig-Holstein and was carried out from the IPN Kiel in cooperation with Göttingen University.

Quantitative and qualitative data were collected to analyse the key multipliers´ subjective concepts on sustainable development (SD) and on sustainable development education. Furthermore target group-analyses, analyses of the educational programmes and the used methods as well as organizational analyses were carried out. The educational programmes were investigated using core competence areas of scientific literacy (SL), e.g. subject competence, ethical competence and action-oriented competence (Gräber et al., 2001; Gräber et al., 2002). In this paper the term ethical competence (SL-concept following Gräber et al. (2001)) is used synonymous with normative competence (Figure 1).

The paper presents crucial aspects of the evaluation study. It focuses on multipliers´ concepts of sustainable development and SDE as well as on their valuation of ethical competences in their educational programmes. For further results of the evaluation, e.g. action-oriented competence, please read the final report (Bögeholz et al., 2002a). The paper gives insight into implementation barriers of SDE and allows drawing consequences for improvement.

## 2. Research and theoretical background

For several years, attitude research has dealt with sustainable development. Jüdes (1997) reports over 70 definitions of "sustainability" and "sustainable development" in Germany. A nationwide representative survey shows that only 13% of German citizens know the concept of sustainable development in 2000; in 2002, 28% of German citizens report knowing the term sustainable development (BMU 2002). These data about knowing sustainable development do not inform about an adequate understanding. Scott & Gough (2003) underline the importance of linking learning and sustainable development.

In Germany, sustainable development was identified as a core educational task in 1998 (BLK 1998). Summers et al. (2003) investigate primary school teachers and judge all aspects related to sustainable development as difficult. Dubs (2002) states that citizens have to understand their own decisions from the normative perspective. Learners should be able (i) to analyse conflicts of aims and interests as well as contradictions, (ii) to judge solutions of problems as well as their consequences and (iii) to build up their own opinion towards problems and to know the normative implications (Dubs, 2002). These are all challenges for the UN-Decade of education for sustainable development (UNESCO 2003a, b).

Giesel et al. (2001) evaluated in a nationwide study the extra-curricular environmental education institutions in Germany. The study classified 11% of these institutions as SDE-institutions. About 5% of the environmental education multipliers wish to obtain a professional qualification in sustainable development education.

The conceptual framework for the analysis in this study is an interpretation of sustainable development literacy (Bögeholz & Barkmann, 2002; Bögeholz et al., 2002a, 2002b), which is based on a synthesis of scientific literacy (Gräber et al. 2001; Gräber et al. 2002) with central features and challenges of sustainable development: basic need orientation, inter- and intragenerational justice, retinity (equal consideration of ecological, social and economic aspects see WCED 1987; SRU 1994) as well as an understanding of sustainable development as a "regulative idea of the discourse on environment and

development" (Hirsch-Hadorn, 1999; Enquête-Kommission, 1998).
SDL consists of subject competences in the fields of ecology, economics and social knowledge. Furthermore, these areas have to be linked by interdisciplinary knowledge. In addition, subject competence about the concept of sustainable development is one core area. Action-oriented competences are essential in all three fields. SDL requires, in addition, normative competences, e.g. competence to reflect norms and values, the ability to define priorities between conflicting aims of sustainable development. Especially, assessment and judgement competences are needed to participate in designing and creating a sustainable future (Bögeholz et al., 2002a, b; Bögeholz & Barkmann, 2003, 2005; Barkmann & Bögeholz, 2003). In addition, the intersecting set areas are very important for the interdisciplinary and transdisciplinary challenge of SDE.

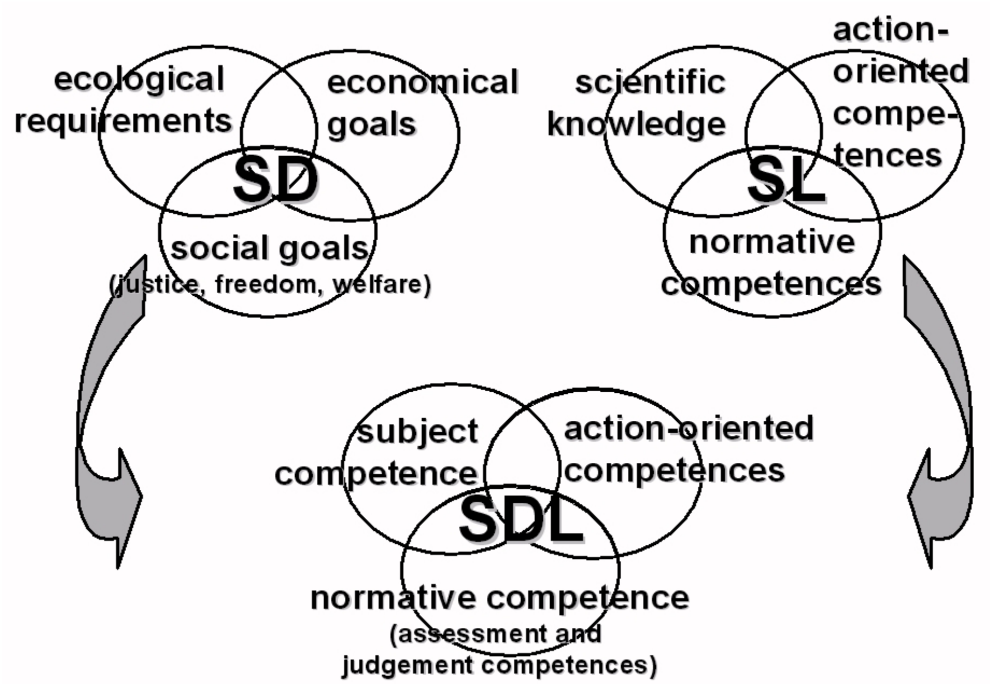


Figure 1. Conceptual framework for sustainable development literacy following the approach of Barkmann & Bögeholz 1999 (SD = sustainable development, SL = scientific literacy, SDL = sustainable development literacy)

## 3. Research design and methodology used

The investigation of extra-curricular educational institutions in Schleswig-Holstein consists of two empirical phases: (i) a quantitative phase with a twenty-page questionnaire and (ii) a qualitative phase with semi-structured interviews.

In the questionnaire, the key multipliers were asked about the main educational areas, which represent the educational profile of their institutions. They had the possibility to choose an answer between the following main areas: (i) environmental education, (ii) global learning, (iii) environmental education and global learning. Traditional environmental education focuses on the environment and aims at contributing to solve environmental problems. Global learning focuses primarily on social aspects and aims at contributing to solve developmental problems. Intragenerational justice is a core feature, which is related to economical and ecological aspects. Sustainable development education should contribute to a sustainable future, which implies to solve local and global environmental and developmental problems by taking into account the related ecological, social and economical aspects. Thus, sustainable development education has to combine the aims and challenges of environmental education and global learning.

The ministry and an advisory board selected 117 out of 331 extra-curricular educational organizations in Schleswig-Holstein for the quantitative study. Selection-criteria for the participating institutions were the geographical distribution in Schleswig-Holstein, heterogeneity of the target groups as well as the educational programme representing the existing variety (e.g. main areas: "environment" (50%), "environment and global learning" (25%), "global learning" (15%) and, in addition, "vocational education" (10%)). The questionnaire was sent to 117 institutions; 71 questionnaires came back in time. Descriptive data analyses were carried out with SPSS, Version 10.

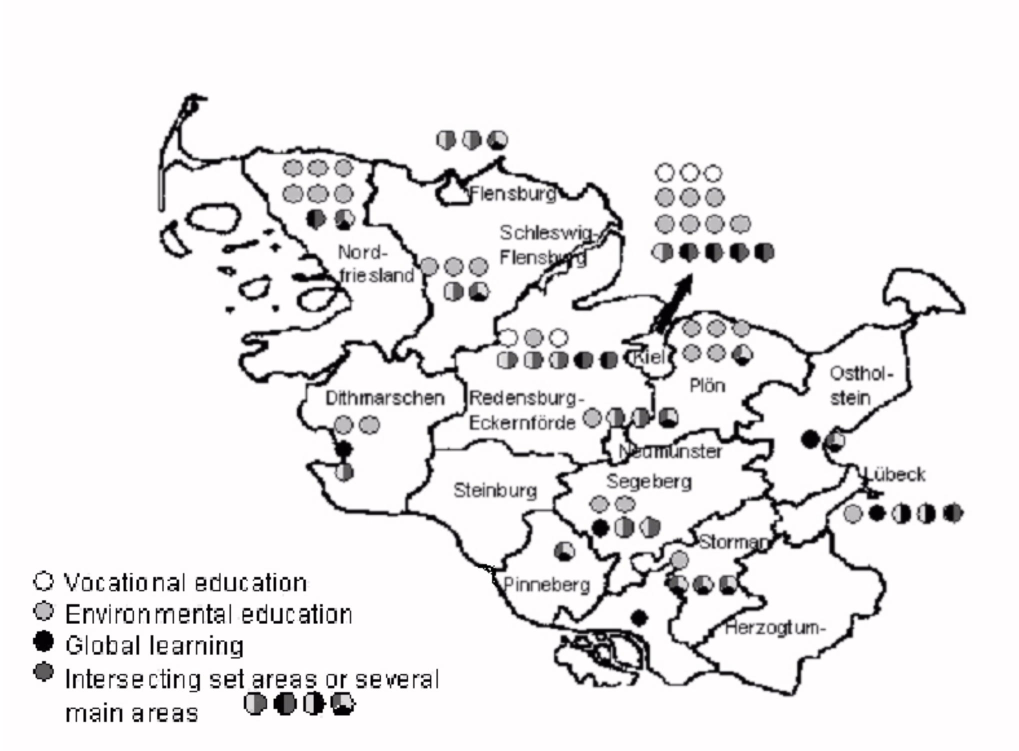


Figure 2. Geographical distribution of investigated institutions in Schleswig-Holstein

For a detailed investigation on the understanding of multipliers´ sustainable development concepts and SDE-concepts, interviews were carried out. The researchers and the advisory board selected 20 key organizations (out of 71). The selected 20 interview partners were highly motivated key multipliers. Selection criteria were very detailed and informative information given in the questionnaire and geographical distribution of the different institutions. Furthermore, the sample of the qualitative study was grouped following the composition of the quantitative study (10 EE multipliers = 50%, 5 multipliers in the fields of EE and GL = 25%, 3 GL multipliers = 15%, 2 "vocational education" multipliers = 10%).

The interviews were semi-structured and followed an interview manual (for selected questions see Table 1, for further questions see Eigner-Thiel & Bögeholz, 2004). The interviews were carried out mostly in the institutions themselves. Each interview took, on average, 90 minutes. This article reports only selected categories and sub-categories (Table 2 and Table 4), identified following the grounded theory (Strauss & Corbin, 1990). Anchor examples will illustrate the content of each category. The number of anchor examples might vary according to the number of namings in the interviews. The more namings there are, the higher the consideration of the diverse participating institutions (representing environmental education, global learning and both). The analyses were technically supported by WinMaxPro-software (Kuckartz, 1999).

Table 1. Selected questions from the interview manual

| | |
|---|---|
| 1. | What are bases of sustainable development? |
| 2. | What do you understand by sustainable development education? What is new and special for you about it? |
| 3. | What specific educational offers to the topic of sustainable development do you provide? |
| 4. | What would you regard as a suitable educational offer concerning sustainable development? |
| 5. | To what extent are there meetings in which the connections between ecology, economics and social aspects are brought up for discussion? |
| 6. | To what extent are there meetings in which contradictions in the goals between these areas are dealt with? |

Before application, both measuring instruments (questionnaire and interview manual) were discussed with the advisory board for validity purposes. Instead of aiming at statistical representativeness, we investigated organizations being maximum diverse and capable in sustainable development education.

## 4. Selected findings

Most of the extra-curricular multipliers (75%) classified "sustainable development" in the interviews as too abstract, too scientific and too theoretic (citations 1-3, Table 2). Similar responses were given according to sustainable development education. Definition attempts were spontaneously classified as "difficult" by 25% of the key multipliers (citations 4-5, Table 2). Regarding key multipliers from vocational education, the following quotation is representative: "Sustainable development education plays no part in our educational system" (Eigner-Thiel & Bögeholz, 2004). Partly, sustainable development education is considered even as a fashionable concept. One interviewee from vocational education mentioned that he works in education for 25 years. He says that names may change, but the contents do actually remain the same. Nearly 50% of the interviewees do not recognize that sustainable development confronts us with new challenges. They think that sustainable development contains nothing new, and believe that the main facets are already integrated in their educational practice. Christian representatives relate justice, retaining Creation and peace with the economical, ecological and social areas of sustainable development (citation 11, Table 2).

Representatives from forestry emphasized that sustainable development derives from their discipline and is applied there for 300 years. Interviewees think that they already incorporated the features of sustainable development education. Geologists and biologists working in environmental education partly believe that sustainable development contains nothing challenging, because they are used to a "systemic" and "holistic" approach (citation l2, Table 2). In sum, diverse disciplines equate sustainable development with their (traditional) concepts instead of facing the innovative challenges. An environmental education key multiplier even reports "[…] Terms such as SD or agenda do not mean anything to the people although they know the specific projects" (citation 5, Table 2).

Table 2. Categories and sub-categories concerning sustainable development and sustainable development education (including numbers of namings and anchor examples)

| ***category name*** | ***number of namings*** | ***anchor examples***<br>*1-5 namings: 1 example; 6-10 namings: 2 examples; >11 namings: 3 examples EE: Quotation from a key multiplier from the environmental area*<br>*GL: Quotation from a key multiplier from the area of global learning ("development")*<br>*EE+GL: Quotation from a key multiplier from the intersecting set area* |
|---|---|---|
| **conceptions about sustainable development (SD)** | | |
| term SD too difficult, too abstract for participants | 15 | 1.) "You should consider the perspectives of the people and where they come from. If you overload them theoretically too much, that's no use." (GL)<br>2.) "The term is not particularly handy, too academic, it does not go into the heads of the people." (EE+GL)<br>3.) "You have to deal with an arbitrariness of adjectives or nouns which are not specific. That leads to a rather ironical handling of the terms." (EE) |
| **definition attempts: SD and sustainable development education (SDE)** | | |
| definition difficult | 6 | 4.) "Very difficult to define, also SDE with contents of Rio is only the smallest common agreement." (EE)<br>5.) "[…] the vocabulary is too technical, so that even university graduates do not understand the contents, that is the arrogance from the ivory tower. Terms such as SD or agenda do not mean anything to the people although they know the specific projects." (EE) |

| contents of SDE | | |
|---|---|---|
| implicit common inspection of the areas economics, ecology and social it) | 14 | 6.) "Not explicit but many topics contain all three columns, topics often are mixed and very difficult to separate." (GL)<br>7.) "The connections altogether are rather implicitly brought up for discussion, when people inquire. It will be a discussion topic concerning old sheep races – and also old cattle races will be purchased as well soon." (EE+GL)<br>8.) "Also different regenerative energy will be used and brought up for discussion." (EE) |
| explicit common inspection of the areas economics, ecology and social | 6 | 9.) "Also topics that do not show the environmental aspect in the beginning, e.g. the programme 'Social City'. It is about districts from which many people want to move away, important are regional-economical aspects, migrants etc. In addition, district quality through nature perception plays a part as well although economics and social are actually given special emphasis." (EE)<br>10.) "An example of a meeting for cross-linking between the areas is ‚Nature to its right and Fisher to their right' to the conflict 'Ecology' vs. 'Economics and Social'". (EE) |
| **special characteristics of SDE** | | |
| nothing new | 9 | 11.) "That is nothing new, it is an old topic which is regarded as a conciliatory process within the church. The terms justice, peace, retaining Creation are nothing different. The church takes responsibility for direct and worldwide connections." (EE+GL)<br>12.) "It is not completely new because environmental conservation is already shaped by holistic, systemic thinking". (EE) |

Some multipliers realized that sustainable development education opens environmental education for global learning (Eigner-Thiel & Bögeholz, 2004). Mostly there are only implicit common inspections of the core areas ecology, economics and social aspects as well as their intersecting set areas (citations 6-8, Table 2). Explicit common inspections of the three areas (as well as their intersecting set areas) are less often (6 instead of 14 namings; e.g. citations 9-10, Table 2).

This qualitative data can be completed by quantitative data answering the question: "Please estimate to which extent your educational offer contains the following aspects of knowledge concerning sustainable development?" from the questionnaire. For the detailed items operationalizing this question of subject competence, see Table 3. The rating scale consists of a four value answering possibility (0 = not, 1 = little, 2 = strong, 3 = very strong).

Table 3. Items operationalizing subject competence about sustainable development

| Educational offer, | |
|---|---|
| … in which the contents of the agenda 21 are imparted | 0 – 1– 2 – 3 |
| … which focus on the relation between ecology, economics and social aspects | 0 – 1– 2 – 3 |
| … in which knowledge about a fair distribution of resources are imparted | 0 – 1– 2 – 3 |
| … in which basic knowledge about a socially fair society are imparted | 0 – 1– 2 – 3 |
| … in which knowledge about methods concerning citizenship skills are imparted | 0 – 1– 2 – 3 |
| … in which sustainable development is described as a social process of inquiry and optimization | 0 – 1– 2 – 3 |
| … in which knowledge about possibilities of sustainable development´s controversial aims are imparted, e.g. bird protection contra protection of the climate concerning wind mills | 0 – 1– 2 – 3 |

Regarding the subject competence about sustainable development, Figure 3 shows, that the educational offer is best for contents relating to ecology, economics and social aspects (EES; mean: 1.83). Contents like agenda 21 (A21; 1.37), a fair distribution of resources (RS; 1.28), controversial aims of sustainable development (CA; 1.25), and socially fair society (SJ; 1.08) are less frequent. Offers promoting citizenship skills (CP; 0.93) and giving insight into an understanding of sustainable development as a regulative idea (RI, social process of inquiry and optimization; 0.73) are rare (less than "little").

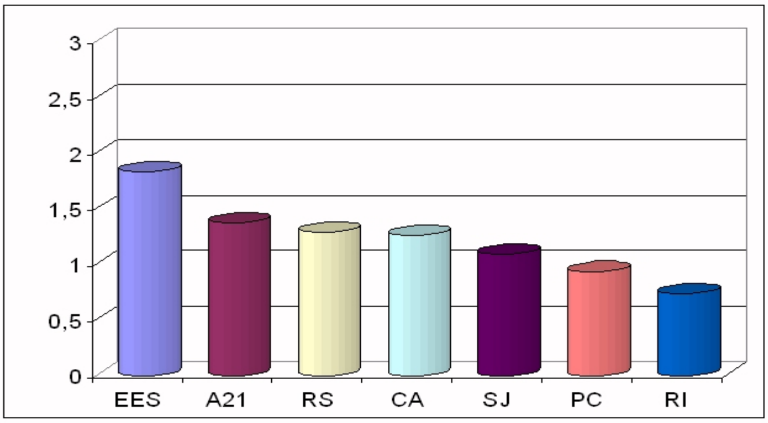


Figure 3. Components of the educational offer concerning subject competence about sustainable development (mean range: 0-3)

Extra-curricular multipliers did not identify yet the development of ethical competences as one crucial aspect of sustainable development education. The interviews show that ethical questions are not in the centre of the SDE-interventions. "Altogether there are approximately 2% of ethical meetings in the educational offer where half of them precipitate because of non-interest" (quotation of GL multiplier). The multipliers report only small interest in ethical questions (Eigner-Thiel & Bögeholz, 2004).

Fostering ethical competence is not recognized as an explicit aim (citation 1, Table 4). Further anchor examples are given in the citations 2 and 3 in Table 4. Implicit ethical components of their own educational interventions are often not identified by the interviewees. But, during the interview some multipliers realise that their interventions contain ethical dimensions. Moreover, they discovered that the ethical aspects could be explored and improved: "In this area a lot of things have to be improved" (quotation of EE multiplier) or "The area should be developed in future" (quotation of vocational education multiplier).

Educational interventions with explicit discussion of ethical questions and closely related to aspects of normative competence, especially assessment and judgement competences, are rather few. In comparison with the implicit discussion of ethical questions, there are only 6 instead of 17 namings for explicit discussions. An example of best practice of explicit discussion is given by the "oil mill" example (citation 4, Table 4). Among the namings for explicit discussions also sectoral approaches - like discussing the idea of Creation in relation to sustainable development (citation 5, Table 4) - were taken into consideration.These qualitative results can be completed by quantitative data analysing the normative competence (Figure 4). The questionnaire question was: "Please tick whether educational offers are carried out containing the following aspects." The according items to normative competences are listed in Table 5.

Table 4. Categories and sub-categories concerning normative competences (including numbers of namings and anchor examples)

| ***category name*** | ***number of namings*** | ***anchor examples***<br>*1-5 namings: 1 example; 6-10 namings: 2 examples; >11 namings: 3 examples EE: Quotation from a key multiplier from the environmental area*<br>*GL: Quotation from a key multiplier from the area of global learning ("development")*<br>*EE+GL: Quotation from a key multiplier from the intersecting set area* |
|---|---|---|
| **normative competence** | | |
| implicit discussion of ethical questions | 17 | 1.) "Ethical questions are not brought up explicitly for discussion, it is aimed at using didactical things in the future which do already exist somewhere." (EE)<br>2.) "Our institution is not a sales agency but it has the goal to bring up different opinions and to look at supporting interests. " (EE+GL)<br>3.) "The Flower-Label-Project is based on an ethical approach that is to say: flowers are a very powerful symbol, how is that at all to be answered for that this symbol is soiled? What ethical questions are on the rose bought from the Pakistani in the tavern, what in these symbols which also have high value?" (EE) |
| explicit discussion of ethical questions | 6 | 4.) "By the example the oil mills the different interests, arguments, ethical consequences, implications for the cultivation of soybeans in Brazil, for the unemployment will be discussed here. No points of view will be taught but the capability to arrive at ones own point, furthermore the ability to take ones own view." (GL)<br>5.) "Questions like the 'idea of creation'; things that come from Christian appreciation represent the basis of sustainable development; are mainly brought up for discussion with women." (EE) |

The answering possibilities were 0 (signifying "not"), 1 (little), 2 (strong) and 3 (very strong).

Table 5. Items operationalizing normative competences

| *Educational offer, in which* | |
|---|---|
| … personal motifs and interests are articulated and reflected | 0 – 1– 2 – 3 |
| … value hierarchies were designed together | 0 – 1– 2 – 3 |
| … risks are assessed comparatively, e.g. health risks caused by noise and electronic smog | 0 – 1– 2 – 3 |
| … ecological assessments are carried out, e.g. compensation regulations and ecobalances etc. | 0 – 1– 2 – 3 |
| … other assessments on the developmental field are carried out, e.g. assessment of social compatibility of developmental projects, trade regulations etc. | 0 – 1– 2 – 3 |
| … decision competence for ambiguous situations is trained | 0 – 1– 2 – 3 |
| … sustainable development indicators are developed, discussed and reflected | 0 – 1– 2 – 3 |

Regarding the results (see Figure 4), it can be shown, that the articulation and reflection of personal motifs and interests are the most frequent educational interventions in this area (PN; mean: 0.96). Even less frequent are interventions related to value hierarchies (VH; 0.75), risk assessments (RA; 0.71), environmental assessments (EA; 0.71), assessments on the developmental field (global learning issues; AGL; 0.63), sustainable development indicators (SDI; 0.56) and decision competence for ambiguous situations (coping strategy for situations with ethical complexity; SEC; 0.33).

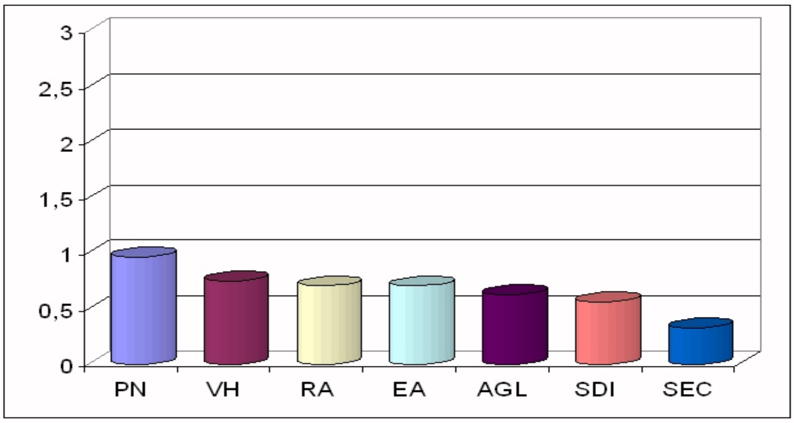


Figure 4. Components of the educational offer concerning normative competences (mean range: 1-3)

## 5. Conclusion

The results show that most of the key multipliers have deficits and barriers regarding the reception of pedagogically valid concepts of sustainable development and sustainable development education. Thus, the interviewees incorporate only few and/or partial aspects of sustainable development into their educational practice.

The qualitative and quantitative data show, that the common inspection of ecology, economics and social aspects has started. Additionally, there are deficits in the promotion of normative competences. Qualitative and quantitative data reveal that assessment and judgement competences (claimed by Dubs, 2002; Bögeholz & Barkmann, 2003) – as well as their prerequisites, e.g. the ability to reflect personal motifs and interests and to deal with value hierarchies – are not in the centre of sustainable development education practice yet.

For judging the results, it has to be taken into account, that only very well informed representatives of the SDE-institutions (key multipliers in environmental education, global learning, environmental education and global learning as well as vocational education) have been interviewed. In sum, multipliers of extra-curricular sustainable development education have to be enabled to improve SDE. We recommend: (i) the implementation of an adequate understanding of sustainable development in trainings of multipliers in environmental education, global learning and SDE, (ii) fostering normative competence as well as didactic competence in this central core area of sustainable development education. Schleswig-Holstein takes up these recommendations, which are crucial prerequisites for successful sustainable development education.

Sustainable development education has to enable learners to contribute to a sustainable future: "To make progress towards more sustainable societies requires a population that is aware of the goals of sustainability and has the knowledge and the skills to contribute towards those goals" (UNESCO 2003a: 2).

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# PRODUCTION OF EXPLANATIONS IN PRIMARY SCHOOLS WHEN INTERPRETING ENVIRONMENTAL DISTURBANCES

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## Abstract

This communication is part of an investigation into 11-year-old students' explanations to interpret environmental disturbances. In particular, we analyse the function of a scale model constructed and manipulated by students when simulating a forest fire in the origin of these explanations. We feel that explanation involves interrelating three levels of organisation: the level at which the phenomenon is observed, a lower level at which causal mechanisms are identified, and a higher level in which environmental constrictions are identified. The data was recordings of conversations in class and students' writing. They were analysed using three categories: 1. 'Levels at which the explanation is situated'. 2. 'Source of the evidence applied' (observations, scale model or previous experiences) and 3. 'Who promotes the explanation' (teacher, student or in interaction). The results show a spiral process of explanation construction. Manipulation of the scale model encourages the inclusion of constrictions in the explanations, while the mechanisms are mostly introduced when resorting to previous experiences and observations. Scientific language is used mostly regarding the mechanisms, and the integration of levels is encouraged by questions posed by the teacher.

## 1. Introduction

One of the aims of science teaching is that pupils construct interpretations of what happens in the world in accordance with current scientific theories. These interpretations should not only be epistemic, but should also enable intervention in the world, i.e. making decisions and acting on them. One aspect that has proved important in this sense is the incorporation of complexity in interpretations of natural phenomena (Izquierdo et al., 2001).

One of the problems when interpreting biological phenomena is not only their complexity but also the occurrence of a wide spectrum of physical and temporal scales, making it difficult for students to observe directly and construct representations of those phenomena (Buckley, 2000). In a case of a phenomenon of such major natural and social impact in the Mediterranean as forest fires, there is an added difficulty, as students make observations on different organisational levels (individuals, communities or ecosystem) (Gómez, 2000).

To approach the aforementioned problems we have conducted a research project over four years that has developed and analysed the implementation of three didactical units in the classroom with eleven-year-old pupils. The final didactical unit collects the results of the analysis of the first two and proposes three relevant aspects:

- The creation by students of a model of the forest and the manipulation of that model by simulating a forest fire and the later regeneration of the forest.
- Conversation management during manipulation of the model while considering the three scales of observation (generalisations, mechanisms and constrictions or limitations) and providing causal explanations.
- The interrelated organisation of ideas about living beings around three functions (nutrition, reproduction and relation).

Taking these three aspects into account, in this report we analyse the function of the model in the construction of explanations during teacher-student interaction about what happens to living beings when there is a fire.

## 2. Outline of theoretical reference

The generation of scientific explanations in the science classroom can be understood as an incorporation of 'ways of seeing' phenomena adapted to a scientific viewpoint (Alfieri et al., 1999). 'Explaining' means different things depending on the author consulted. We agree with suggestions made by Veslin (1988) when he considers that scientific explanation answers to the why, or the cause of an observation, according with a science model; we also consider that explanation involves approaching a lower organisational level with respect to the one in which the observation was made (Llibourty, in: Veslin, 1988).

We also consider that, in explanations that enable children to interpret observations of living beings, it is also important to take a *higher organisational level* into consideration, so as to incorporate a dynamic and complex vision of the phenomenon. To do this, we take the concept of "complex adaptive system" (Gell-Mann, 1995), which enables us to stress understanding what phenomena are like and what their dynamics are. We go back to Allen and Starr's (1982) "middle-number systems" in which a theory is developed for hierarchically organised systems. In these, the system is organised into sub-structures that are hierarchical to each other, such that the original complexity is subdivided into properly coordinated sub-systems, making them accessible for analysis.

Explanations made based on the aforementioned concept are named by Pickett, Kolasa and Jones (1994) '*hierarchically nested explanations'*. These authors consider this kind of explanation to be tools that can be used by the scientific community for the construction of theories. Scientists identify regularity or patterns of the phenomenon of interest and make a *generalisation*. They later seek the cause of the observed pattern on a lower scale or level of organisation in which the causal *mechanisms* that enable the determination of the processes, interactions or conditions that produced the pattern of the phenomenon are found, along with possible predictions. At the same time, *constrictions* are sought on a higher scale level (Allen y Starr, 1982), which determine the speed and intensity of the response of the mechanism. Both mechanisms and constrictions are considered causes of the observed pattern.

When dealing with forest fires, the starting point where the generalisation is located enables positioning oneself in one or other type of relationship between scale levels. We understand that this consideration is the key for the teacher to manage classroom conversation by manipulating the model and supporting the generation of hierarchically nested explanations.

In the didactical unit that we made, we considered it convenient to locate generalisations in the organisms level (and not in communities, for example). This responds, on the one hand, to the fact that it works on this level in a curricular sense and, on the other, to the fact that in the history of science, ecology models (which locate generalisations on the community level) appear later than organismic biology models (which locate generalisations on the organism level) and uses basic concepts of organismic biology and other sciences, integrating them (Giordan et al., 1998).

## 3. Analysis methods

In the study being presented, an analysis was made of the discourse of interactions between teachers and pupils in six activities performed around the construction and manipulation of a scale model of a forest. This is done from an ethnographic perspective, as we consider cultural knowledge, antecedents, and the outlines of relevance within which the discourse is given (Cicourel, 1992). We take this broadened perspective by approaching the discourse in a way that is articulated to the content (Candela, 1997), in this case about living beings.

To describe hierarchically nested explanations constructed in the classroom, discursive sequences are identified. In these, conversation units are selected whose content is located on one of the three hierarchical levels of organisation: a) *generalizations* where the phenomenon to be explained on the organism level is identified, b) *mechanisms* that explain the causes of the phenomenon and are located on the level below (what happens within the organisms, and how), c) *constrictions* that constitute limits and are located on the level above (in the environment).

The sources of evidence are also identified for each of the sequences. Those coming from direct observations, from the scale model itself, and those originating from other sources (previous experiences or authority).

Finally, we identified who had provoked the explanation: teachers, pupils, or interaction between both.

## 4. Results and discussion

Within the six analysed activities, the creation of ten explanations was identified. In Table 1, as an example, the explanations are presented along with some ideas used for each scale organisation level for three activities.

Table 1. Some hierarchically nested explanations identified in the activities and part of the conversations of the discursive sequence

| Activity | What is explained | Generalisation | Mechanism | Constriction |
|---|---|---|---|---|
| Model without living beings.<br><br>Before placing plants and animals, identify what things there could be that are not living beings. | Seeds are living beings | There is controversy among pupils as to whether seeds are living beings or not.<br><br>*Girl.- Fruits aren't living beings, only what is inside is a living being* | Transformation is used as an argument<br><br>*Girl.- Yes. But you could say that seeds are living beings because they grow and transform, but not fruit, because they don't turn into anything* | Fruits are incorporated into the nutrient cycle<br><br>*Boy.- Fruit is used to feed the earth, when you leave a fruit in the forest it dec...*<br>*Teacher.- ...decays and leaves minerals in the soil which later …* |
| The fire<br><br>Simulation of a fire in the forest | Animals escape from the fire | Birds fly away when there is a fire<br><br>*Teacher.- well, very good Josy, a fire has started, but well, what happens to all the plants and animals there*<br>*Girl.- the birds fly away, the animals escape, the nearest ones first* | Why birds fly away is explained<br><br>*Girl.- they get information about the environment*<br>*Teacher.- they get information about the environment, that is the relation,*<br>*Teacher.- heat, light from the fire, the sound of the fire, that is what we said the stimuli were, they give us information,* | The environmental conditions change<br><br>*Teacher.- so why do they fly no, they fly because they know there is a fire,*<br>*Girl.- because it's hot*<br>*Girl.- because they feel the heat*<br>*Teacher.- while we're talking about that, what do they see, what do they feel and might they hear anything?*<br>*Boy.- yes, the* ***waves***<br>*Teacher.- waves of what?*<br>*Boy.- of fire*<br>*Girl.- of heat*<br>*Girl.- Yes! Could be…* |

| | | | | |
|---|---|---|---|---|
| Two sections<br><br>The model is divided into two sections, in one there has been a drought and in the other normal rain and the two zones are compared. | Ants need food to survive | Ants look for food<br><br>*Teacher.- ok, think about ants. What happens in a forest when everything is dry? What do ants do in summer?*<br>*Boy- Ants look for food* | Food provides energy and materials<br><br>*Teacher.- what happens when ants don't have food?*<br>*Childrens.- they die*<br>*Girl.- because their reserves run out*<br>*Teacher.- Marisol already said that. And then?*<br>*Girl.- the body gets weak and they can't do anything, not even exercise*<br>*Teacher.- why?, what does food give us?*<br>*Girl.- nutrients*<br>*Girl.- strength*<br>*Teacher.- that strength to do things, what is it called?*<br>*Boy.- energy*<br>*Teacher.- nutrients on the one hand and energy on the other …*<br>*Teacher.- and what are nutrients used for?*<br>*Girl.- to grow!*<br>*Teacher.- to grow!*<br>*Girl.- to reproduce*<br>*They carry on talking about the subject ...* | In a drought, there is no food for animals<br><br>*Boy.- it is all dry in this part of the forest, there is no food*<br>*Childrens.- no*<br>*Girl.- it is all dry*<br>*Girl.- the ants will go to the other side [*of the model, where there is vegetation*] to find food* |

## 4.1- In relation to the explanations

The different explanations that were constructed relate the three functions of living beings (nutrition, reproduction and relation). These are complemented as work progresses through the didactical unit. Some ideas that are widely discussed in the first activities are then presented in packaged form. One example is the case of the idea of 'information about the environment', which is profoundly debated in consensus in the first activity, and used later by the pupils as an argument. The explanations present a spiral construction in which the different aspects are retained, broadened, or extended. Table 2 shows fragments of two discursive sequences that serve as examples of this aspect.

Table 2. Comparison of two moments in the construction of explanations (The 2nd uses an idea constructed in the 1st )

| Activity: "Creation of a diagram of living beings for thinking and acting" (before manipulation of the model) | Activity: "Simulation of a forest fire" |
|---|---|
| The pupils have talked about how animals move, and discuss whether plants also move.<br><br>*Boy.- animals move by themselves but you have to pick up plants to move them*<br>*Teacher.- plants never move?*<br>*Girl.- yes, when they grow*<br>*Boy.- but there are some that move towards the sun / some move around walls looking for light*<br>..<br>*Boy.- there's the fly-catcher too*<br>….<br>*Teacher.- there are flowers that close up at night and open up again at dawn*<br>*Boy.- the Christmas plant*<br>*Teacher.- it opens in the morning as if to welcome the new day*<br>*Boy.- there aren't any Christmas plants in my country*<br>They debate what this 'movement' should be called<br><br>*Girl.- when they feel*<br>*Boy.- when something approaches*<br>…<br>*Girl.- when they have reactions*<br>*Teacher.- and what does that mean?*<br>*Girl.- when they give us information*<br>*Teacher.- so, it seems that we change due to information, and that's true for animals and plants*<br>*Ns.- yes*<br>*Ns.- they give us information*<br>*Teacher.- so rays of sunlight are information for plants, they tell them where the sun is* | Going back to the three basic ideas that the pupils must consider in their argumentation during the manipulation of the model.<br><br>*Teacher.- to speak about* ***living beings****, we said we were going to think about three things, what are the three most important things for living beings?*<br>*Boy.- nutrition*<br>*Boy.- reproduction*<br>*Teacher.- what else?*<br>*Girl.-* ***the getting information thing***<br>*Teacher.- taking information from the environment, what did we call that information?*<br>*Girl.- sti, stim,*<br>*Teacher.- stimuli*<br>*Teacher.- we said that that was part of relation* |

## 4.2- In relation to generalisations

The analysis of the discourse in the ten explanations shows that initial generalisations are produced. These are proposed by the pupils, generally in response to the teacher's questions like "What would happen to the living beings now?". In this process, the model is the key to presenting the phenomena to be explained, given that when constructing and manipulating it, the pupils are approaching a landscaped vision, especially in the distribution of trees, and a structural vision of the characteristics of each living being that it is made up of. An example of this is the fragment of Table 3, taken from the activity 'The Forest Regenerates'.

Table 3. Fragment of conversation in which it is observed that the pupils approach a landscape and structural vision of the model

| Activity: 'The Forest Regenerates' |
|---|
| Teacher.- we see **what the forest was like after the fire,** the trees burnt down and the animals escaped. I observe that **there is an area that is more badly burnt and one less burnt, there are a few trees here, why?,** let's see first Marisol, then Abraham, then Josy, why?<br>Girl.- on **this side there were pine trees and on the other side there were holms**<br>Boy.- the same<br>Girl.- me too<br>Boy.- **it's also different for the cork oaks, this was a cork oak**<br>Teacher.- and what could the difference be<br>Boy.**- because they've got cork**<br>Teacher.- yes, that'll be the cork oaks, the cork protects them<br>Girl.- **and the normal oak trees?**<br>Teacher.- where were they?<br>Girl.- **round here**<br>Teacher.- they were there were they?<br>Girl.- **they have burnt a lot too**<br>Teacher.- because they don't have the same protection as the cork oaks<br>Girl.- yes, they got burnt badly |

The model establishes a bridge between the pupils' initial ideas and the complexity of the specific relations of the phenomenon to be interpreted. I.e. between their ideas of what could happen to the specific living beings they are talking about and the conditions created by the burning and recuperation of the forest. In interaction, it is normally a student that proposes the generalisation, it being the common context of the model that leads other pupils to be incorporated into the argumentation. In the example of Table 4, this form of elaboration by the pupils is shown. It shows the most common generalisation made by all the pupils with respect to what happens to living beings when there is a fire (Gómez, 2000). These types of generalisation enable teachers to guide the conversation in order to speak about the mechanisms and constrictions. To be more specific, the conditions of the environment are used as a constriction and the capacity for receiving stimuli and processing them as a mechanism.

Table 4. Fragment of conversation in which a generalisation is produced

| Activity: 'The Forest Fire' |
|---|
| Teacher.- right, very good Josy, a fire has started, but well, what will happen to all the plants and animals there?<br><br>Girl.- the birds fly away, the animals escape, the nearest ones first |

Elsewhere, it is observed that pupils of this age tend to make generalisations that only include animals, and exclude plants. The teachers support the broadening of the generalisation through questions and examples, particularly drawing upon pupils' previous experiences. This leads the pupils to make broader generalisations. An example of this can be observed in Table 2, in the first column, where the generalisation that "all animals move" is broadened to include plants. This type of broadening leads to changes in the meanings attributed to the generalisation. To be more specific, the case of exemplifying movement is related to the response to the information received from the environment. It was found that this change in meaning is associated to a change in the way of naming the phenomenon. Once the pupils had broadened their generalisation about movement by including plants, the expression 'they respond to information from the environment' was used instead of 'they move', both for plants and for animals.

### 4.3- In relation to mechanisms and constrictions

In the explanations that were analysed it was found that once the generalisation had been made, the conversation could be included within mechanisms or constrictions in no specific order. Given that argumentative contexts are generated in interaction (Candela, 1997), the order in which these two levels of explanation are presented seems to depend on the dynamics of the interaction, specifically of the significant participation of each pupil.

The analysis of the conversations indicates that the model is an element that enables visualisation of the constrictions, or limiters, of the environment. Once again we find that the fact that pupils can manipulate landscape and constituent elements (living beings) of the scale model enables them to go further and speak about interactions between organisms and between these and the environmental conditions.

Meanwhile, the mechanisms that are directly related to the three interrelated functions of living beings (reproduction, relation and nutrition) require teacher intervention, either through direct questions and indirect requests, designed for pupils to give examples. Table 5 shows an example of nested hierarchical explanation taken from the activity 'The forest regenerates', in which a mechanism and a constriction can be seen, created basing on this type of teacher intervention.

Table 5. Fragment of conversation in which an added hierarchical explanation is shown

| Activity 'The forest regenerates' |
|---|
| Initial generalisation:<br><br>The animals return to the forest after the fire!<br><br>*Teacher.- well now we've got a bit of vegetation, what else might happen?*<br>*Girl.- the animals come back*<br>*Teacher.- what animals?*<br>*Boys and girls.- ants; insects* |
| Constriction produced:<br><br>To return they need food to be there!<br><br>*Teacher.- why?*<br>*Boy.- because the ants are coming and they need their food*<br>*Boy.- ants are small are going to get, uh, fruit*<br>*Boy.- from little leaves, from trees, from bushes too*<br>*Boy.- small seeds will do as food*<br>*Girl.- the bees can't come back yet, there aren't any flowers*<br><br>The children start manipulating the model by placing the insects that return to the forest<br><br>*Teacher.- let's see, there are small insects here that eat off leaves, let's see Ignasí*<br>*Boy.- it's starting to eat a bit*<br>*Boy.- I'll put it here because it will find lots of food*<br>*Teacher.- but we said it can't come back yet because there aren't any flowers* |
| Mechanism produced:<br><br>They know there is food because their senses receive stimuli<br><br>*Teacher.- how does this insect know there is food there?*<br>*Boy.- using its instincts, its senses, it is the relation*<br>*Girl.- because it has received the stimulus that there is food*<br>*Teacher.- how did it receive it?*<br>*Boy.- by smell, by looking, by smelling* |

During work on the didactical unit, given that the model did not favour the incorporation of mechanisms, there was a need to introduce experimental activities to approach them. So, for example, in one of the implemented activities, exercises were performed that involved identifying colours, tastes and sound to, in turn, identify and differentiate the stimulus, the receiving organ, the response and the required intervention of the brain as a translator of the information received. After that, an activity is performed that links these ideas to the generalisation, related to what happens when the animals run away when there is a fire. To do this, a drawing was made in response to the question: "What happens inside the body of a bird so that it knows that there is a fire?". An example of one of these drawings is shown in Figure 1.


Figure. 1. Girl's drawing of what happens inside the body of a bird when there is a fire

In making constrictions, it is observed that if the pupils visualise and express them spontaneously, there is a need for teacher intervention to help them relate the constrictions to the three functions (nutrition, relation and reproduction). This can be seen in the fragment of conversation in Table 6. This starts from the moment when the pupils move the animals in the scale model, especially the insects, as they consider that they can return to a forest after a fire as a few plants will have grown.

Table 6. Fragment of conversation in which a constriction is shown

| Activity: 'The forest regenerates' |
|---|
| *Boy.- why's it here* |
| [the boys and girls start placing animals in the model] |
| *Girl.- a ladybird* |
| *Girl.- can a ladybird fly?* |
| *Teacher.- yes but not so high* |
| *Girl.- ok* |
| *Boy.- it's starting to eat a little bit* |
| *Boy.- I'll put it here because it will find lots of food* |
| ----------- |
| The teachers refer to the pupils' decisions to draw their attention to the three functions |
| *Teacher.-for example, here, they put this insect here. How does the insect know that there is food there?* |
| *Boy.- because of its instincts* |
| *Girl.- because of its instincts* |
| *Girl.- it's the* ***relation*** |
| *Teacher.- we have* ***relation, nutrition*** *and* ***reproduction.*** *How does this insect know that there is food there* |
| *Girl.- because it has received the* ***stimulus*** *that there is food* |
| The pupils are manipulating the model and placing insects |

## 5. Conclusions

We found that the proposal of integrating not only the lower level in the pupils' explanations, but also a higher organisation level (a constriction according to Allen, 1982) helps pupils to interpret the phenomenon of forest fires from a more complex, dynamic perspective. Living beings are seen as diverse, and it is seen here that changes to the environmental conditions will affect them in a differential way. Meanwhile, relating the higher and lower levels through the three functions (nutrition, relation and reproduction) makes it possible to unify ideas and to model explanations.

A second point of interest is the fact that taking the three proposed scales into consideration helps the teacher manage classroom conversation. It helps him or her to produce the right questions and the accurate experimental activities in accordance with the interest of expanding one level or another. We found that levels (generalisations, mechanisms and constrictions) respond to the need to deepen, broaden and organise pupils' ideas, and not only mechanisms, as has been suggested traditionally. In the analysed didactical unit, it was found that ideas are broadened, deepened, and organised on the three levels, but a tendency is also observed to the use of scientific language when speaking about mechanisms, but not about constrictions, which are expressed by pupils and teachers through more colloquial language. In the incorporation of scientific language, there is a *reductionist* tradition making lower levels more important in explanations.

Finally, we could say that the model functions as an intermediary between the pupils' initial ideas and the difficultly interpreted phenomenon. It helps the pupils to identify phenomena and to produce generalisations, and also to visualise constrictions as limiters of the activities performed by living beings. It supports construction in interaction, as it allows the class to 'speak about the same thing' by generating a joint representation of the phenomenon. The teachers' function is to help relate the observation levels in order to generate hierarchically nested explanations that are related to the three functions of living beings (nutrition, reproduction and relation). In this study we have shown that it is possible for eleven-year-old pupils to make relations between the three observation scales and the three functions by manipulating the scale model so as to interpret what happens to living beings when faced by a forest fire and, with the help of the teacher, to relate them in such a way that it is possible to identify a spiral construction of the interpretation of the phenomenon. We now consider it necessary to continue our research into how schoolchildren incorporate and apply these hierarchically nested explanations constructed in interaction within their personal interpretations of the phenomenon, and to ascertain whether they are capable of transferring these to the interpretation of other phenomena.

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# CHILDREN' S REPRESENTATIONS ABOUT THEIR BODY AND SEXUAL DEVELOPMENT

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## Abstract

This study focuses on the representations that school-aged children have about their body and sexual development, as a basis for developing health and sex education programmes. The study was conducted during 2002 with thirty-four children aged 11 to 12 years. Focus group interviews using stimulus materials were adopted for this exploratory research. The findings indicate that children have a limited knowledge about the reproductive system. More specifically the boys represent only the external reproductive organs, while the girls drew the internal ones. The girls were more informed regarding pregnancy and contraception and both groups mentioned the condom as a means against unwanted pregnancy and AIDS. However, the majority of children lack information about other sexually transmitted diseases (STD) and they expressed a fear and anxiety about STDs without any mention of the ways of prevention. The findings indicate that children reproduce the "common everyday knowledge" about sexual issues and require more knowledge and accurate information about their developing bodies and sexuality. Furthermore, our results have implications for sex education in schools. Giving teachers this information could help them target areas of particular ignorance or young people at particular risk.

## 1. Introduction

For some years there has been growing concern in many countries in Europe about health and sex education in schools, as many changes in young people' s physical and sexual development have taken place in recent decades. Of particular importance is the fact that, whereas 20 years ago few girls in primary school would have been menstruating, approximately one in 10 have now started menstruating by their final year (Winn et al., 1995).

Moreover, young people are now having their first experience of sexual intercourse at a younger age and the rate of unplanned teenage pregnancy in Europe has increased. There is also evidence of a low level of contraceptive use amongst young people and this is related to the high incidence of STDs and HIV/AIDS amongst this group (Kruss, 1992; Meyrick & Harris, 1994; Donovan, 1990). There is also strong evidence that young people are lacking knowledge on important sexual issues (Thomson et al., 1999).

Taking into account that many young people do not discuss sexual issues with their parents, school has an important role to play in promoting sexual health. So, sex education programmes in schools are crucial to educating young people about their bodies and developing sexuality, as well as about methods to reduce high risk sexual behaviours. Sex education programmes were also found to be effective when given before young people become sexually active, because knowing what risks exist and how to avoid them is essential for adopting safe sexual behaviour. Moreover, if sex education is to contribute to preparing young people for the changes of adolescence, it will need to begin during primary school (Green, 1998), because if they know what will happen to their body they will adjust easier to the oncoming changes.

A number of researchers (see for example Winn et al., 1995; Watson et al., 1996) have argued that before developing health and sex education programmes it is necessary to investigate the knowledge and the «common sense» understanding of health and sexual development that children have. Moreover, a growing body of evidence suggests that theory-based programmes are more effective than routine practice in targeting the most important determinants of young people's sexual behaviour (Wight et al., 1998).

Regarding young people's understanding of what is inside themselves, there are several studies showing that children as young as 10 do not have a holistic view of their internal body map (Cuthbert, 2000; Reiss & Tunnicliffe 2001; Reiss et al., 2002). The results of this research seem that there is lamentable lack of knowledge about the reproductive organs and system. However girls have a better understanding than boys regarding the internal organs of their reproductive system.

Moreover, there have been a few studies looking at the knowledge that young people have about their sexual development and puberty (Winn et al., 1995; Thomson et al., 1999; Potsonen & Kontula, 1999). The main results of the studies were that although girls knew more than boys about some aspects of sexual development, the majority of young people between 11 to 16 years lack information which is essential if they are to avoid unwanted pregnancy. As far as young people's knowledge about HIV/AIDS the results show that young people have a good level of knowledge about HIV/AIDS related issues. However, we are unaware of any work that simultaneously examines the representations that school-aged children have about their body and their sexuality.

Investigating children's assumptions about the human body and reproduction provides us with a wider scope, because the children's assumptions reflect the ideas, images and representations of the social group they belong to and are shared by all its members. Such research helps us understand better the worldview of this social group, its beliefs about what kind of behaviour is proper and what not, the way its social institutions function, the kinds of social conflicts that exist among different groups, and, also to what extent the children's knowledge is based on rumors (Emler, 1988). Specifically, this study examines how children as social subjects perceive the facts of everyday life, as well as the information and the thought models they have received through tradition, social communication and education regarding their body, contraception, sexually transmitted diseases and AIDS.

The present research focuses on the following questions:

- What are the representations that school-aged children have about their developing body?
- How do children represent their sexual development?
- How do children talk about contraception, STD and AIDS and
- Which are the children's sources of information?

## 2. Research design and Method

The methodology used incorporated standard focus group interviews based on a set of questions developed by the research team that focused on aspects of body development and other sexual issues. The decision to use focus groups was based on previous research in the field of health education including work by Basch (1987), Basch et al. (1989), Skinner et al. (1995), Turner et al. (1998) and Zimvrakaki (1998).

Focus group interviews provide a good technique in exploratory research to identify issues important to a specific target group. Moreover, school aged children appear comfortable, relaxed and forthcoming in group discussion, making this process an appropriate one for probing complex and perhaps controversial issues. Group pressures appear to inhibit individuals from providing misleading information and may create an atmosphere where different topics can be discussed openly. Individuals who hear others share their concerns or views feel more comfortable to indicate their agreement. The expression of different views and the rationales underlying such differences are extremely useful when exploring topics that are relevant to this research.

The study was carried out in two stages. During the first, the pilot study stage, one interview was undertaken in order to trial the questions and the stimulus materials to be used in subsequent work and to test the reliability of the research instrument. The interview was taped and later transcribed. After analyzing the interview from the initial stage, no changes were made to the interview schedule and we proceeded with the main study.

The second phase of the study was undertaken with groups consisting of no more than six children, aged 11 to 12 years. A total of six interviews were undertaken during the study. Each interview lasted approximately 45 minutes and took place in an area outside the classroom. At the start of the interview the purpose of the research was explained; the children were asked if they were willing to take part and for permission to record the discussion. They were assured of the confidentiality of the research. The interviews were carried out by the authors, who acted as moderators across the focus group sessions; this strategy served to enhance the reliability of the interviews (Klein, 1989). An additional member of the research team observed the interviews and noted both verbal and non-verbal communication.

Prior to the interview the children were asked to draw their body. This strategy, which has been used by some previous researchers (Williams et al., 1987; Turner et al., 1998;

Zimvrakaki, 1998) was designed to provide a starting point for discussion. Further stimulus materials were used during the course of the interview (e.g. cards with pictures of body development, the reproductive system and the stage by stage development of the embryo from the first to the ninth month of pregnancy).

Representative questions used during the interviews included:
1. Can you describe the changes that you observe in your developing body?
2. What do you know about the reproduction system?
3. What do you know about pregnancy?
4. What do you know about contraception, sexually transmitted diseases and AIDS?
5. Where do you learn about sexual issues?

## 3. Analysis of data

Inductive analysis, based upon the grounded theory method (Glaser & Strauss, 1967; Glaser, 1978) and the naturalistic inquiry method (Lincoln & Guba, 1985) is the main form of analysis being used in the study. In essence, the combination of the theories mentioned above involves moving from data to theory through a general method of comparative analysis, rather than working from a predetermined hypothesis. The main themes (thematic units) are grounded in the data rather than a priori theoretical ideas and are as follows:
- The changing body
- The reproductive system
- The pregnancy and contraception
- The sexually transmitted diseases and AIDS

## 4. Findings

### 4.1- The changing body

When children were asked to consider the changes in their developing body they talked about changes that can be broadly grouped around *physical appearance* and *reproductive organs.* One student (boy, 11 years old) described changes in his body in the following way: "As we grow up we change, as I said, we grow taller, we get larger size shoes …", " We get pimples, hairs grow …"

The development of hair on specific areas of the body such as the armpit and the reproductive organs were other changes mentioned. However, both boys and girls agree that "Boys are not so developed as girls …" (boy, 11 years old), "The breast changes … In girls the breast grows, the nipples develop …" (girl, 11years old)

The second area is related to changes in the reproductive organs and the ***reproductive system:*** "We see the genitals change, grow bigger …" (boy, 11 years old)

Boys talk about their external reproductive organs while girls talk about the internal aspect of the reproductive system: "…various organs develop, the ovaries …the fallopian tubes, the period starts …". This probably happens because boys are more familiar with their genitals than girls, both because they are physically more obvious and also because boys handle their penises regularly to urinate.

It is worth-noticing that not even one girl mentioned the clitoris. This finding has many explanations. First, the clitoris is smaller and less obvious than the penis. Second, for the majority of girls, their introduction to the world of sex is via menstruation and reproduction and, third, for many young men, the meaning of sex focuses on genital pleasure while for young women it tends to focus on reproduction and relationships. The latter is related to different cultural assumptions, which surround gender/body experiences.

Moreover, one girl (11years old) mentioned that the breast is also a reproductive organ: "The girls have the breast...". This probably has two explanations. First, the growth of the breast is connected with the appearance of puberty and, second, the baby is fed from the breast after his birth.

Although the girls talked about the internal reproductive organs, none of them drew, in the beginning of the discussion, the internal aspect of their reproductive system. The girls also know where in the body these organs are located but they do not know how these particular organs are joined together to form the reproductive system. This finding is in agreement with previous research in the field of science education regarding children's understanding about human organs and organ systems (Cuthbert, 2000; Reiss et al., 2001).

At this point, it is worth mentioning that, throughout the discussion, the embarrassment of the children and the difficulty they had to actually name the reproductive organs were obvious. In their discourse, children reproduce the dominant social discourse about the particular organs, just like their parents who also use euphemisms when they refer to the genitals, indicating to the children that these parts of the body are different to the rest, - i.e. the eyes, the nose, the knees – words and concepts that are used openly in discussion.

### 4.2- The sexually transmitted diseases and AIDS

*HIV infection and prevention*

Regarding HIV/AIDS knowledge, it appeared that the children have limited knowledge about infection by HIV. Both boys and girls named the intercourse as the main mode of infection.: "...AIDS is transmitted by sex..." (boy, 11 years old), "…When the two sexes have contact the one can transmit it to the other and it is fatal…" (girl, 11 years old).

Regarding HIV prevention, the children mentioned mainly the condom. However, saliva, injuries and blood were mentioned as other ways of infection. Following are some excerpts from the discussion of children on becoming infected: "AIDS is an illness that you get through sex, or through the saliva or because of an injury, that is, if someone is hurt and has AIDS and you get hurt and your blood comes to contact with his blood, you'll catch it, too" (girl, 11 years old), " …the one who has AIDS should not go onto another person …" (boy, 11 years old).

The concept of "catching" the disease enters the children's representation of how AIDS is transmitted. The phenomenon of transmission is understood and explained by the children as the consequence of being close and in contact with someone. This way of transmission of illness is familiar to the children, as the various viral and bacterial infections they have experienced are transmitted from patient to patient through contact. The idea of the infected patient brings about the idea of the stigmatized patient, someone with whom we have to be very careful with, someone we cannot approach.

At this point it becomes apparent that the children overestimate the danger regarding the ways AIDS is transmitted, a fact that reflects the wider social receptions with respect to AIDS patients and carriers, too. So the need clearly emerges for right and proper education and information concerning the ways of transmission as well as for the recommendation of "safe" forms of behaviour.

Although they know that the infection is a problem for everyone they think that it is not a current problem for themselves. One student (girl, 11 years old) mentioned:
"...There is a probability of infection for older people not for us because we do not have such relationships yet..."

So, since the children do not belong to a "high risk group" they may not feel that avoiding high-risk behaviour is their problem. This, of course, is of obvious consequences for the promotion of health.

As far as the other STDs are concerned the knowledge that children have is very limited.
One student (boy, 11 years old) mentioned:
"...AIDS, cancer, other microbes..."

Among the diseases that are transmitted through sexual contact, children mention cancer and other illnesses supposedly "caused by microbes". Adults who deliberately misinform and scare the children probably cause this misunderstanding. Usually parents employ such threats of infectious fatal diseases as a means of preventing their children from having premature sexual intercourse. Still, it is clear that such threats enhance representations related to the stigmatization and social exclusion of the patient.

### 4.3- Pregnancy and contraception

Children know that human beings come from the union of the egg with the sperm, without, however, being able to describe with clarity the stages of reproduction. One student (boy, 11 years old) described sexual inner course in the following way: "The man's genital joins the woman's genital and this way the man's sperm joins the woman's egg and so the child is made….".

Another student (girl, 11 years old) described sexual inner course as the following:
"When father and mother have sex, father's sperm goes into mother's egg and so the embryo is made…".

Of the internal female genitals they only mentioned the womb, without any reference to the fallopian tubes and the ovaries. This is probably due to two reasons. First, the image of a pregnant woman may provoke a question as to where exactly in the abdomen the baby is located and the answer they get is the womb and, second, the contemporary social discourse that is related to issues of human reproduction focuses on the egg, the sperm and the womb, because these are necessary for child-bearing within the framework of the new technologies of reproduction, which occupy an important position in developed Western-type societies.

Where contraception is concerned, all the children mentioned the condom. In addition, however, the girls mentioned the pill and the diaphragm: "The man (uses) the condom and the woman the contraceptive pills…", "The man wears the condom and the woman a thing she puts inside the vagina…".

Girls know more about contraception than boys, as they have a more personal interest in the matter, since women are the ones who suffer the consequences of an unwanted pregnancy: "With the spiral. The doctor places it inside the woman's organ and so you can avoid getting pregnant a number of times. You have to change is every month or year…"

At this point it is worth mentioning a boy's response to a question related to contraception: "If/when a woman gets pregnant by mistake she should go and get rid of (abort) the child…"

The thinking of these children reflects wider assumptions and practices regarding contraception; we should take into account the fact that Greek women are statistically the last in consumption of contraceptive pills and the first in number of abortions in the European Union. It appears then that the discourse and the reasoning of the children with respect to the various aspects of sexual relationships under investigation are to a large extent socially formed and determined. This means that the programs of promotion of the sexual health of young people must take into account the social and cultural environment of the target group.

### 4.4- Sources of information

The children's demand for more and better knowledge was constantly present throughout the duration of the interviews, because the children are able to process much more information and more complex information compared to what we provide them with at the moment, concerning reproduction and the prevention of sexually transmitted diseases. This demand concerns mainly the school and the school textbooks, given that they rarely talk about such matters with their parents:

"Do we discuss such matters with our parents? Not that often …"
" Once I was listening to a TV program on these issues and my dad didn't tell me off … he didn't switch it off, he said sit and listen to learn …"
"With our parents the talk is more childish…"

Parents are frequently in embarrassment when they face the children's questions and thoughts related to issues of sexual health. Lots of them, due to the complexity of the matter of sexual education, regard themselves inadequate for this task and assign the responsibility to the school. The children, however, ask for more and more detailed information than what is offered by their textbooks: "No [the Physics textbook] does not have many things we want to learn .." "… it should have more information and more pictures…".

All the children who participated in our research ask from their book more information about the human body and how it functions, about the reproductive system and the development of the embryo: "…what I want to learn about the grown-ups is how they make children […]. I know how the child is made but I don't know what happens in the nine months it is inside the mother's tummy, how it breaths, what happens in there, how it gets air and such things…".

The children of the Sixth Form of the Primary School feel that they are abandoned just at the moment when the important questions emerge, questions that remain unanswered in the end, since the parents, as we already mentioned, rely on the teacher's responsibility; the latter, however, do not have a complete syllabus-guide on which to base their teaching. Also, the children exchange information and knowledge between them and specifically with children of the same sex: "When we have such lessons like that we talk about them a little … sometimes with our friends … only boys with boys and girls with girls…".

For most young people their sexual identities are primarily shaped by interaction with same-sex peers, which makes their identities vulnerable to contact with the opposite sex (Wight, 1994). Taking into account this fact one of the most important theme of sex education programs is to promote heterosociality by involving the sensible discussion of sex between young women and young men. Moreover, discussing sexual issues with the opposite sex should develop a greater understanding of gender perspectives and, hopefully, greater respect for the ways in which the opposite gender views sexual relationships (Wight et al., 1998).

It was apparent from the discussion that television was another source of information for all the children: "I have seen some documentaries with genitals … films", "It shows that a man and a woman make love…".

Accepting that sex is not a natural act' (Tiefer, 1995) but rather a social practice, the role of the media in the creation of social representations concerning the image of the body, what is 'normal' or 'abnormal' sex and other sexual behaviour related issues is clear. So, we shouldn't be surprised by the misunderstandings and the misinformation that we observe in children, since it is institutionally sanctioned and preserved by various means of lack of means.

## 5. Discussion

In discussing the findings from this study, it is important to recognize the results that we have obtained are dependent on the specific sample population and the conditions in which the interviews were undertaken. However, it is apparent that the findings are supported by earlier studies in the related field (see for example, Reiss et al., 2001; Cuhbert, 2000; Winn et al., 1995).

Our study revealed that as the children of 11-12 years old begin to mature physically they become aware of puberty and sexual development. However, both boys and girls have limited knowledge regarding the reproductive organs. More specifically, boys talk about the external reproductive organs while girls about the internal ones without any mention of the clitoris. This finding is consistent with earlier studies, for example, Reiss, et al. (2001). This finding also indicates that sexuality is learnt and learnt differently according to one's gender as the females are socialized through a discourse in which sex tends to be bound with menstruation and reproduction, while for most males their introduction to the world of sex is via genital pleasure.

Moreover, the children have no holistic view of the reproductive system and they are not able to connect them and to explain their function. There is evidence from previous research that children of this age group have little understanding of bodily systems (Cuthbert, 2000). Furthermore, girls were more informed regarding pregnancy and contraception. This finding is similar to those found by other researchers (Kraft, 1993; Winn et al., 1995) and it is likely to be because risks such as unplanned pregnancy affect girls most directly.

The results also demonstrate that the children were ignorant of sexually transmitted diseases. The absence of knowledge about other STDs could be explained by the more recent emergence of HIV/AIDS and its particular risk to health. Regarding AIDS knowledge, the children responded that using a condom could prevent HIV infection, as they believe that the main mode of infection is the intercourse. They also think that there is no probability for HIV infection for themselves and thus they do not feel the need to protect themselves.

All the children interviewed felt that the instruction concerning sexual development, the reproductive system, pregnancy and contraception as far as AIDS and other STDs was limited and fragmentary. Moreover, their parents have taboos and tend to avoid to discuss with their children the issues mentioned above so the children look for answers to their questions either to mass media or to same-sex peers.

## 6. Implications for Sex and Health Education

Although the outcome of a focus group discussion cannot be generalized but consists of the opinions of the selected group on the topics discussed, the results reported have a number of implications for sex education in schools. As far as the biological aspect of instruction concerns, it might be better to begin with individual organs and then help children learn that these are assembled into functional systems.

As sexuality is socially constructed, a central theme of sex education programs would be to move young people on from their homosocial perspective to a more heterosocial perspective. One way to achieve this is to de-sensitize the discussion of sexual issues and to encourage discussion of sexual issues with the opposite sex. As girls have more knowledge than boys in almost all areas and perceive sexuality in a different way, a sex education program would have to promote a discussion about sexual issues with the opposite sex in order to develop a better understanding of gender perspectives and, probably, greater respect for the ways in which the opposite gender views sexual relationships.

There is also need for better and correct information so that the children learn to protect themselves from risks such as STDs and HIV/AIDS, while also caring about infected persons and the consequences of AIDS. Employing active learning techniques and group discussions have been shown to be very effective methods in improving understanding, targeting cognitions and developing social skills. An important problem in developing sex education programs in schools is the teacher's position on the related issues and there is a need for pre and in-service teacher's education on sexual issues.

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# ANALYSIS OF VALUE AWARENESS AND PURCHASE INTENTIONS IN THE FIELD OF NUTRITION

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## Abstract

The analysis of motives and purchase intentions in the field of nutrition could be a helpful instrument for assisting students to notice the motives underlying their food consumption. Such an instrument could also be useful for research concerning the effectiveness of teaching units on nutrition. In this paper we present an example for such an instrument developed for both purposes. The questionnaire was tested in a preliminary study with 82 students in order to evaluate whether students' nutrition motives are mirrored in a differentiated way, whether there are age- and gender-specific effects, and whether there is a correlation between students' nutrition motives and their purchase intentions. This pre-test did not correspond to an intervention study, however, its results indicate how the questionnaire has to be optimised to be used in such study.

## 1. Introduction

Education is seen as a key instrument for bringing about changes in values, attitudes, skills, behaviours and lifestyles consistent with sustainable development (Pigozzi, 2003). In a broader sense health education can also be seen as a part of education for sustainable development, because one should handle ones body with care to save its functionality for the future. However, it has been shown that only a few studies measured a change in behaviour caused by educational interventions. These results concern the education for sustainable development (Zelezny, 1999) as well as health education (Parker & Fox 2001). To achieve changes in behaviour is an ambitious goal. We believe that the effect of teaching is not always visible on the level of behaviour, however it may become apparent on preceding phases: the formation of motives and/or the intention to act. If the kind of changes in these preceding phases would be analysed it might be a useful hint in what way teaching units should be constructed to be more effective. For this purpose we developed a questionnaire to collect data on students' motives and intentions. We refer to the topic nutrition because it is characterised by a whole bunch of decision / value categories, which have been compiled in the concept of nutrition ecology by v.Koerber et al. (1999). In this paper we present the data of a preliminary study in which the questionnaire was tested.

## 2. Key objectives

The research questions we wanted to get answered by testing the questionnaire are as follows:

A) Is our questionnaire adequate to detect the different value categories / nutrition motives compiled by v.Koerber et al. (1999)?
B) Which target group will be most suitable for our planned intervention study? We decided to work with students of the lower secondary level, however we had to clarify whether it should be 5th or 9th graders. Therefore we analysed students' nutrition motives (B1) and purchase intentions (B2) in these two class levels. In addition we also looked for gender-specific effects.
C) Is there a correlation between students' motives and their intention of buying certain foods?

## 3. Target group

*Specification 1: students of comprehensive secondary school.* Heseker et al. (2001) uncovered a deficit in teaching nutrition which is particularly high in comprehensive secondary schools (Gymnasien) in Germany. A reason for this is that home economics is not part of the German curricula for "Gymnasien". While home economics comprises nutrition as a central topic, nutrition education has just a subordinate place in the biology curricula. Biology curricula, however, are the place where health and nutrition education dealt with in German comprehensive secondary schools. Due to lack of time, consumers' purchasing patterns are often neglected as a topic. In order to broaden nutrition education in comprehensive secondary schools, we planned our study to take place in this school type.

*Specification 2: students of lower secondary level.* The study is designed for the lower secondary level (class 5 to 10). Three reasons speak for choosing this school level: (1) During this age students start to remove from parents' influence and make up their own minds. Concerning the "impressionable years model" (Krosnick & Alwin, 1989) young people are very susceptible to attitude change. This openness, however, dramatically declines in the late adolescence and in early adulthood. Even if other models say that this flexibility of mind is retained for a longer time ("increasing persistence model": Glenn, 1980; "lifelong openness model": Tyler & Schuller, 1991), it is obvious that adolescence is a very sensitive phase. Therefore it seems reasonable that students should learn to reflect on their decisions and analyse their decision criteria during this phase of uncoupling. (2) Another reason for choosing the lower secondary level instead of the advanced one is that the topic nutrition is scheduled in the biology curricula for this age. Thereby it is less problematic to find teachers willing to take part in our planned study with their classes. (3) The third reason for choosing the lower secondary level is that the investigation could be expanded from high school into other school types if necessary and therefore, could reach more learners.

*Specification 3: students of grade 5 and 9.* Our preliminary survey was conducted in two fifth (n = 51) and two ninth grade classes (n = 31) of a German high school located in Schleswig-Holstein. We chose these different class levels since nutrition education is scheduled twice in the respective curricula referring to the lower secondary level.

## 4. Theoretical background for the design of the questionnaire

Prerequisites for a change in behaviour are corresponding motives and intentions which have to be developed first. This is demonstrated in the "Integrated Action Model" by Martens & Rost (1998) which refers to environmentally sound behaviour. This model brings together central elements from other action models, e.g. from the "Theory of Planned Behavior" (Ajzen, 1991) and from the "Health Action Process Approach" (Schwarzer, 1992). It is empirically proven and it was used as a starting point for several investigations concerning an education for a sustainable development (Martens et al., 2000; Bögeholz et al., 2000.). Its main statement is that an action is influenced by the intention of a person and that the latter is mainly determined by the person's motives. These motives may arise from different areas, e.g. health, ecology, economy and social life. However, the motives as well as other phases of the action model are influenced by further variables, e.g.: by the anticipated vulnerability concerning a certain threat (environmentally and/or health-related), by the anticipated results of an action, and by the expected competence in being able to conduct a certain action. While these independent variables have been analysed in other studies (e.g. Göltz, 1996), we want to concentrate on the coherence of general attitudes/motives and intentions concerning nutrition.

### 4.1- Instrument for analysing students' motives

For analysing students' motives and intentions concerning nutrition, a questionnaire was designed. Since the choice of foods and the related decision criteria vary with respect to the situation, the questionnaire refers to a defined situation, the school breakfast. The questionnaire is based on the concept of "nutrition ecology" (v.Koerber et al., 1999). We decided to use this concept as a basis for our investigation because it refers to a variety of value categories and therefore presents the whole spectrum of superordinate decision criteria a person could have. The value categories listed refer to health, enjoyment, suitability, psychological, ecological, socio-cultural, political and economical values. These value categories are assigned to three areas: the individual human, the environment and the society. Corresponding to this classification, three demands have to be made on food: it shall be conducive to health, ecology and society (s. 4.2). The expression "values" was introduced by v.Koerber et al. and will be adopted by us. However, these values categories should not be seen as objective, generally accepted values, but as subjective values, which means personal preference. For these categories 53 items (decision criteria) were formulated.

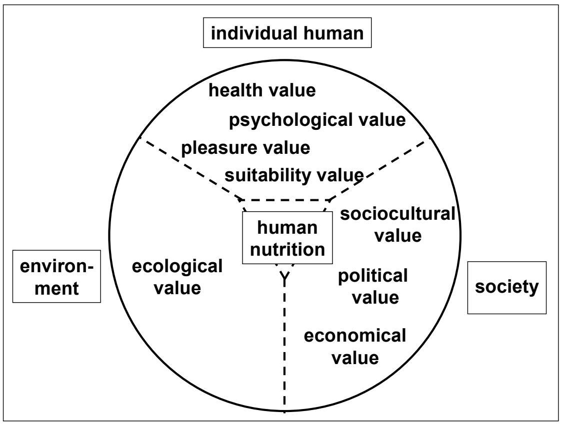


Figure 1. Categories of food quality concerning natural food
(v. Koerber et al., 1999, p. 54)

## 4.2- Instrument for analysing students' intentions

For analysing students' purchase intentions we adopted the classification of food products used by v. Koerber et al. (1999) because this classification refers to a holistic view of food quality by considering health as well as ecological and social aspects. Thus it supports the idea of sustainable development and corresponds to constitutive value categories listed before (s. 4.1). Referring to ecological and health aspects the way of food processing is seen as an important grouping criteria by v. Koerber et al. (Table 1). The authors distinguish three different product groups. Product group 1 contains very recommendable foods, which should be eaten frequently. It can be split up in two subgroups: (a) fresh, minor processed products and (b) moderately processed products. Product group 2 refers to less recommendable, highly processed foods and product group 3 to exaggerated processed foods, which are not recommendable. Food examples for these three categories are given in Table 1.

Table 1. Orientation table for natural nutrition (v. Koerber et al., 1999, p. 154/5)

| product group | no. 1: highly recommendable | | no. 2: less recommendable | no. 3: not recommendable |
|---|---|---|---|---|
| **description of the stages** | | | | |
| degree of processing | not / little processed (unheated) | moderately (heated) | highly (preserved) | exaggerated (isolates, ...) |
| recomman-dation of quantity | 1/2 of the food quantity | 1/2 of the food quantity | very seldom | avoid |
| **examples of food products** | | | | |
| cereals | sprouted cereals, ... | whole wheat products | not whole wheat products | isolated roughage products |
| sweeteners | fresh fruits | honey, dried fruits | non refined sucrose, sugar beet sirup | refined sugars, sweets |

We used this classification of foods for the analysis of our preliminary survey, however with two changes: Foods containing sugar are, in case they were declared as recommendable, downgraded by one category, for the following reasons: they contain added empty calories, sugar is not a necessary component of our nutrition and sugar adds to the growth of caries. In the same way foods, which are very fatty and therefore should only be consumed moderately, are downgraded by one category, e.g. salted peanuts.

An overview of the classification of the food products is given in Table 2. For the analysis of the survey the foods were rated, depending on their affiliation to a product group, with 2, 1 or 0 points and with the minor processed, recommendable products marked with 2 points. The questionnaire contained a task where the students had to go over a product list of a hypothetical school kiosk and had to choose 5 foods, they would like to consume during recess. In this task they could achieve a maximum amount of 10 points corresponding to a choice of 5 very recommendable products according to v.Koerber et al.. The minimal amount would be 0 points. This is equivalent to a school breakfast that consists of five non-recommendable foods, e.g. fast food or sweets.

Table 2. For each food product the quality was defined by referring mainly to v.Koerber et al. (1999). In addition the number of students is given who would buy the products for school breakfast when could choose from the supply listed below.

| Conventional drinks | product quality [points] | students [%] |
|---|---|---|
| ice tea | 0 | 22,0 |
| mineral water | 2 | 20,7 |
| Coke, Pepsi | 0 | 17,1 |
| energy drinks, e.g. Red Bull, Tiger Shot | 0 | 8,5 |
| whole milk | 2 | 7,3 |
| milk mix drinks, e.g. cocoa, strawberry milk | 1 | 7,3 |
| lemonade, e.g. Fanta, Sprite | 0 | 7,3 |
| packed juice | 1 | 3,7 |
| herbal tea | 2 | 2,4 |
| | | |

| Food from organic farming | product quality [points] | students [%] |
|---|---|---|
| *organic* topping: cheese or meat | 2 | 12,2 |
| local *organic* fruits, e.g. apples or pears | 2 | 11,0 |
| *organic* wholemeal bun | 2 | 7,3 |
| *organic* granola bars, nuts and honey | 1 | 6,1 |
| local *organic* vegetables, e.g. carrots, cucumbers, tomatoes | 2 | 6,1 |
| *organic* whole milk | 2 | 4,9 |
| *organic* fruit yoghourt | 1 | 3,7 |
| slice of *organic* cake or *organic* cookies | 1 | 2,4 |
| packed *organic* juice | 1 | 0,0 |

| Conventional food | | |
|---|---|---|
| granola bar, e.g. Corny | 0 | 35,4 |
| wheat bun | 1 | 26,8 |
| topping: cheese or meat | 1 | 25,6 |
| local fruits, e.g. apples or pears | 2 | 23,2 |
| french fries | 0 | 18,3 |
| wholemeal buns | 2 | 17,1 |
| Crisps | 0 | 14,6 |
| imported fruits, e.g. kiwis, bananas, clementines | 2 | 14,6 |
| chocolate bar, e.g. Mars, Nuts, Bounty | 0 | 12,2 |
| slice of cake or cookies | 0 | 12,2 |
| topping: chocolate cream or chocolate marshmallow | 0 | 8,5 |
| trail mix (nuts and raisins) | 1 | 8,5 |
| local vegetables, e.g. carrots, cucumber, tomatoes | 2 | 8,5 |
| cornflakes | 1 | 7,3 |
| dextrose, e.g. Dextro Energen | 0 | 7,3 |
| fruit yoghourt | 1 | 6,1 |
| salted peanuts | 0 | 2,4 |
| dried fruits | 1 | 1,2 |
| | | |

| Food with additional health value | | |
|---|---|---|
| granola bar with vitamins | 0 | 12,2 |
| juice with added vitamins and calcium | 1 | 9,8 |
| chocolate bar with vitamins | 0 | 8,5 |
| energy milk (with flavouring, 5 vitamins, dextrose, fibers, calcium, protein) | 1 | 0,0 |
| fruit yoghourt with special bacteria, which are supposed to be good for the intestines | 1 | 0,0 |
| | | |
| **Dietary food** | | |
| Coke light or Fanta light | 0 | 6,1 |
| low-fat fruit yoghourt | 1 | 4,9 |
| dietary chocolate | 0 | 4,9 |
| low-fat milk mix drinks, e.g. cocoa, strawberry milk | 1 | 3,7 |
| skim milk | 2 | 0,0 |
| | | |
| **Freshly prepared food** | | |
| fresh pressed juice | 2 | 39,0 |
| yoghourt with fresh fruits, no sugar | 2 | 12,2 |
| granola with oatmeal, fresh fruits and raisins | 2 | 2,4 |

Table 3. For each decision criteria the per cent of students is given who consider it to be important as well as its original classification to the different value categories

| The following reasons are important for choosing my school breakfast | students [%] | original value category |
|---|---|---|
| **FACTOR 1: health and sustainability aspects (ecological & political)** | | |
| The food does not trigger allergies. | 85,4 | health |
| The food contains a lot of energy. | 74,4 | suitabiliy |
| The food contains a lot of vitamins. | 73,2 | health |
| The food contains a lot of nutrients. | 70,7 | health |
| The food is healthy. | 68,3 | health |
| The food is not excessively packed. | 63,4 | ecology |
| The food contains little fat. | 58,5 | health |
| Fruits & vegetables were not treated with pesticides. | 58,5 | health / ecology |
| The food was not preserved via ultraviolet radiation. | 56,1 | health |
| The food is as unprocessed as possible (e.g.: an apple). | 54,9 | health / ecology |
| The food is not genetically modified. | 52,4 | health / ecology |
| The food contains a lot of fibers. | 51,2 | health |
| The food supports the fair trade movement. | 41,5 | policy |
| The food does not contain preservatives. | 40,2 | health |
| I know the substances of content on the label. | 39,0 | health |
| The food comes from organic farming. | 39,0 | ecology |

| The following reasons are important for choosing my school breakfast | students [%] | original value category |
|---|---|---|
| **FACTOR 2: particularly. psychological and pleasure aspects** | | |
| The food makes me lively. | 57,3 | psychology |
| The food makes me strong. | 51,2 | psychology |
| The food is easy to get. | 51,2 | suitability |
| I can share the food with my friends. | 46,3 | society |
| The food puts me into good humor. | 43,9 | psychology |
| The food decreases feelings of stress. | 37,8 | psychology |
| I have always eaten the food. It has a tradition for me. | 34,1 | society |
| The food makes me slim. | 31,7 | psychology |
| The food smells good. | 30,5 | pleasure |
| The food is available in the school kiosk. | 25,6 | suitability |
| The food looks good. | 22,0 | pleasure |
| The food makes me beautiful. | 15,9 | psychology |
| The food increases my credit among my classmates. | 14,6 | society |

| | | |
|---|---|---|
| The food supports the organic farming. | 37,8 | policy |
| The food is additionally enriched with substances which have an additional positive health effect. | 36,6 | health |
| The food has a low calorie content. | 35,4 | health |
| The food does not contain any flavouring substances. | 35,4 | health |
| My parents think the food is good. | 35,4 | society |
| The food is wholemeal. | 32,9 | health |
| The food is locally grown in Schleswig-Holstein. | 19,5 | ecology |
| The food does not come from conglomerates from the food industry. | 18,3 | policy |

| FACTOR 3: particularly suitability values | | |
|---|---|---|
| The expiry date of the food is not exceeded. | 90,2 | health |
| The food makes me fit for sports or a test. | 82,9 | psychology |
| The food can be eaten with hands. | 69,5 | suitability |
| The food can be shelved, which means it does not have to be eaten directly. | 65,9 | suitability |
| The food is good to carry / not sensitive to pressure. | 50,0 | suitabiliy |

| ITEMS NOT USABLE for the factor analysis, since they are important just for a few students | | |
|---|---|---|
| The food is „in“ right now in our class. | 6,1 | society |
| The food contains collectable stickers or other toys. | 6,1 | suitability |
| My friends eat or drink the food. | 4,9 | society |
| The food is being currently advertised. | 3,7 | psychology |
| **since they are important for nearly every student** | | |
| The food tastes good. | 97,6 | pleasure |

| ITEMS NOT USABLE for the factor analysis, ... | | |
|---|---|---|
| **since statistically not integrable in factor** | | |
| The food is filling. | 76,8 | suitability |
| The food is on sale. | 15,9 | suitability |
| The food is vegetarian, which means, it does not contain any meat. | 13,4 | health / ecology |
| I do not know the food yet and want to try it. | 43,9 | psychology |
| **since theoretically not integrable in factor** | | |
| The food is cheap. | 37,8 | siutability |
| The food is conform to religious rules. | 11,0 | society |

## 5 Research findings

### 5.1- Concerning research question A

Factor analysis was used to subsume the 53 decision criteria to get a lower number of factors which present superordinate value categories / motives. Three value factors could be determined by this process: The first value factor mainly refers to health and ecological items. The second one comprises mainly psychological items and the third one suitability items. An overview of the various items belonging to the three factors is given in Table 3. Some items could not be included into the factors because they were chosen by too many or too few students either or they did not theoretically fit into the factor they had been statistically assigned to. For example, the item relating to the price (*for me it is important that the food is cheap*) was statistically assigned to the psychological value factor. Concerning the theoretical basis of v.Koerber et al. (1999), however, this item belongs to the category of suitability.

### 5.2- Concerning research question B1

Multiway analyses of variance and t-tests for independent samples were used to analyse whether the variables age and gender have an effect on the students' motives.

For the value factor 1 "health and ecology" (comprising 24 items), a correlation between the number of items graded as important by the students and the age group (fifth or ninth grade) could be shown: The fifth graders consider health and ecology items to be more important than the ninth graders ($M_{5th\ graders}$ = 14.7 items, $M_{9th\ graders}$ = 6.9 items, $F_1 = 69.7$, $p \leq 0.001$). In addition an interacting effect of age and gender on the number of important items became apparent ($F_1 = 16.4$, $p \leq 0.001$): Fifth grade boys consider health and ecology items to be more important than the fifth grade girls ($M_{boys}$ = 16.4 items, $M_{girls}$ = 13.3 items, $T_{49} = 2.5$, $p \leq 0.05$). In the ninth classes the result is reversed ($M_{boys}$ = 4.3 items, $M_{girls}$ = 9.1 items, $T_{29} = -3.3$, $p \leq 0.01$) (Figure 2).

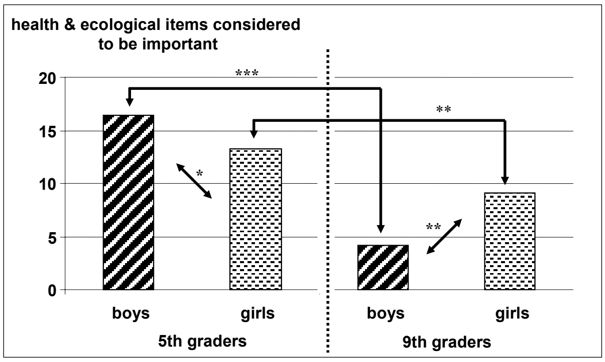


Figure 2. Number of health and ecology items considered to be important by the students
(p≤0.05, **p≤0.01, ***p≤0.001, n.s. = not significant)

Concerning the value factor 2 "psychology" (comprising 13 items) an interacting effect of both independent variables on the number of items seen as important could be detected

($F_1 = 5.2$, $p \leq 0.05$): Fifth grade boys generally consider more items to be important than their older colleagues ($M_{5th\ graders} = 5.6$ items, $M_{9th\ graders} = 3.5$ items, $T_{35.7} = 2.2$, $p \leq 0.05$). Concerning the girls, an age specific difference cannot be detected (Figure 3).

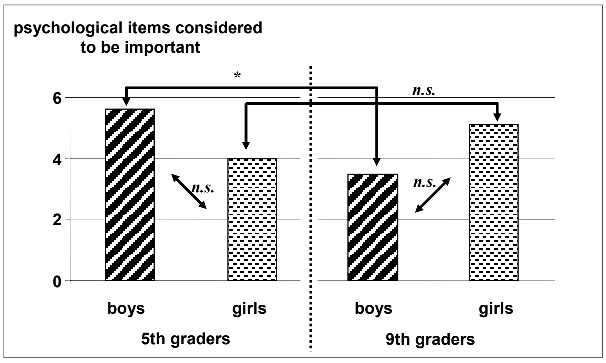


Figure 3. Number of psychology items considered to be important by the students (p≤0.05, **p≤0.01, ***p≤0.001, n.s. = not significant)

Referring to the value factor 3 "suitability" (comprising 5 items) no significant correlation could be detected with the independent variables age or gender.

A group of students were detected who perceive just 0-2 items of the value factor 1 "health and ecology" (which comprises 24 items) as important and thus demonstrate minimal interest in health and ecological aspects of food. These adolescents are all ninth graders and male. They represent one fifth of ninth graders which took part in our investigation (n = 7 of 31). Their minimal interest in health and ecological characteristics of food does not correspond to their interest in the other value categories: These boys consider 25% of the items of the value factor 2 "psychology" and 63% of the items of the value factor 3 "suitability" to be important.

### 5.3- Concerning research question B2

Descriptive data analysis shows that the quality of the food products which students intend to choose for school breakfast covers the whole quality range: There are students who take 5 non recommendable products (= 0 points) as well as there are students who take 5 very recommendable ones (= 10 points). The achieved number of points follows a standard distribution (Figure 4).

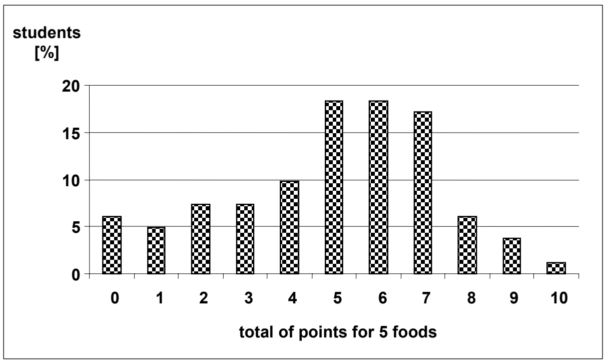


Figure 4. Distribution of students concerning the quality of the food products chosen for school breakfast

By multiway analyses of variance it was investigated, if the grade and the sex of the students have an effect on the quality of the products chosen for the school breakfast. The results show a main effect with regard to students' sex ($F1 = 7.5$, $p \leq 0.01$). When this effect is analysed more closely, it becomes apparent that this gender-related effect exist only within the group of the ninth graders, but not within the group of fifth graders. The average amount of points of ninth grade girls is about 2,5 points higher than the amount of their male colleagues (M boys = 3.1 points, M girls = 5.6 points, $T29 = -3.1$, $p \leq 0.01$). Within the group of fifth graders the average amount of points is 5.1 and 5.5 respectively (boys/ girls). Additionally, a combined effect of grade and gender on the amount of points was found. Among the male subpopulation, the younger students achieve 2 points more than the older ones (M 5th graders = 5,1 points, M 9th graders = 3,1 points, $T36 = 2.4$, $p \leq 0.05$). Thus the younger students decided for qualitatively higher products for school breakfast than their older colleagues (Figure 5).

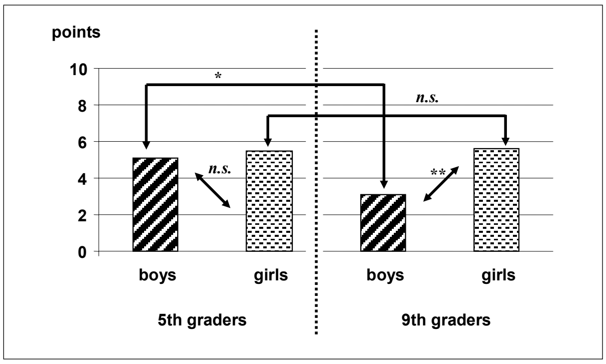


Figure 5. Quality of the food products chosen for school breakfast by the students (maximal number of points: 10)
(p≤0.05, **p≤0.01, ***p≤0.001, n.s. = not significant)

### 5.4- Concerning research question C

By correlation analysis it was tested if the quality of the products chosen for school breakfast (number of obtained points) correlates with the importance of the three value factors (number of items, which are seen as important). Concerning the value factor 1 "health and ecology", a correlation could be found (coefficient of correlation of 0.37, $p < 0.01$).

## 6. Discussion of the results & outlook

### 6.1- Concerning research question A

v.Koerber et al. (1999) developed a concept of value categories in the food sector on a theoretical basis which we wanted to confirm empirically with our investigation. Instead of 7 value categories our investigation resulted only in three categories, with the first one summarising health and ecological decision criteria.

Two reasons are conceivable for the combination of these two value categories which have been listed separately by v.Koerber et al. (1999): (a) Those students who pay attention to a healthy standard of living show greater interest in their environment as well. In this case, the sustainability aspect would be the combining element in both value areas. (b) The ecological decision criteria will be interpreted as health related criteria by the students. - A relationship between health and ecological decision criteria was also detected in other investigations, e.g. in a consumer inquiry (ZMP 2001). Consumers of organic products reason their decision by health and ecological arguments as well, apart from the argument of good taste. The other two value categories comprise mainly items belonging to psychological or suitability decision criteria. Thus, all three value categories refer primarily to individual aspects.

Socio-cultural items were partially included in the mentioned factors while others could not be included at all because they were chosen too rarely. We did not expect that only a few students (5 - 6%) consider it to be important that they eat and drink food which is also consumed by their friend or which is "in" in their class. So either students do not want to admit that their opinion depends on those of their friends or they do not expect food to be a prestige object since other criteria like good taste are more important for them. Another reason could be that food is quickly consumed and therefore cannot serve as an object of prestige. According to Barlösius (1999) the effect of socio-cultural aspects is much larger than it is demonstrated in this study. Even the decision criteria "good taste" is influenced by the eating culture a person is used to.

Political decision criteria were included in the value category 1 "health and ecology" by statistical analysis. This can be reasoned by the supposition that not only economical but also health and ecological arguments serve as a basis for a political attitude. A person who does not want to buy food from a conglomerate of the food industry might e.g. refuse food additives for allergic reasons (health reasoning) or prefers less processed food because of a lower energy use (ecological reasoning).

We believe the three value categories which resulted from statistical analyses will present a less precise value spectrum of a person than the theoretical construct of value categories by v.Koerber et al. Thus in our main study, we would like to use a qualitative strategy to assign items to value categories: students are to reason why they believe an item is important for them. In addition, the information about the number of students who consider an item as important does not include the aspect of how important an item is. Therefore, we want to use ranking scales in the main study instead of rating scales. In addition, the number of items shall be reduced for the main study so that students are able to handle the ranking process. Therefore, higher-level items which summarise other decision criteria (e.g. "*the food is healthy*"), similar/overlapping items (e.g. "*the food comes from / supports organic farming*" which can be seen as an ecological or political item), and rarely chosen items (e.g. *"the food contains collectable stickers"*) are removed.

The data of this preliminary study give an idea which decision criteria concerning nutrition are seen as important by many students and therefore might be of interest to them in nutrition education too. More than 80% of the students consider the aspects taste, expiry date, allergies and fitness for sport and mental work as important. However, not all of these topics are part of general nutrition lessons.

### 6.2- Concerning research question B

For intervention studies concerning nutrition ninth graders seem to be a suitable target group for two reasons: (a) At this age - especially male students - do not care much for the health and ecological aspects of food products, but more for psychology and suitability aspects. In order to counteract this situation, a teaching unit which encourages students to reflect on their consumer behaviour seems to be advisable. If such a teaching unit would lead to any positive effect, it should be easily detectable. (b) Ninth graders depend less on their parents' attitude. This could be derived from their much lower approval to the decision criterion of food consumption: "*My parents think the food is good.*" (approval of 9th graders: 14%, approval of 5th graders: 61%, $p \leq 0.001$).

### 6.3- Concerning research question C

A correlation between the number of health and ecology items considered being important and the quality of the chosen products for school breakfast could be detected. Especially the ninth grade boys distinguish themselves from the girls or younger students by preferring lower quality products, that means highly processed food, and attach little importance on health and ecological aspects.

### 6.4- General outlook

The questionnaire itself can also be used as an element of nutrition teaching. Students' awareness concerning their motives and intentions on food consumption might be roused when they fill in the questionnaires and evaluate them in class. By this, they will recognise that their motives, intentions and their actions only partially correspond with each other. In addition, they may notice that different people consider different decision criteria/motives to be important. This will especially become apparent when students get the task to prepare a common judging table in groups and to use this table as a subjective instrument for determining food quality (Ahlf-Christiani et al., 2003). An intervention study following this approach is under way.

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